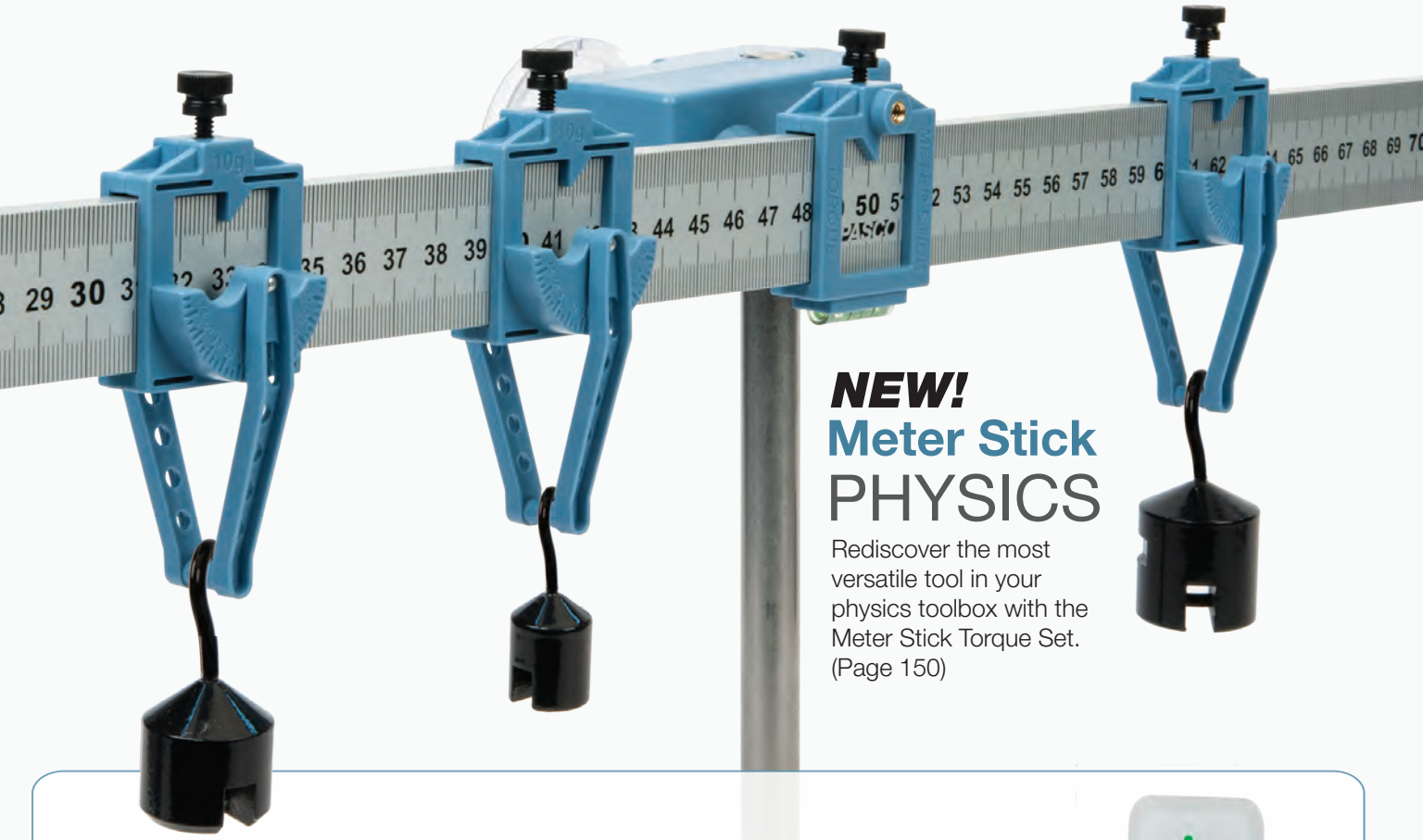
PASCO® scientific

Physics & Engineering

Leading Innovation in Physics Education Since 1964



NEW!

Meter Stick PHYSICS

Rediscover the most versatile tool in your physics toolbox with the Meter Stick Torque Set. (Page 150)

Meter Sticks Optics

Everything you need to investigate optics and lenses for less, without compromising accuracy. (Page 299)

NEW! **Physics Bundles**

Explore all new equipment sets for mechanics, optics, and more. (Pages 98-103)

PASCO

Support You Want
Technology You Trust

Why *PASCO*

Why do thousands of teachers worldwide trust PASCO for their lab equipment and technology?

Meets Teachers' Needs: PASCO labs and equipment are designed by educators, for educators.

Built for the Classroom: Our solutions are made durable for years of reliable use in your lab.

Hands-On by Design: Easy-to-use tools let students measure and visualize phenomena.

World-Class Support: Free standards-aligned labs, webinars, training, and technical support.

Table of Contents

New Products

Meter Stick Optics System

OS-7052

Features:

- Bright, rechargeable LED light source
- Lenses mounted in holders to protect from damage
- Organized storage box for easy classroom management

See page 299.

Wave Driver

WA-9855

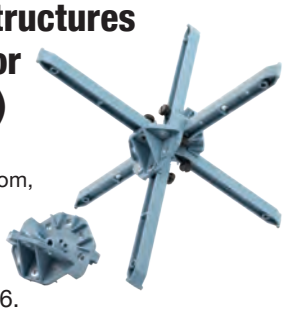
- New improved design
- Greater amplitude
- Stronger magnet for stronger force
- Sturdy construction

See page 272.

6-Way Structures Connector (Set of 6)

ME-7019

- For multi-room, multi-level buildings



See page 166.

Wireless Optical Dissolved Oxygen Sensor

PS-3246

See page 80.

SPARK LXi2 Datalogger

- PASPORT sensors connect directly to the LXi2.
- The LXi2 also has built-in ports for the included temperature and voltage probes.
- Simultaneously connect up to five PASCO Wireless Sensors.

Features:

- 8-hour battery life (standard use)
- Ruggedized, water resistant case for use indoors and outdoors
- 8" full-color capacitive touchscreen (1280 x 800 pixels)
- Simultaneously connects up to 5 PASCO Wireless Sensors
- Includes 2 PASPORT ports
- Includes Voltage Probe and port
- Includes Fast Response Temperature Probe and port
- Internal GPS, accelerometer, microphone, speakers/line out, and front camera
- Supports an additional five PASPORT sensors when used with the AirLink, SPARKlink Air, or 550 Universal Interface
- Installed software: PASCO SPARKvue, MatchGraph, and Spectrometry
- Android operating system
- WiFi, Bluetooth®, and USB connections
- Tools for data export: graphs, files, and images

See pages 58-59.

Scan to learn more:

pasco.com/lxi2

New Physics Bundles

NEW Physics Lab Stations

Physics Lab Station: Mechanics Starter

ME-5300

Perform These Experiments:

- Average Speed and Velocity
- Graphing Motion
- Speed and Velocity Graphs
- Conservation of Energy
- Work and Kinetic Energy
- Newton's Second Law
- Coefficients of Friction
- Momentum and Impulse
- Periodic Motion: Mass and Spring

See page 98.

Physics Lab Station: Mechanics Extension

ME-5301

Perform These Experiments:

- Conservation of Momentum
- Momentum and Explosions
- Simple Pendulum
- Atwood's Machine
- Two Dimensional Motion: Projectiles
- Exploring Torque
- Exploring a Rotating System
- Momentum and Impulse
- Exploring Physical Pendulums

See page 99.

Physics Lab Station: Fluids

ME-2040

Perform These Experiments:

- Boyle's Law
- Hydrostatic Pressure
- Buoyant Force

See page 100.

NEW Physics Lab Stations

Physics Lab Station: Optics

OS-8910

Perform These Experiments:

- Spherical Mirror Reflection
- Snell's Law
- Focal Length of a Converging Lens
- Virtual Images
- Telescope and Microscope
- Shadows

See page 102.

Physics Lab Station: Electricity and Magnetism

EM-3557

Perform These Experiments:

- Ohm's Law
- DC Circuits
- Capacitors and RC Circuits
- Magnetic Field of a Permanent Magnet
- Electromagnetic Induction
- Magnetic Field in a Coil
- Planck's Constant

See page 101.

Physics Lab Station: Waves and Sound

WA-9515

Perform These Experiments:

- Resonance and Standing Waves
- Properties of Sound Waves
- Measuring the Speed of Sound
- Decoding DTMF Tones

See page 103.

New Wireless Experiments

NEW Wireless Experiments

Projectile Motion Experiment

EX-5602

Concepts:

- Independence of x- and y-motion
- Muzzle velocity vs. time of flight
- Angle vs. horizontal range

See page 332.

Centripetal Force on a Pendulum Experiment

EX-5605

Concepts:

- Centripetal force
- Angular velocity
- Periodic motion

See page 335.

Ballistic Pendulum Experiment

EX-5611

Concepts:

- Conservation of momentum
- Conservation of energy

See page 337.

Rotational Inertia Experiment

EX-5616

Concepts:

- Rotational inertia of a ring and disk
- Torque

See page 342.

Conservation of Energy II Experiment

EX-5612

Concepts:

- Potential energy of a falling ball
- Kinetic energy of a falling ball
- Use different size balls to change friction

See page 339.

Physical Pendulum Experiment

EX-5618

Concepts:

- Parallel Axis Theorem
- Period of a physical pendulum
- Computer modeling of a system
- Rotational inertia

See page 345.

Specific Heat Experiment

EX-5624

Topics Covered:

- Thermal energy
- Equilibrium temperature
- Specific heat

See page 352.

NEW Wireless Experiments

Electrical Equivalent of Heat Experiment

EX-5625

Concepts:

- Compare electrical energy input to changes in internal energy

See page 353.

Ideal Gas Law Experiment

EX-5627

Concepts:

- Ideal Gas Law
- Boyle's Law
- Gay-Lussac's Law

See page 354.

Ratio of Specific Heat Experiment

EX-5631

Concepts:

- C_P/C_V for a gas
- Ruchardt's method of measuring the ratio of specific heats
- Adiabatic process

See page 357.

Heat Engine Cycles Experiment

EX-5630

Concepts:

- Heat engine efficiency
- Isothermal processes
- Isobaric processes
- Ideal Gas Law

See page 356.

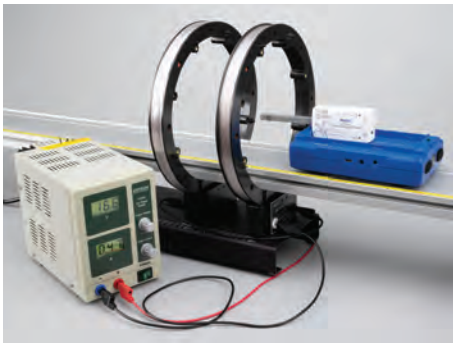
Magnetic Fields of Coils Experiment

EX-5640

Concepts:

- Magnetic fields of single coil, Helmholtz coils, and inside a solenoid

See page 367.



Faraday's Law of Induction Experiment

EX-5641

Concepts:

- Magnetic flux
- Faraday's Law of Induction
- Lenz's Law
- Conservation of energy
- Electrical power

See page 369.

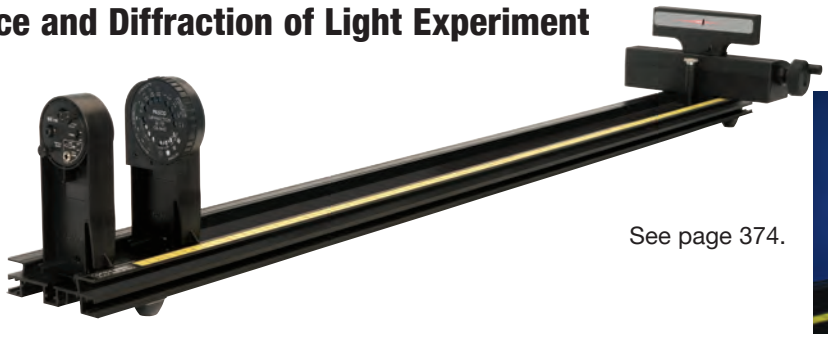
Interference and Diffraction of Light Experiment

EX-5645

Concepts:

- Two-slit interference
- Single-slit diffraction
- Multiple-slit minor maxima

See page 374.



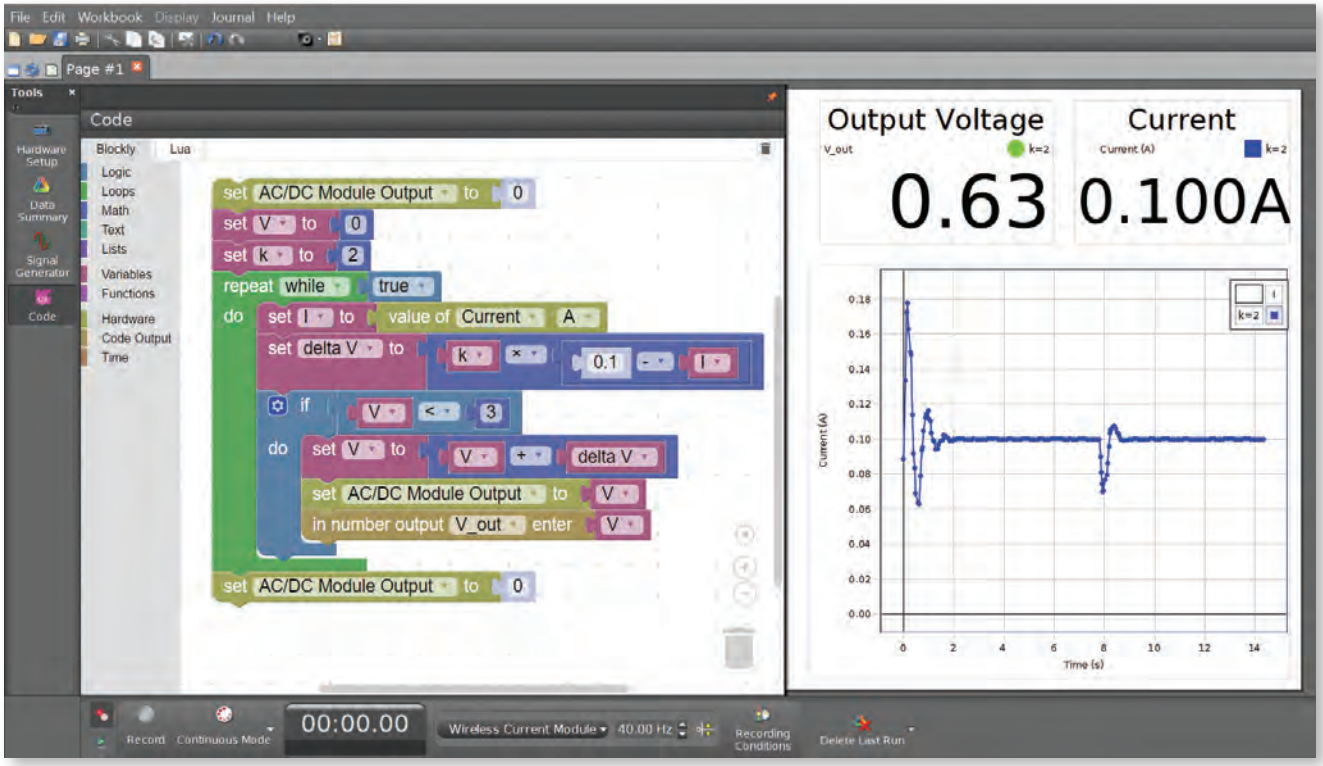
Sense and Control

Use PASCO Sensors, Output Devices, and Equipment to:

- Explore new applications with Blockly programming, available in PASCO Capstone and SPARKvue software.
- Access all sensor readings through code, create feedback loops, and more.
- Use code to control outputs such as fans, signal generators, and motors.

How PASCO Makes Sense and Control Seamless

The recent integration of Blockly coding into our data collection software lets students use code to collect sensor data and control how devices respond to that data – all without having to download any drivers. Graph the output from your code in real time or display it using any Capstone display.



In PASCO Capstone, the Blockly code runs adjacent to a graph of the Current Sensor measurement, and a Digits Display shows output from the code.

Example: Construct a Constant Current Source

- Use the Modular Circuits (EM-3536) variable resistor, Wireless Current Module (EM-3534), and AC/DC Module (EM-3533).
- The voltage is adjusted in code to react when the resistive load is changed so as to keep the current constant.
- Use Capstone to record the current and voltage readings and view a graph of the current in real time as the code is executed.

Modular Circuits (pages 228-231)

Sense

- Use the Blockly integration in PASCO Capstone to code with any PASCO sensor or interface.
- Explore plug-and-play programming with PASPORT, ScienceWorkshop, and Wireless Sensors!

PASPORT Sensors (pages 37-57)

ScienceWorkshop Sensors (pages 32-36)

Wireless Sensors (pages 61-81)

//control.Node (page 10)

Control

- New //control.Node (PS-3232) controls motors, fans, lights, and the PASCObot (PS-2994).

//control.Node (page 10)

PASCObot (pages 16-21)

- Control the speed and direction of a Smart Fan (ME-1242) on a Smart Cart (ME-1240).

Smart Fan (page 110)

- Control the speed and direction of a Smart Cart Motor (ME-1247).

Smart Cart Motor (page 113)

- Activate motors, lights, and a coil in Modular Circuits (EM-3536) using the AC/DC Module (EM-3533).

AC/DC Modular (page 230)

- On the //code.Node (PS-3231), change the color of the LED light, the intensity of the LED array, and the frequency of the speaker output.

//code.Node (page 67)

- Control the frequency and amplitude of the signal generator outputs on the 550 (UI-5001) and 850 (UI-5000) Universal Interfaces.

550 Universal Interface (page 28)

850 Universal Interface (page 26)

- Control the frequency and amplitude of the Function Generator (PI-8127).

Function Generator (page 266)

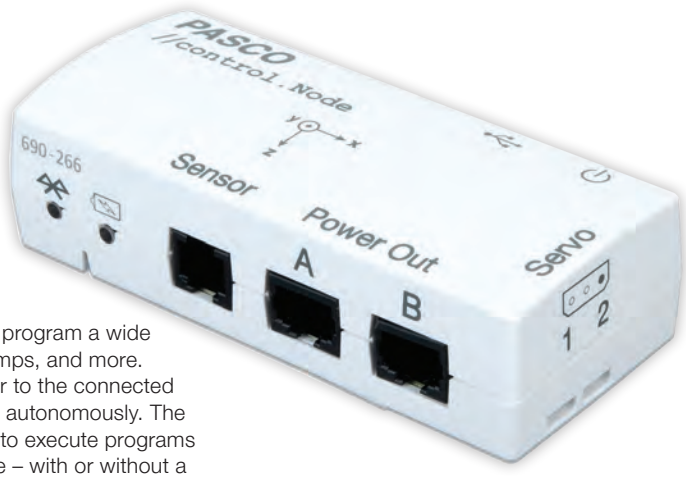
- Control when or where the ball is launched by a Smart Ballistic Cart Accessory (ME-1246).

Smart Ballistic Cart Accessory (page 112)

//control.Node

PS-3232

- Control motors, fans, pumps and more.
- Program with Blockly code in PASCO Capstone or SPARKvue
- Use the Sensor Port to incorporate sensor data into a program.
- View and record sensor measurements as the program runs.
- Rechargeable battery provides power to the //control.Node and connected devices.
- Upload code to the //control.Node, then disconnect it to run a program autonomously.



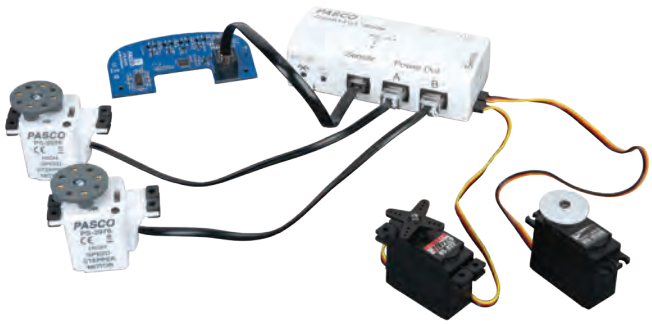
The //control.Node is a compact control device that enables students to program a wide variety of accessories, including stepper motors, servo motors, fans, pumps, and more. Complete with a rechargeable battery, the //control.Node provides power to the connected accessories, allowing students to create unique systems that can be run autonomously. The //control.Node features both Bluetooth and USB connectivity, allowing it to execute programs – written in Blockly code within SPARKvue or PASCO Capstone software – with or without a wired connection to a computer.

Built-in Features:

- Accelerometer
- Speaker
- Sensor Port
- Two Power Output Channels for Stepper Motors and Power Output Module
- Two Servo Ports for Regular Servos and Continuous Rotation Servos
- Rechargeable Lithium Ion Battery
- Bluetooth BLE Communication
- USB Port for Charging and Connectivity
- Two 6-32 Threaded Holes for Mounting

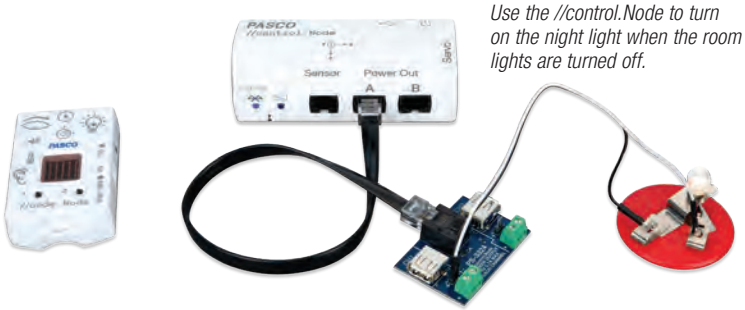
Designed to Work With:

- PASCObot Sense and Control Kit (ST-7840)
- Greenhouse Sense and Control Kit (ST-2997)
- //control.Node Sense and Control Kit (PS-5050)
- Stepper Motors (PS-2976)
- Servo Motors (Standard and Continuous Rotation)
- Power Output Module (PS-3324)
- Greenhouse Sensor (PS-3322)
- PASCObot (PS-2994)



The //control.Node can power and control two stepper motors, two servo motors, and a sensor (such as the Line Follower Module shown).

Build an automatic night light! Use the //control.Node to turn on the night light when the room lights are turned off.



Specifications:

Two Power Output Ports: ±5 VDC, 0.7 A
Two Power Output Ports: Auto-ID stepper motors and Power Output Module
Two Power Output Ports: 8-pin modular jack
Two Servo Ports: Accepts standard servos and continuous rotation servos
Two Servo Ports: 3-pin connector
Two Servo Ports: Not auto-ID
Two Servo Ports: Built-in servo current sensor for detecting load
Sensor Port: I2C
Sensor Port: 6-pin modular jack
Onboard Acceleration Sensor: 3-axis
Onboard Acceleration Sensor: ±16g
Rechargeable Battery: 3.7 V, 3000 mA-hr LiPo (3C), USB chargeable
Communication: Bluetooth BLE or USB
Speaker: Produces audible beep when code is uploaded
Dimensions: 11.5 x 5 x 3 cm
Mass: 142 g

Includes:

- //control.Node
- USB Charging Cable

Order Information

//control.Node..... PS-3232

Stepper Motors

High Speed Stepper Motor PS-2976

Low Speed Stepper Motor PS-2978

This Low Speed Stepper Motor is geared down to rotate slower than the High Speed Stepper Motor (PS-2976). The Stepper Motors plug into one of the Power Output ports on the //control.Node using the included cable. The Stepper Motors can be set to rotate through a given angle or at a given speed with a resolution of 480 steps/revolution (0.75 degrees). The feedback loop that makes it go at a constant speed is contained within the //control.Node, so there is no delay while waiting for the computer to respond. The Stepper Motors monitor how far and how fast the motor moves using the //control.Node and PASCO Capstone or SPARKvue software.

The Stepper Motors can be mounted using the two 6-32 inserts included on its exterior. The conventional, 24-tooth spline and custom case match the form factor and attachment hole pattern of a Servo Motor, making it easy to substitute a Servo Motor for a Stepper Motor in your project designs. These Stepper Motors also include a hub with threaded holes that can be fitted onto the spline to securely mount accessories such as the PASCObot wheels, pulleys, or gears.

Specifications:

Spline: 24 tooth
Voltage: 5 V
Max Speed: 2 rev/s (high)
0.33 rev/s (low)

Each Motor Includes:

- Stepper Motor
- Cable for connecting motor to //control.Node
- Hub with threaded holes for mounting accessories

Order Information

High Speed Stepper Motor PS-2976
Low Speed Stepper Motor PS-2978

Continuous Rotation Servo

SE-2977

This Continuous Rotation (non-proportional) Servo can rotate continuously in the same direction and is ideal for robotic applications.

Specifications:

Operating Voltage: 4.8 V to 6.0 V
No-Load Speed (6.0 V): 52 rpm
Dimensions: 40.6 x 19.6 x 36.6 mm
Mass: 41.7 g
Output Shaft Spline:
24 tooth

Includes:

- Hitec HSR-1425CR Servo
- Servo Horns (4)

Order Information

Continuous Rotation Servo SE-2977

Power Output Module

PS-3324

- Blockly control over channel 1 or channel 2 for independent control of accessories

The Power Output Module supports additional connections to the //control.Node, enabling students to extend their engineering projects beyond the contents in their kit. Simply plug the Power Output Module into the //control.Node, attach your accessory to the Output Module, and start coding your project! The Power Output Module splits access to the //control.Node's battery power, enabling students to power motors, solenoids, switches, lights, and many other accessories using the Blockly programming integration available in SPARKvue and PASCO Capstone.

Specifications:

Connector: 16" 8-pin modular plug to the control node
Channels: 2 independently controlled sides of the board
Device connector options: 0.025" square post header, terminal block screw, USB
Current per output channel: 0.7A
Voltage: 5V
Dimensions: 3.7 x 5.7 cm

Includes:

- 8-pin modular plug to connect to the //control.Node

Order Information

Power Output Module PS-3324

Servo Motor

SE-2975

This standard Servo Motor plugs into one of the two server ports on the //control.Node (PS-3232). The motor rotates through 180 degrees, moving a push rod that rotates a part, such as the aileron on an airplane.

Within the //control.Node is an internal current sensor that monitors the Servo Motor Ports, making it easy for students to know when a load is placed on the servos. When the servos on the PASCObot Gripper start to draw more current, the code can detect that an object has been gripped and determine how hard the object is being squeezed.

Specifications:

Operating Voltage: 4.8 V to 6.0 V
Maximum Torque Range: 3.3 to 4.1 kg/cm
Dimensions:
40.6 x 19.8 x 36.6 mm
Mass: 45.5 g
Output Shaft Spline:
24 tooth

Includes:

- Hitec HS422 Deluxe Servo
- Servo Horns (4)

Order Information

Servo Motor SE-2975

//control.Node Sense and Control Kit

PS-5050

The //control.Node Sense and Control Kit empowers students to create and explore through code. This kit includes a //control.Node and accessories that students can use to turn on lights, run a cooling fan, open doors, launch rubber bands, and much more. The kit also includes materials and instructions for six projects:

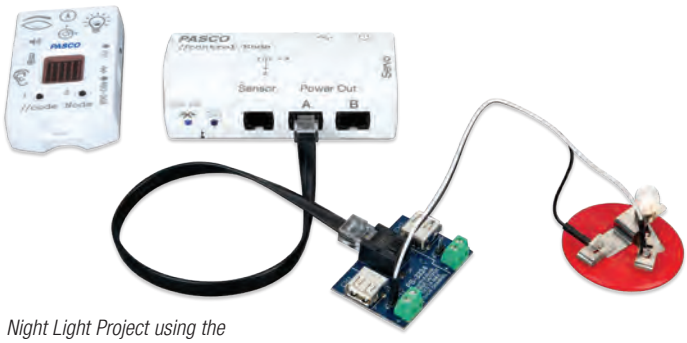
- Night Light
- Game with Meter
- Automatic Door Opener
- Thermostat-Controlled Fan
- Light-Activated Winch
- Remote Control Rubber Band Launcher

These projects use elements of the engineering design process:

- Define the problem
- Research solutions
- Design a prototype
- Test solution
- Iterative design and improvement

Night Light Project

Goal: Construct a night light that automatically turns on when the room goes dark and turns off when the room is lit.



Night Light Project using the //control.Node and //code.Node

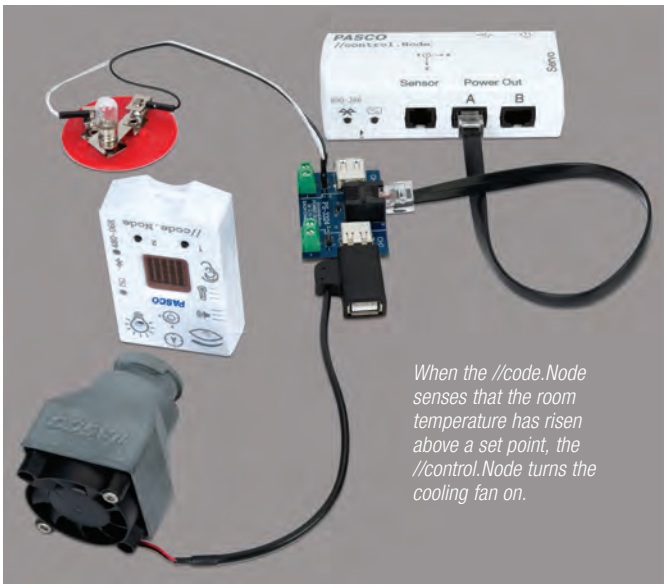
Game with a Meter

Goal: Make a meter that uses a stepper motor to rotate the indicator proportional to a sensor reading. Design a game that uses the meter to determine the outcome.

A stepper motor rotates the meter indicator to match the angle at which the //code.Node is tilted.

Thermostat-Controlled Fan Project

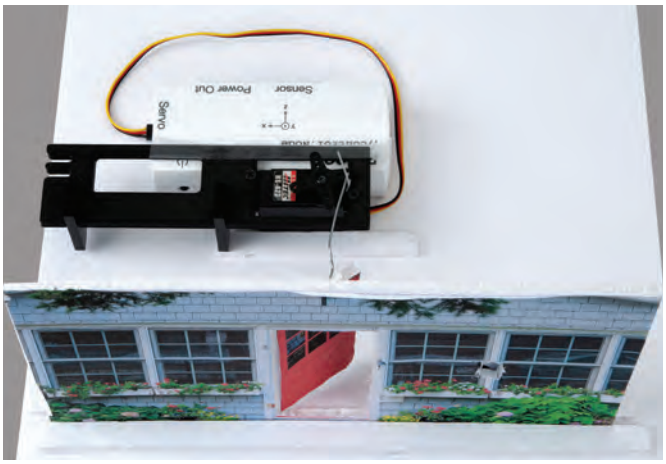
Goal: When the temperature rises above a specified point, turn on the fan, which cools the air by blowing into a wet cloth. When the temperature falls below a specified point, the fan turns off.



When the //code.Node senses that the room temperature has risen above a set point, the //control.Node turns the cooling fan on.

Automatic Door Opener Project

Goal: Build a house with a door. Push Button #1 on the //code.Node and the servo opens the door. Push Button #1 again and the servo closes the door.



The front of a house is constructed from foam core and the servo rod is attached to the door, allowing it to be opened and closed.

Light-Activated Winch Project

Goal: Place a white cup in front of a //code.Node with its light turned on. The reflected light triggers the winch to go down and the permanent magnet sticks to the object, hauling it up. Stop the winch when the cup is lifted above the //code.Node.

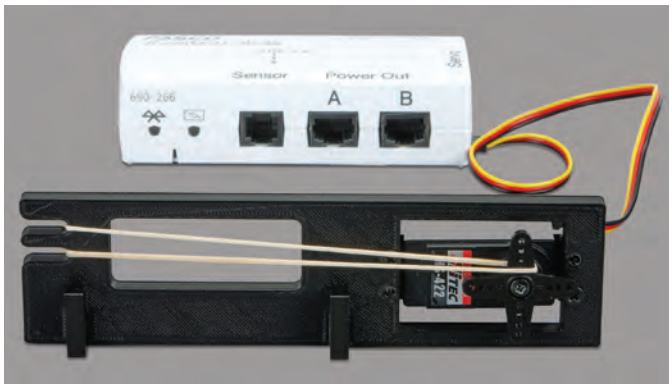
Light reflected from the cup triggers the winch to lower.

The winch picks up the cup.

Automatic Rubber Band Launcher Project

Part 1 Goal: Program the servo motor to hold its position while the rubber band is loaded. Push the button on the //code.Node to fire the rubber band.

Part 2 Goal: Expand on Part 1 by launching the rubber band when you clap your hands near the //code.Node's sound sensor. Use the //code.Node as a target, so that when the rubber band knocks it over, its accelerometer detects the motion, causing the //code.Node to flash its lights and sound an alarm.



Launch a rubber band when you clap your hands.

Includes:

- //control.Node (PS-3232)
- //code.Node (PS-3231)
- Servo Motor
- High Speed Stepper Motor
- Fan (USB)
- Light Bulb and Stand: EM-9099
- Motor Bracket and Stand
- Power Output Module
- Small Magnet
- Pulley
- Electrical Wires (2)
- Rubber Bands (10)
- Jumbo Paper Clips for Servo Pushrods (10)
- Mounting Bolts and Nuts for Motors
- House and Meter Paper Templates
- Phillips Screwdriver

Order Information

//control.Node Sense and Control Kit..... PS-5050

Sense and Control Kit without //control.Node

PS-5051

This kit is intended for courses that already have a //control.Node. The kit is identical to PS-5050 except it does not include a //control.Node (PS-3232).

Order Information

Sense and Control Kit without //control.Node PS-5051

Greenhouse Sense & Control Kit

ST-2997

Designed for the exploration of biological concepts, the Greenhouse Sense & Control Kit includes everything students need to design, build, program, and study their very own greenhouse.

Ideal for studies in biology, environmental science, and STEM, the Greenhouse Sense & Control Kit comes fully customizable, enabling students to explore countless interactions between plants and environmental factors.

Potential topics of study include soil moisture, humidity, temperature fluctuations, light availability, inter- and intraspecies competition, wind disturbance, and so much more.

Applications:

- Study and control greenhouse conditions.
- Use code to automate light and watering schedules.
- Identify patterns over time with continuous data logging.
- Includes equipment and accessories, as well as five student activities.

Block-Based Coding

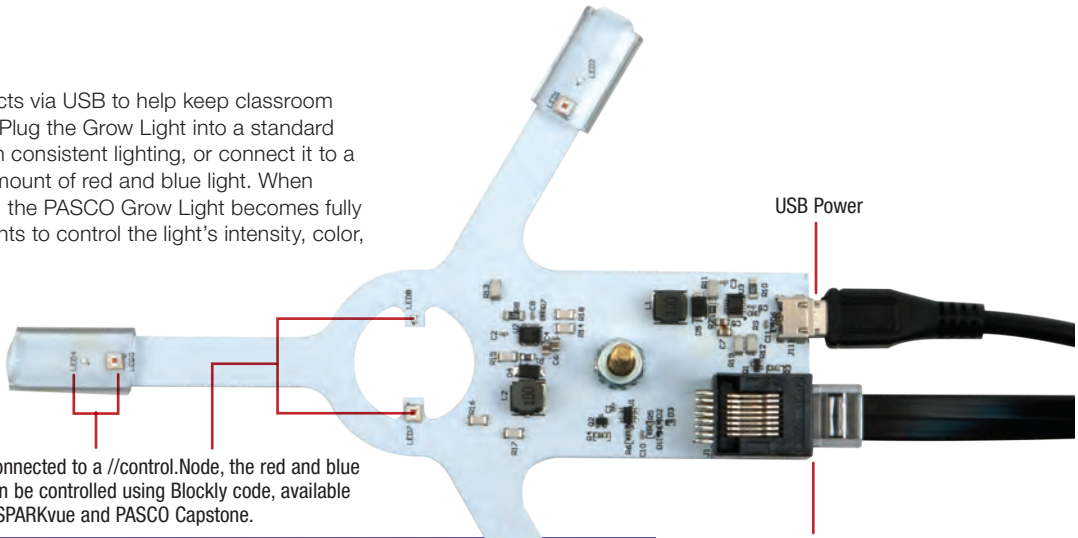
Includes 5 Student Activities:

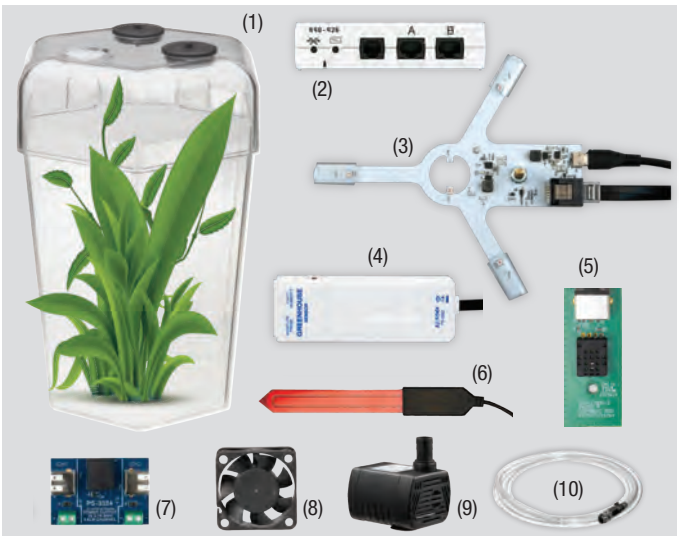
- Program a Sunny Day for Plants
- Code a Cooling Breeze for a Greenhouse
- Program Perfectly Timed Rain
- Optimize Water Movement in a Greenhouse
- Program a Greenhouse Sense and Control System

PASCO Grow Light

PS-3347

The PASCO Grow Light connects via USB to help keep classroom terrariums green and growing. Plug the Grow Light into a standard USB port to provide plants with consistent lighting, or connect it to a //control.Node to control the amount of red and blue light. When powered by the //control.Node, the PASCO Grow Light becomes fully programmable, enabling students to control the light's intensity, color, and schedule.





The Greenhouse Sense & Control Kit Includes:

(1) EcoChamber
(2) //control.Node
(3) PASCO Grow Light
(4) Greenhouse Sensor
(5) Humidity/Light/Temp Probe
(6) Soil Moisture Probe
(7) Power Output Module
(8) Fan
(9) Water Pump
(10) Tubing with drip-watering ends

Order Information

Greenhouse Sense and Control Kit	ST-2997
Greenhouse Sense and Control Kit (without //control.Node)	ST-2998
Available Separately:	
Greenhouse Sensor	PS-3322
PASCO Grow Light	PS-3347

PASCObot

PS-2994

- Learn to code
- Simple operation
- Expandable for limitless learning
- Compatible with PASCO sensors

The PASCObot includes everything students need to assemble the robot, including the //control.Node, two stepper motors with wheels, and the car body. Assembled in minutes, the PASCObot's unique modular design makes swapping components easy, enabling students to use the //control.Node and stepper motors in additional projects outside the PASCObot.

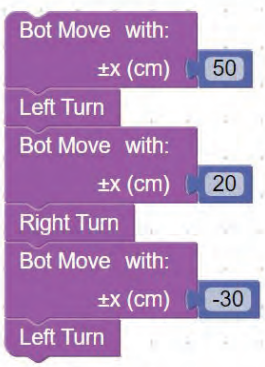
Using Blockly coding within SPARKvue or PASCO Capstone, students can command the PASCObot to move forward or backward, make turns, and navigate mazes. After creating their program, students can command the PASCObot to execute the code in real-time, or store it onboard the //control.Node to be run autonomously at the push of a button.

The //code.Node can ride in the PASCObot and be programmed to make turn signals on the LED array.

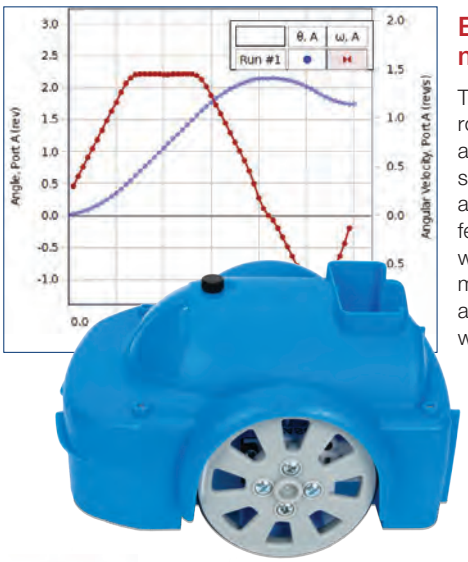
Since the Blockly coding environment is embedded in SPARKvue and PASCO Capstone, students can program the PASCObot's movements alongside graphs of the motion data coming from the PASCObot's stepper motors and onboard acceleration sensor.

The PASCO Code Library (available in PASCO Capstone and SPARKvue) supports new coders with a collection of prepared Blockly code blocks designed specifically for use with the PASCObot.

The PASCObot can be easily expanded by placing a //code.Node in the top slot and integrating it into programs. Use the //code.Node as a remote control for the PASCObot by programming the PASCObot to turn when the //code.Node is tilted, or use the PASCObot with any PASCO sensor connected to a computer via Bluetooth. Learn without limits with PASCObot!



Confident coders can control the two stepper motors independently to create turns and movements forward and backward. New programmers can choose from a variety of prepared Blockly code blocks to simplify more complex commands, like moving and turning the bot.



Execute code and produce motion data with PASCObot.

The PASCObot is more than just a robot. As students run their code, a real-time display of the bot's speed and distance can be viewed alongside the robot's motion. This feedback helps inform students when debugging their code and makes it easier for students to assess the effects of their code when it is executed.

The PASCObot is available with or without the //control.Node.

Students can assemble the PASCObot in minutes, putting together only seven parts, compared to the hundreds of parts in other robot kits.

Includes:

• PASCObot Body	PS-3318
• High Speed Stepper Motor (2)	PS-2976
• PASCObot Wheel with Tire (Set of 2)	PS-3319
• //control.Node	PS-3232
• Small #1 Phillips Screwdriver	
• PASCObot Assembly Hardware	

Order Information

PASCObot	PS-2994
PASCObot (without //control.Node)	PS-2995
Required:	
PASCO Capstone Software	pp. 84-87
OR	
SPARKvue Software	pp. 88-89

PASCObot Sense & Control Kit

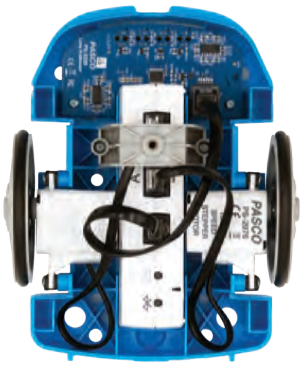
ST-7840

The PASCObot Sense & Control Kit helps harness students' interest in robotics to drive deeper learning in science and STEM. This complete kit includes a PASCObot, //control.Node, and accessories, as well as digital activities to support students' coding journey.

Sense and Control with PASCObot

Simple to build and easy to program, the PASCObot consists of just seven pieces, including a PASCObot Body, two Wheels, two Stepper Motors, and a rechargeable //control.Node that enables students to execute their code in real time, or store it onboard for execution later.

With PASCObot, students can go beyond basic robotics applications, combining PASCO's real-time data collection, graphing, and analysis system with an intuitive coding interface that scales to their skill level. From programming the bot's first movements to navigating obstacle courses to head-to-head competitions – there's no limit to what students can do with PASCObot!



Mount accessories like the Line Follower Module (included) in the PASCObot to expand your sense & control capabilities.

Includes:

• PASCObot Body	PS-3318
• High Speed Stepper Motor (2)	PS-2976
• PASCObot Wheel with Tire (2)	PS-3319
• //control.Node	PS-3232
• PASCObot Line Follower Module	PS-3320
• PASCObot Range Finder Module	PS-3321
• PASCObot Gripper Accessory	PS-3325
• Servo Motors (2)	PS-2976
• White/Black Tape (one roll each)	SE-2953
• Colored Plastic Cup Set (Set of 5)	SE-2952
• Small #1 Phillips Screwdriver	
• PASCObot Assembly Hardware	

See pages 18-21 for details about the contents of this kit.

Order Information

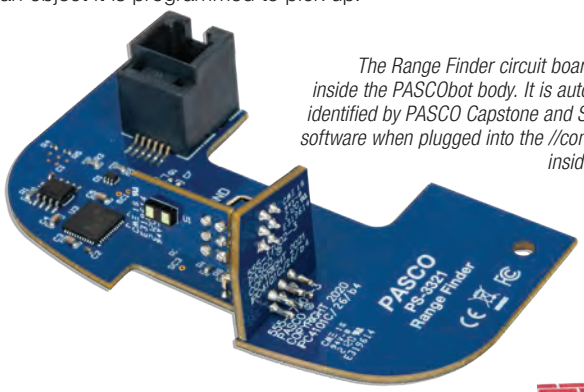
PASCObot Sense & Control Kit..... ST-7840
PASCObot Sense & Control Kit
(without //control.Node) ST-7841
Required:
PASCO Capstone Software..... pp. 84-87
OR
SPARKvue Software..... pp. 88-89

PASCObot Range Finder Module

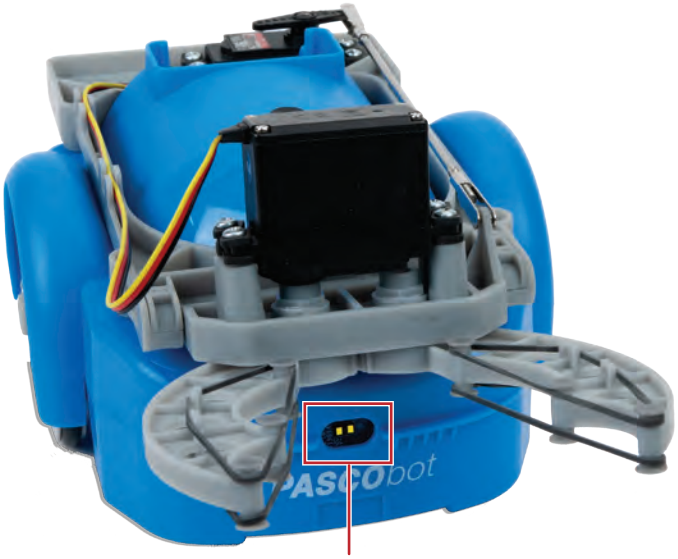
PS-3321

- Lidar range detector
- Detects objects closer than one meter

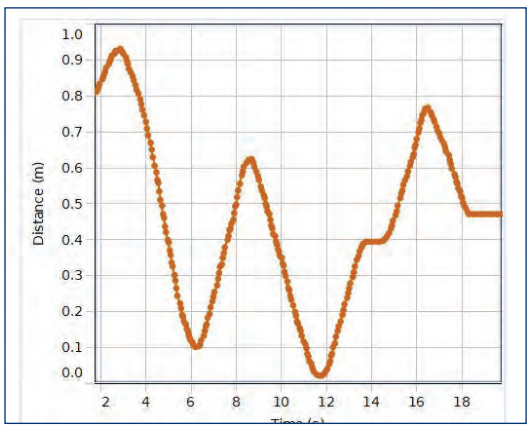
The Range Finder Module enables students to program how the PASCObot interacts with objects. A Lidar sensor on the circuit board uses infrared light to detect how far away objects are from the PASCObot, allowing students to program the bot to avoid or hit objects. The accessory offers enhanced features when used with the PASCObot Gripper, enabling the bot to detect the distance of an object it is programmed to pick up.



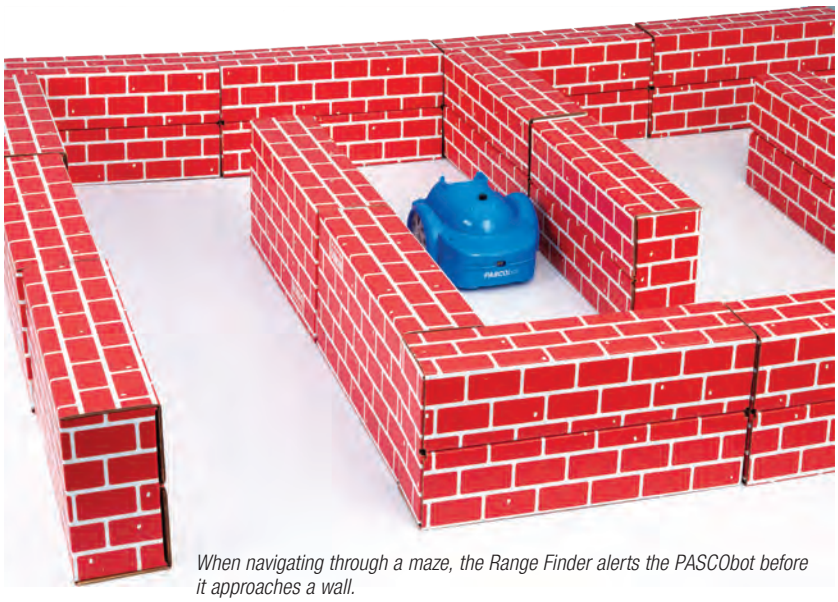
The Range Finder circuit board mounts inside the PASCObot body. It is automatically identified by PASCO Capstone and SPARKvue software when plugged into the //control.Node inside the bot.



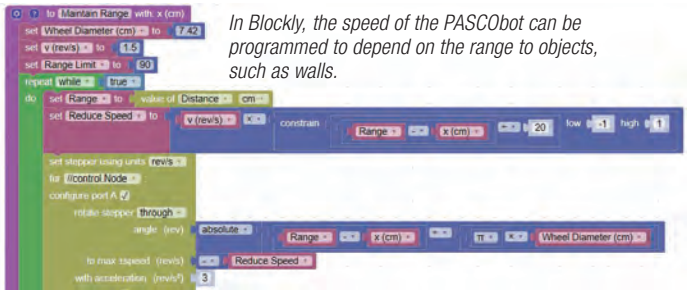
The Range Finder Lidar infrared emitter/detector pair peeks through a hole in the front of the PASCObot.



Distance data streams from the Range Finder to student devices, so students can see what the bot is seeing and interpreting.



When navigating through a maze, the Range Finder alerts the PASCObot before it approaches a wall.



In Blockly, the speed of the PASCObot can be programmed to depend on the range to objects, such as walls.

Note that the Range Finder cannot be used simultaneously with the Line Follower since both occupy the same slot in the PASCObot.

Includes:

- PASCObot Range Finder Module
- Cable to connect the module to //control.Node
- 4-40 x 7/16" screw for mounting the module to the PASCObot body (2)

Order Information

PASCObot Range Finder Module	PS-3321
Required:	
PASCObot	PS-2994
PASCO Capstone Software	pp. 84-87
OR	
SPARKvue Software	pp. 88-89
Recommended:	
PASCObot Gripper Accessory	PS-3325

PASCObot Gripper Accessory

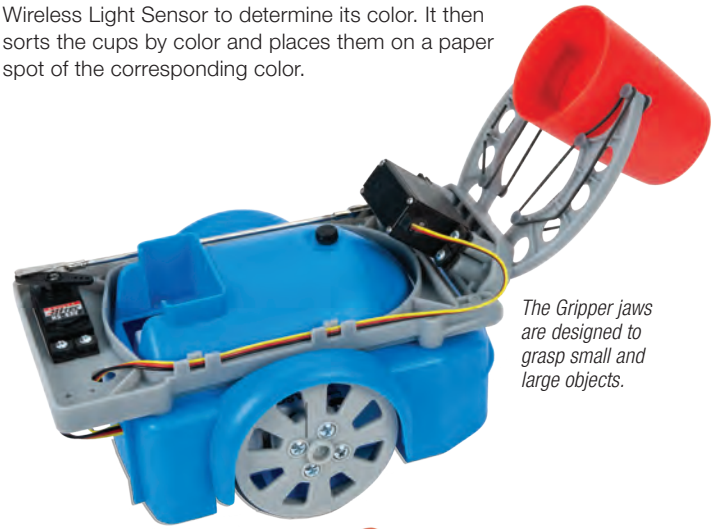
PS-3325

The Gripper Accessory brings a new range of motion to the PASCObot, enabling students to program the bot to lift, move, or stack objects.

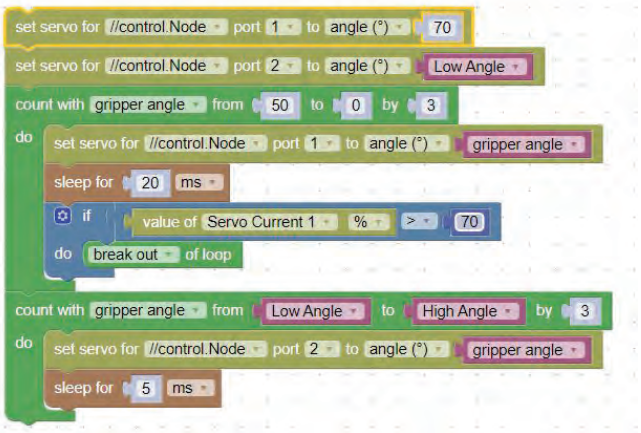
The Gripper mounts to the PASCObot, where its motion is controlled by servo motors that can be programmed to make the bot grasp and move objects.

Power is supplied and monitored by the rechargeable //control.Node, which has an internal current sensor for the servo motor ports. When the servos on the PASCObot Gripper begin to draw more current, the current sensor detects the load, and the Gripper closes onto the object. This unique feature also makes it possible for the code to recognize that an object has been gripped and determine how hard the Gripper is squeezing it.

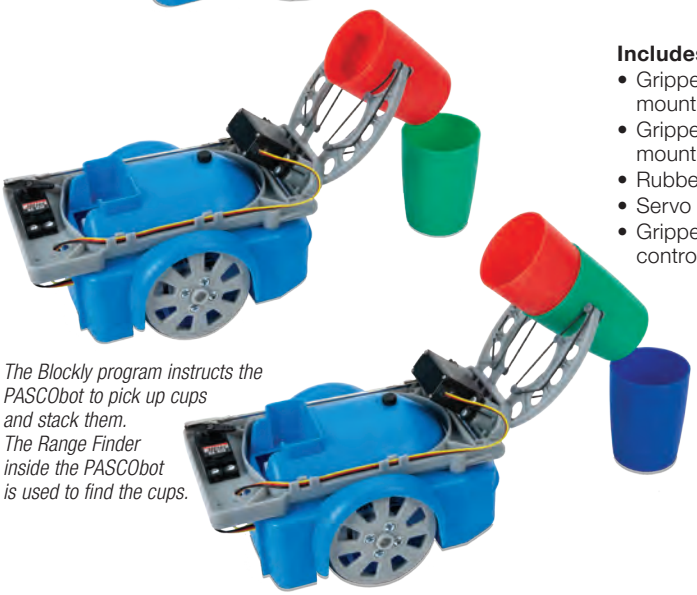
The Gripper's functionality is most robust when used with the Range Finder Module. When the Range Finder detects the bot's distance to an object, student code moves the PASCObot up to the object, and the Gripper squeezes around the object, lifting it up. In one activity, the PASCObot picks up a colored cup and takes it to a Wireless Light Sensor to determine its color. It then sorts the cups by color and places them on a paper spot of the corresponding color.



The Gripper jaws are designed to grasp small and large objects.



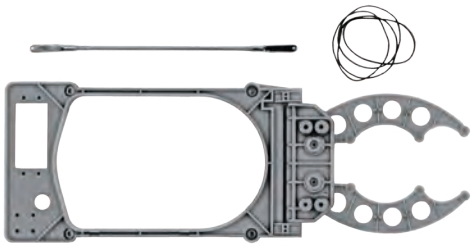
In Blockly, the strength of the Gripper's grasp is programmed in response to the amount of current the servo motor is drawing. The higher the current, the stronger the grip.



The Blockly program instructs the PASCObot to pick up cups and stack them. The Range Finder inside the PASCObot is used to find the cups.

Includes:

- Gripper arms and mounting brace assembly
- Gripper accessory mounting hardware
- Rubber bands
- Servo extension cable, 12”
- Gripper raise and lower control rod with clips



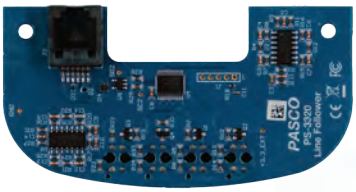
Order Information

PASCObot Gripper Accessory	PS-3325
Required:	
PASCObot	PS-2994
Servo Motor (2)	SE-2975
PASCO Capstone Software	pp. 84-87
OR	
SPARKvue Software	pp. 88-89
Recommended:	
PASCObot Range Finder Module	PS-3321
Colored Plastic Cup Set (Set of 5)	SE-2952

PASCObot Line Follower Module

PS-3320

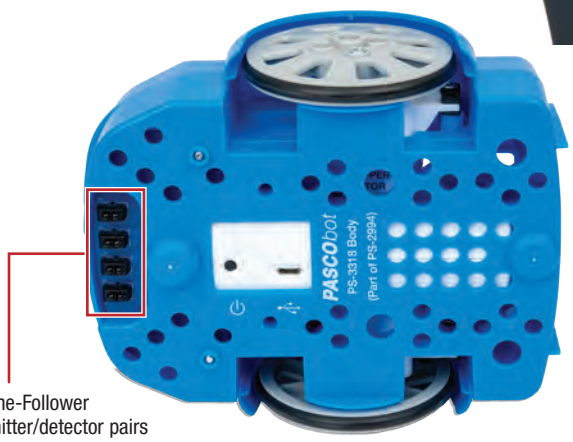
- Program the PASCObot to follow a custom line path!



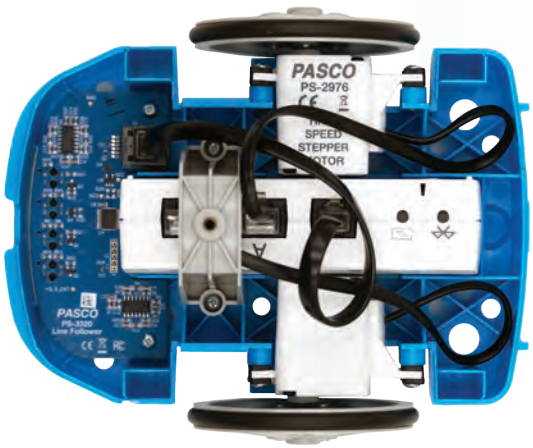
When fitted with the Line Follower Module, the PASCObot can detect, follow, and respond to line paths based on code. To create a path, students use either the black or white tape included with the PASCObot Sense & Control Kit (ST-7840). They can then program the bot's navigation through the path, upload their code to the bot, and put their coding skills to the test!

Loaded code is run autonomously, allowing guiding decisions to be made onboard the PASCObot for more instantaneous responses. As the PASCObot autonomously executes the uploaded code, students can monitor data from the bot's onboard sensors in real time by connecting their computer via Bluetooth.

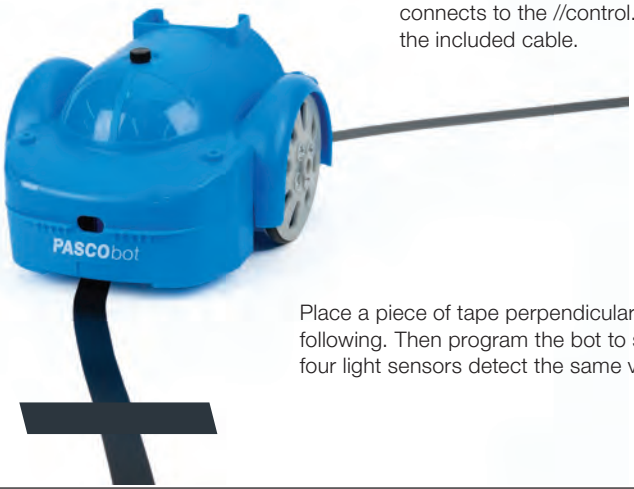
Students can make their own curved path using the white or black tape that is supplied with the PASCObot Sense and Control Kit (ST-7840). The tape is very flexible and leaves no residue after removing it from a table or floor.



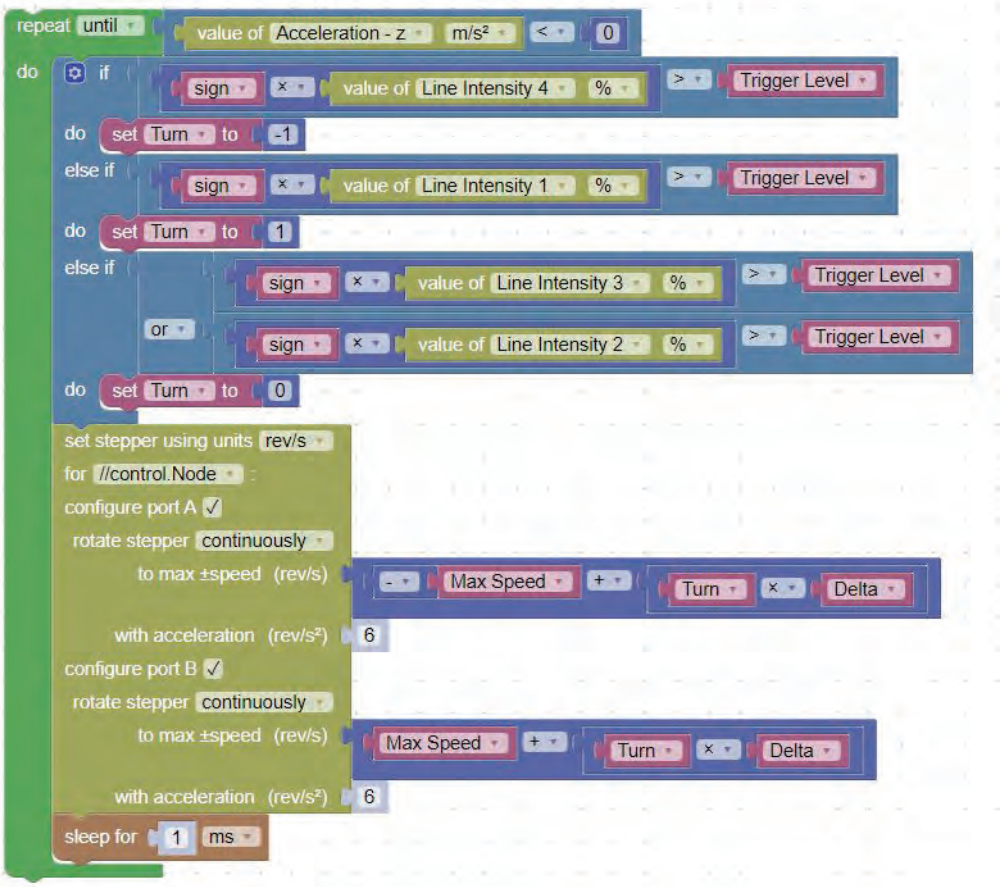
The four Line-Follower infrared emitter/detector pairs shine through a hole in the bottom of the PASCObot.



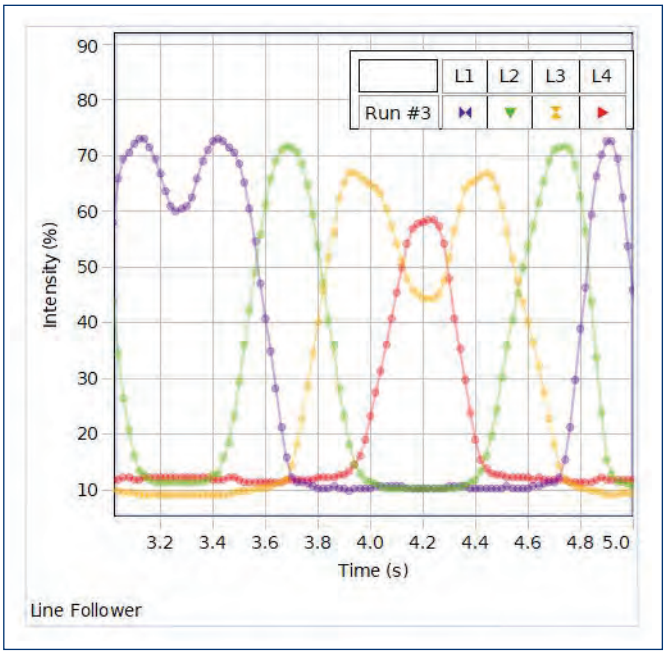
This circuit board mechanically fits into the PASCObot and connects to the //control.Node's Digital Sensor Port using the included cable.



Place a piece of tape perpendicular across the line the bot is following. Then program the bot to stop and reverse when all four light sensors detect the same value.



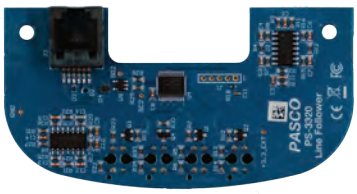
The PASCObot readily scales to student learning levels. Students can write their own line-following code, or they can download prepared line-following blocks from the PASCO Code Library (included in SPARKvue and PASCO Capstone).



By studying the reflected light levels coming from the four emitters, students can design code that recognizes when the PASCObot is over the line and which direction the PASCObot needs to go to return to the line.

Includes:

- PASCObot Line Follower Module
- Cable to connect the module to //control.Node
- 4-40 x 7/16" screw for mounting the module to the PASCObot body (2)



Note that the Line Follower cannot be used simultaneously with the Range Finder since both occupy the same slot in the PASCObot.

Order Information

PASCObot Line Follower Module	PS-3320
Required:	
PASCObot	PS-2994
Black & White Tape Rolls (1 each)	SE-2953
PASCO Capstone Software	pp. 84-87
OR	
SPARKvue Software	pp. 88-89

Measuring with Sensors

In Physics and Engineering, we measure everything in every way we can. Sometimes sensors make it possible to perform measurements that cannot be obtained any other way.

At PASCO, we offer two types of sensors: Sensors that require an interface (PASPORT and ScienceWorkshop) and sensors that connect Bluetooth (wireless). These sensors can be implemented individually or simultaneously depending on your class devices and learning goals.

Which platform do you use?

1. Mac® and/or Windows® Desktop Computers or Laptops

Recommendation:

- **PASCO Capstone Software** (see pages 84-87): This data collection and analysis software is the preferred choice of physics and engineering teachers.
- **550 or 850 Universal Interface:** Choose the 550 if you are teaching high school physics (unless you are one of those high school teachers who has to have the most powerful tools). Choose the 850 if you are teaching college physics or engineering.

PASCO capstone™

850 Universal Interface
UI-5000 (see page 26)

or

550 Universal Interface
UI-5001 (see page 28)

Wireless Force Acceleration Sensor
PS-3202 (see page 65)

PASPORT High Resolution Force Sensor
PS-2189 (see page 42)

2. Tablets (iPad® or Android™), Smartphones and/or Chromebook™

Recommendation:

- **SPARKvue Software** (see page 88-89): SPARKvue is data collection software for tablets, smartphones, and Chromebooks. While PASCO Capstone is very powerful, it is only available for Mac® and Windows®.
- **Wireless Sensors and Wireless AirLink Interface:** Use Wireless Sensors because tablets may not have a USB port. Whenever a Wireless Sensor is not available, use the AirLink with a PASPORT sensor.

sparkvue SPARKvue®

Wireless Force Acceleration Sensor
PS-3202 (see page 65)

AirLink®
PS-3200 (see page 60)

3. Need a Standalone Datalogger?

SPARK LXi2 DATALOGGER

Recommendation:

- **SPARK LXi2:** This all-in-one datalogging solution works for classrooms without computers or for outdoor use. The SPARK LXi2 can be used with wired PASPORT sensors as well as PASCO's Wireless Sensors. It is battery-powered, has a large color touchscreen, and is loaded with PASCO SPARKvue, MatchGraph, and Spectrometry software.

SPARK LXi2 top view

SPARK LXi2
PS-3600B (see pages 58-59)

New to sensors? Have sensors already?

1. New to Sensors?

- **PASCO Capstone Software** (see pages 84-87): Unless you are using tablets, smartphones, or Chromebook™, we recommend using PASCO Capstone for physics and engineering labs.
- **550 Universal Interface:** The 550 Universal Interface is perfect for beginning data acquisition. It has multiple sensor ports to accommodate experiments that require more than one sensor (as most experiments do). It also has a signal generator and powered output for electronics and speakers.
- **PASPORT Sensors:** Many of these sensors have multiple sensor elements in one sensor, such as the Absolute Pressure/Temperature Sensor (page 45).
- **Wireless Sensors** (see pages 61-81): These sensors connect via Bluetooth® to devices running either PASCO Capstone or SPARKvue Software. They offer an affordable solution for courses without interfaces.

550 Universal Interface
UI-5001 (see page 28)

Wireless Force Acceleration Sensor
PS-3202 (see page 65)

Wireless Smart Cart
ME-1240 (see page 62)

2. Have ScienceWorkshop Analog Sensors?

- **PASCO Capstone Software** (see pages 84-87): Unless you are using tablets, smartphones or Chromebook™, we recommend using PASCO Capstone for physics and engineering labs.
- **850 Universal Interface:** The 850 Universal Interface is our most versatile and powerful instrument. It has twice as many sensor ports as the 550 for those more demanding experiments. It also has three signal generators, a high-power output (15 V at 1 A) for speakers and heating elements, and two high-frequency outputs (DC to 500 kHz) for electronics.
- **Use Your Existing ScienceWorkshop Sensors** and add any PASPORT sensors you need. You may want to use the PASPORT 2-Axis Force Platform (page 43) or the Absolute Pressure/ Temperature Sensor (page 45).

850 Universal Interface
UI-5000 (see page 26)

550 Universal Interface
UI-5001 (see page 28)

3. Have PASPORT Sensors?

- **PASCO Capstone Software** (see pages 86-89): Unless you are using tablets, smartphones, or Chromebook™, we recommend using PASCO Capstone for physics and engineering labs.
- **550 or 850 Universal Interface:** Choose the 550 if you are teaching high school physics (unless you are one of those high school teachers who has to have the most powerful tools). Choose the 850 if you are teaching college physics or engineering.
- **Use Your Existing PASPORT Sensors** (see pages 37-57) and add the UI-5100 Voltage Sensor (page 35) for high speed sampling of circuits and the UI-5101 Sound Sensor (page 34) to detect sound waves.
- **SPARK LXi2:** Choose the SPARK LXi2 if you want to use your PASPORT sensors without computers, or if you need to collect data outside.

SPARK LXi2
PS-3600B (see pages 58-59)

Interfaces

Use an interface to connect sensors to devices running PASCO software.

AirLink®

PS-3200

The AirLink is the most cost-effective way to wirelessly connect PASPORT sensors.

Connect one PASPORT sensor via Bluetooth® or through a USB connection. USB cable included.

Order Information

AirLink Interface PS-3200

SPARKlink® Air

PS-2011

Connect two PASPORT sensors via Bluetooth® or through a USB connection. Also includes dedicated ports for the included temperature and voltage probes. USB cable included.

Order Information

SPARKlink Air Interface PS-2011

SPARK LXi2

PS-3600B

Collect data from PASPORT and Wireless Sensors with the SPARK LXi2. Includes two ports for PASPORT sensors, five virtual ports for Wireless Sensors, and two ports for use with the included Fast Response Temp Probe and the Voltage Probe.

Scan to learn more:

pasco.com/lxi2

Order Information

SPARK LXi2 Datalogger PS-3600B

550 Universal Interface

UI-5001

The 550 Universal Interface is fast, flexible, and powerful while staying affordable. The 550 has half the ports and many of the great features of our 850 Universal Interface in a smaller package, with Bluetooth® and USB connectivity.

Order Information

550 Universal Interface UI-5001

850 Universal Interface

UI-5000

The 850 Universal Interface is the most powerful science education lab interface in the world. It has the most ports, the highest sampling rates, and the most powerful functionality. It can also replace several pieces of lab instrumentation, saving both lab space and budget dollars.

Order Information

850 Universal Interface UI-5000

Interface Comparison

Compare the features and capabilities and see which interface works best in your lab.

	AirLink PS-3200	SPARKlink Air PS-2011	SPARK LXi2 PS-3600B	550 Universal Interface UI-5001	850 Universal Interface UI-5000
PASPORT Ports	1	2	2	2	4
Built-in Temp and Voltage	No	Yes	Yes	No	No
Analog Inputs	0	0	0	2 (±10 V, optional gain voltage 10x, 100x)	4 (±20 V, optional gain voltage 10x, 100x, 1000x)
Digital Inputs	0	0	0	2	4
Connects via USB	Yes	Yes	Yes	Yes	Yes
Connects via Bluetooth	Yes	Yes	Yes	Yes	No
Rechargeable battery for cordless operation	Yes	Yes	Yes	No (AC adapter only)	No (AC adapter only)
Works with PASCO Capstone Software	Yes	Yes	No	Yes	Yes
Works with SPARKvue Software	Yes	Yes	Yes	Yes	No
Accepts PASPORT Sensors	Yes	Yes	Yes	Yes	Yes
Accepts ScienceWorkshop Sensors	No*	No*	No*	Yes	Yes
Maximum Sampling Rate	Sensor-dependent <1000 Hz	Sensor-dependent <1000 Hz	Sensor-dependent <100 kHz	Up to 2 MHz on one channel	10 MHz on two channels simultaneously
Signal Generator	N/A	N/A	N/A	±8 V, at 400 mA, DC to 100 kHz	#1 ±15 V at 1 A, DC to 100 kHz #2 & #3 ±10 V at 50 mA DC to 500 kHz, independent
Included Items	USB Cable	AC adapter, USB cable, fast response temperature probe, voltage probe	AC adapter, fast response temperature probe, voltage probe	USB cable, power supply	USB cable, power supply
Expansion Port	No	No	No	No	44-pin port with voltage outputs, analog inputs, and digital I/O channels

* The AirLink, SPARKlink Air, and SPARK LXi2 can accept most ScienceWorkshop sensors with the proper adapter (see page 62), although they won't have the same high maximum sample rates. One exception is the Sound Sensor (UI-5101), which is not recommended for use with an adapter.

The PASCO 850 Universal Interface:

The Ultimate Sensor Interface for Physics and Engineering

When used with PASCO Capstone, the 850 Universal Interface has the same functionality as several lab devices combined, all while taking up less than half the bench space.

An incredible value!

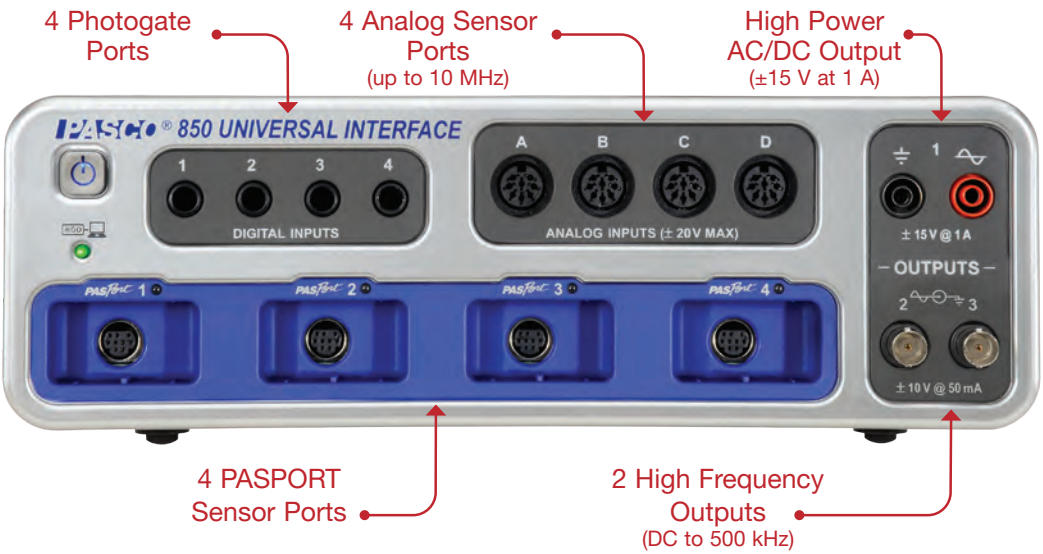
850 Universal Interface

+

PASCO Capstone Software

=

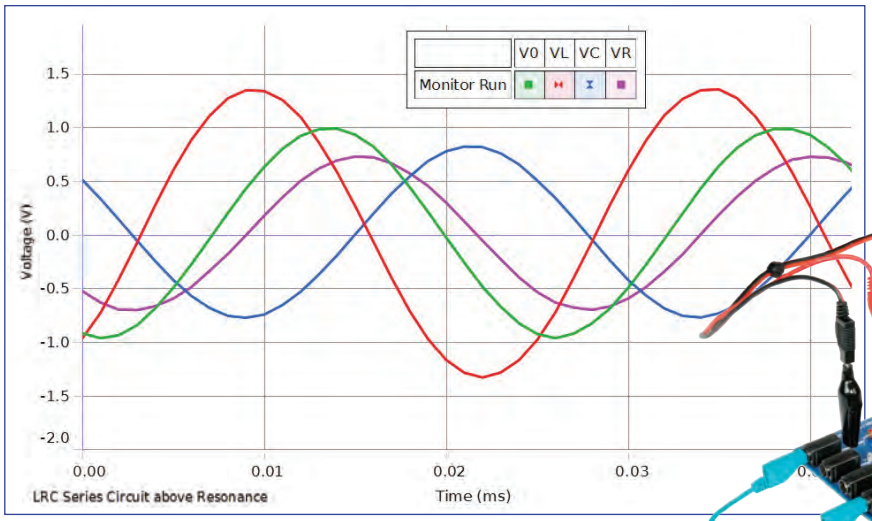
DC Power Supply, Oscilloscope, Digital Multimeter, and Function Generator

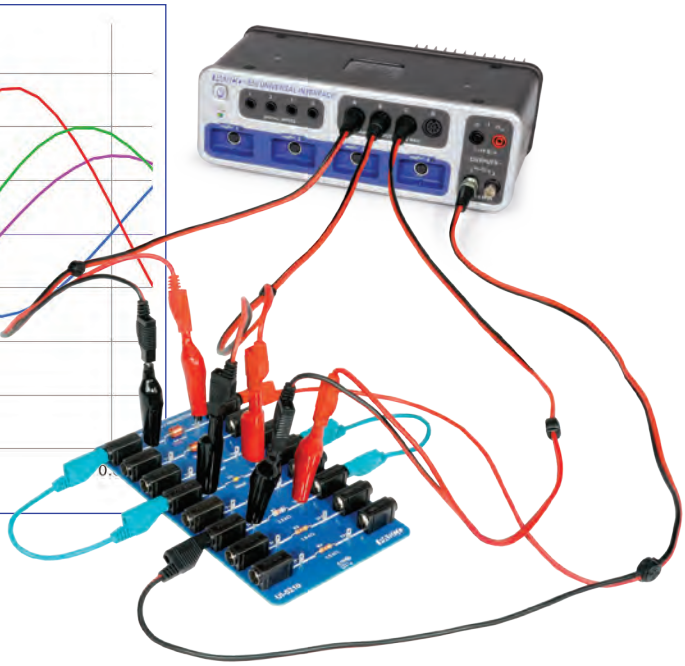


- **Study AC Circuits:** 10 MHz sample rate on two analog channels simultaneously; two independent high frequency outputs (50 mA at 10 V; DC to 500 kHz)
- **Power Speakers and String Vibrators:** High power function generator (1 A at 15 V; DC to 100 kHz)
- **Use Any Sensors You Have:** Collect data with ScienceWorkshop and PASPORT sensors, individually or simultaneously at the same time
- **Explore Modulation:** External trigger input/output for synchronizing multiple 850s
- **Do 87 Core Physics Experiments:** Check out the Comprehensive 850 Physics Lab Manual (UI-5813; see page 93). Download online at pasco.com/comprehensivephysics
- **For detailed specifications:** www.pasco.com/850

Order Information

850 Universal Interface	UI-5000
Required:	
PASCO Capstone Software	pp. 84-87
Recommended:	
BNC Function Generator Output Cable	p. 27
Replacement Part:	
850 Universal Interface Replacement Power Supply	UI-5200





Four Channel Oscilloscope in PASCO Capstone

Dual Independent High Frequency Function Generators

Independent control of frequency, waveform, and amplitude. The voltages across the source, inductor, capacitor, and resistor are displayed in the oscilloscope.

BNC Function Generator Output Cable

UI-5119 (unshrouded) UI-5129 (shrouded)

- Converts the BNC output to two banana cords for the 850's function generators #2 and #3.

UI-5119

UI-5129

Shown in use with the 850 Universal Interface.

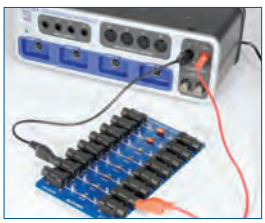
Order Information

BNC Function Generator Output Cable (unshrouded)	UI-5119
BNC Function Generator Output Cable (shrouded)	UI-5129

Resistor Capacitor Inductor Network

UI-5210

Board components can be used to investigate Kirchhoff's Circuit Laws, Ohm's Law, RC circuits, and AC. LRC circuit theory with resonant frequencies between 55 kHz and 135 kHz, depending on values used.



Includes

- Two inductors: 6.8 mH, 2.5 mH
- Two capacitors: 3900 pF, 560 pF
- Four resistors: 47 kΩ, 3.3 kΩ, and two 1.0 kΩ.

Shown in use with the 850 Universal Interface.

Order Information

Resistor Capacitor Inductor Network	UI-5210

8-Pin DIN Extension Cable

UI-5218

- Use to connect analog sensors to ports A through D on the 850.
- Analog sensors can also be plugged in directly to the 850 ports.

The 1.8 m long Extension Cable allows ScienceWorkshop Sensors to be used even further away from the interface. Multiple cables CAN be used in series. Also works with 750 and 500 interfaces.

Order Information

8-Pin DIN Extension Cable	UI-5218

The PASCO 550 Universal Interface

This powerful interface for Physics connects wirelessly or via USB.

This is the interface with the measurement capability for all types of physics experiments. It features:

- 2 MHz sampling rate
- 2 high-speed analog inputs
- 2 digital inputs for photogates and other timing sensors
- 2 PASCO PASPORT sensor inputs
- Signal generator with built-in Voltage and Current sensors
- Use with other PASPORT interfaces
- Connect to computers via USB
- Bluetooth® Low Energy

With the 550, your Physics lab is equipped with high-speed data collection, signal generation, a power supply, oscilloscope and FFT displays, timers, and more.

550 Universal Interface Specifications:

2 High-speed Analog Inputs

Measurement Range: ±10 V differential input
Input Impedance: 1 MΩ
Input Protection: ±250 V continuous
Selectable Voltage Gain: X1, X10, X100
Resolution: 14-bit, 0.12 mV

2 Digital Inputs

Digital sensors such as Photogates and Time-of-Flight plug directly into the 550 Interface.

- Compatible with all ScienceWorkshop digital sensors
- Sensor Connect Detection
- 0-5 V TTL
- Bi-directional

2 PASPORT Inputs

Compatible with PASCO's complete line of more than 80 PASPORT sensors.

- Sample rates depend on sensors

Signal Generator

Waveforms: sine, triangle, square wave, positive and negative ramps, DC

Frequency Range: 0.001 Hz to 100 kHz; 1 mHz resolution
Amplitude Range: ±8 V
Resolution: 1.33 mV, 12-bit DAC.
Max Output Current: 400 mA at 8 V, over-current detection
Selectable Voltage Limit
Selectable DC Offset
Frequency Sweep Function
Measure Output Current, Voltage, Frequency, Peak Amplitude

Order Information

550 Universal Interface	UI-5001
Required:	
PASCO Capstone Software	pp. 84-87
OR	
SPARKvue Software	pp. 88-89

Choose the Universal Interface that is right for you.

The 550 Universal Interface

is fast, flexible, and affordable, and it has all the power you need to ignite student learning in your lab. The 550 is equipped with high-speed data collection, signal generation and power supply, FFTs, timers, and more. (If you have tablets, this is the interface you need.)

The 850 Universal Interface

has all the speed and power you need for your most demanding physics experiments. And it can replace most of the equipment in your physics lab including oscilloscopes, power supplies, timers, function generators, multi-meters, and more.

Specs:	550 Universal Interface	850 Universal Interface
Sampling Rate:	Up to 2 MHz on one channel	10 MHz on two channels simultaneously
Connection:	Connect to computers or tablets* via USB or Bluetooth® * iPad®, Chromebook™, and Android™ tablets require SPARKvue®	Connect to computers via USB
Signal Generator:	±8 V at 400 mA, DC to 100 kHz	#1: ±15 V at 1 A, DC to 100 kHz #2 and #3: ±10 V at 50 mA, DC to 500 kHz, independent
Analog Input:	±10 V, optional voltage gain 10x, 100x	±20 V, optional voltage gain 10x, 100x, 1000x
Compatibility:	Works with all PASPORT and ScienceWorkshop sensors and works with other PASPORT interfaces	Works with all PASPORT and ScienceWorkshop sensors and works with other PASPORT interfaces
Ports:	2 high-speed analog inputs + 2 digital inputs for photogates and other timing sensors + 2 PASCO PASPORT sensor inputs	Twice the number of ports as the 550
Software:	PASCO Capstone™, SPARKvue	PASCO Capstone™

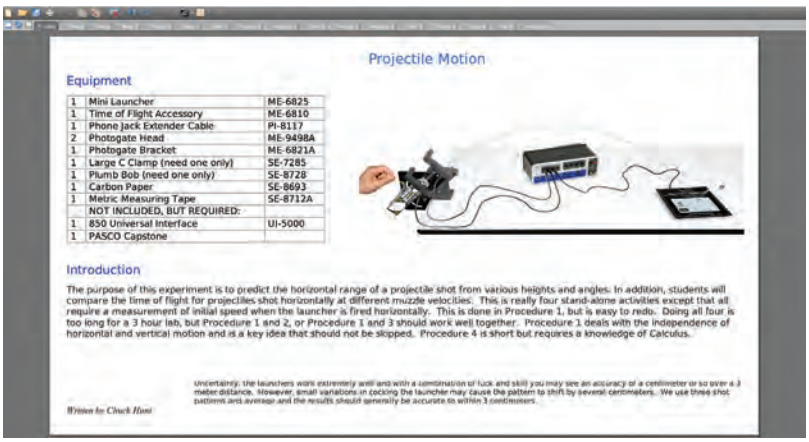
Labs and configuration files available: pasco.com/capstoneexperiments

Included Labs:

- Mechanics
- Fluids
- Rotation
- Structures
- Materials
- Thermodynamics
- Electricity
- Magnetism
- Waves
- Optics
- Quantum

Each lab includes:

- Word® document file
- PASCO Capstone configuration file
- Image files
- Sample data

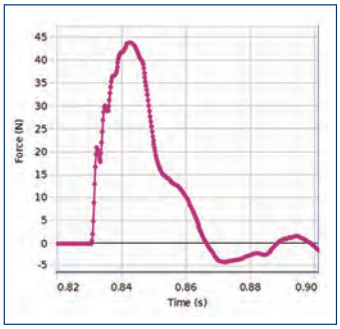


See pages 96-97 for more 550 Physics Labs

Advantages of Using Analog Sensors with the 550 and 850 Universal Interfaces

The 550 and 850 Universal Interfaces are called “Universal” because they are capable of using ScienceWorkshop (analog) sensors as well as PASPORT sensors. Although the PASPORT sensors are the newer digital line of sensors, there are advantages to using the analog technology in the ScienceWorkshop sensors. Here are a few examples:

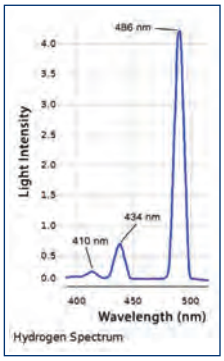
1. High Speed Collision with the Force Sensor (CI-6537)



A cart colliding with a Force Sensor equipped with a clay bumper was recorded using a 5000 Hz sampling rate. Details of the clay's collapse can be seen in the data.

See page 32.

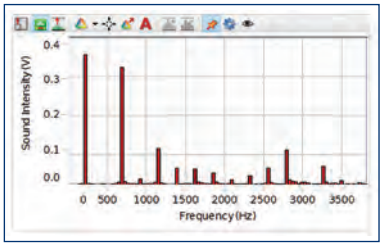
2. High Gain Detection of Violet Hydrogen Lines with the High Sensitivity Light Sensor (CI-6604)



This Light Sensor has a high gain that, when combined with the interface gain, allows even the dimmest of the Balmer series to be detected.

See page 36.

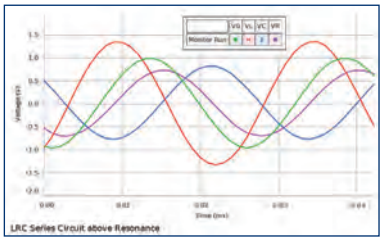
3. High Resolution Sound FFT Spectrum of a Clarinet Note with the Sound Sensor (UI-5101)



This FFT of a note being played on a clarinet was captured at a sample rate of 20 kHz. The waveform can also be seen on an oscilloscope in Capstone software.

See page 34.

4. High Synchrony LRC Circuit with the Voltage Sensor (UI-5100)



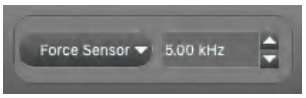
This oscilloscope display in PASCO Capstone shows the voltages across several components of an LRC circuit. The sample rates required for this can be as high as 10 MHz.

See page 35.

Students learn how various sensor settings and experimental setups affect the quality of their measurements.

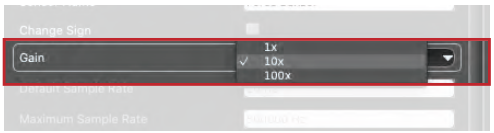
1. Sampling Speed

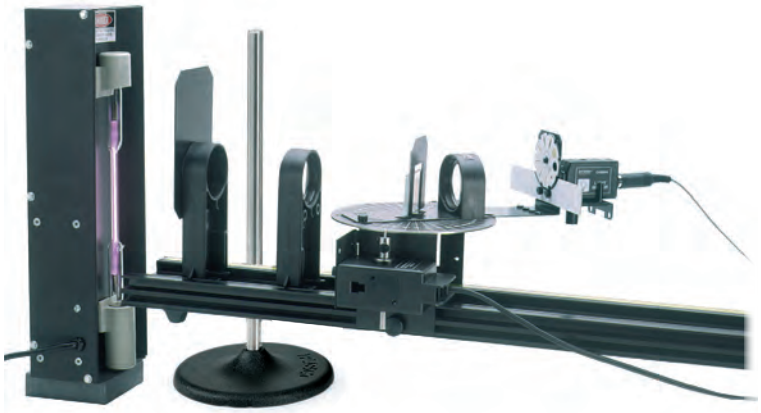
Set the sampling rate high enough to capture the details of the phenomenon being measured.



2. Voltage Gain

Changing the gain of an analog sensor increases the resolution over a smaller voltage range.



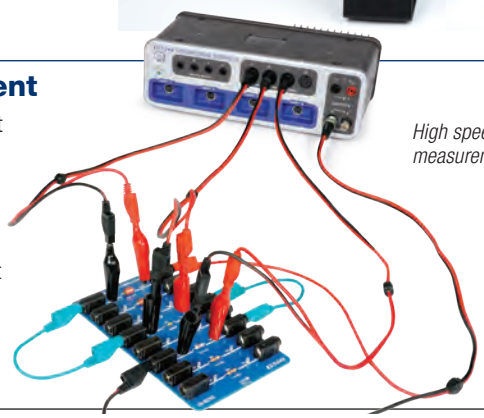


3. Voltage-Based Measurements

Analog sensing is based on voltage measurements. Understanding how devices convert physical changes like temperature, pressure, material deformation, and vibrations into voltage helps students understand the science behind their instrumentation.

4. Measurement Alignment

High speed voltage and current measurements in LRC circuits require that all measurements are synchronized on the same clock to ensure data integrity, and the accurate measurement of phase relationships.



High speed voltage and current measurements in LRC circuits.

Motion Sensor II

CI-6742A

PASCO's digital ScienceWorkshop Motion Sensor II is used to measure position, velocity and acceleration. Ultrasonic pulse-ranging technology has a switch-selectable Standard Beam or Narrow Beam to reject false signals and produce cleaner data. The Motion Sensor sits firmly on a desktop or easily mounts to a rod stand or PASCO Dynamics Track.

Connector:
Dual stereo phone plug for 850, 550, and ScienceWorkshop interfaces.

Order Information

Motion Sensor II	CI-6742A
Recommended:	
Motion Sensor Guard	SE-7256
Motion Sensor Bracket	PS-2546
Cart Adapter Accessory	ME-6743
Accessory Cable – Motion Sensor	CI-6748

Allows CI-6742A to be used with CBL/EA100.

Motion Sensor Guard

SE-7256

Use this wire guard to protect the Motion Sensor when dropping objects from above.

Order Information

Motion Sensor Guard	SE-7256

Motion Sensor Bracket

PS-2546

This magnetic bracket allows a Motion Sensor to be easily hung from a drop ceiling. Simply screw the bracket into the 1/4"-20 threads on the sensor and use the included adjustment nut to hold the sensor in the desired orientation.

The bracket can also be used to hold the Motion Sensor on vertical surfaces such as filing cabinets and magnetic whiteboards.

Order Information

Motion Sensor Bracket	PS-2546

Cart Adapter Accessory

ME-6743

The Cart Adapter Accessory allows the Motion Sensor and many other sensors to be mounted to a Dynamics Cart or a PAScar.

Mounting a Motion Sensor on a cart is ideal for the study of relative motion. The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Includes:

- Two M5 thumb screws to attach to cart
- 1/4"-20 screw at center

The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Order Information

Cart Adapter Accessory	ME-6743

Rotary Motion Sensor

CI-6538

Measure angle and angular velocity or measure distance and linear velocity using the rack or the pulley. This sensor is also bi-directional, indicating the direction of motion.

Specifications:

Resolution: 1°/0.087 mm and 0.25°/0.022 mm (software selectable)
Maximum Speeds: 13 rev/sec at 1° resolution (360 data points/revolution); 3.25 rev/sec at 0.25° resolution (1440 data points/revolution)
Optical Encoder: Bidirectional, indicates direction of motion
Connector: Dual stereo phone plug for 850, 550, and ScienceWorkshop interfaces

Order Information

Rotary Motion Sensor	CI-6538	
Recommended:		
Linear Motion Accessory	CI-6688A	p. 41
3-Step Pulley	CI-6693	

Force Sensor

CI-6537

PASCO's durable, reliable Force Sensor has been designed specifically for the student physics lab. Its wide-range, high-frequency response and low noise transducer help generate excellent impulse graphs, smooth harmonic motion data, and more. The sensor's special strain gauge consistently generates the same output for the same force and is designed to minimize side loads. Damping materials reduce vibrations caused by collisions without affecting results. Any dynamics cart accessory can be mounted on top of the Force Sensor.

Specifications:

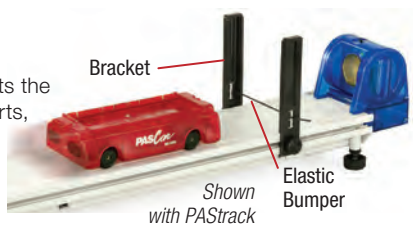
Force Range: ±50 N
Resolution: 0.03 N or 3.1 grams
Zero (Tare) Function: Push-button
Force-overload Protection: Mechanical stop prevents forces of more than 50 N from damaging the sensor
Pin Configuration: 8-pin DIN plug mounts on standard 12.7 mm support rods
Maximum Sample Rate: Depends on interface

Order Information

Force Sensor	CI-6537

Elastic Bumper

ME-8998



The Elastic Bumper protects the Motion Sensor from the carts, but doesn't interfere with the ultrasonic pulse.

Shown with PAStrack (see page 104)

Includes:

- Two pairs of brackets
- 10 meters of elastic material

Order Information

Elastic Bumper	ME-8998

Photogate Head

ME-9498A

The Photogate Head monitors the motion of objects passing through its gate, counting events as the object breaks the infrared beam.

Specifications:

Photogate Width: 7.5 cm
Fall Time: < 50 ns
Spatial Resolution: < 1 mm
Timing Resolution: 0.1 millisecond
Connector: Stereo phone plug

Order Information

Photogate Head ME-9498A
Recommended:
Photogate Stand ME-9805

Accessory Photogate

ME-9204B

Applications:

- Conduct basic position, velocity and acceleration experiments
- Measure acceleration due to gravity (free fall)
- Measure pendulum periods

Includes both a Photogate Head and a Photogate Stand for flexible experiment design. The Photogate Stand is also sold separately.

Includes:

- Photogate Head (ME-9498A)
- Photogate Stand (ME-9805)

Order Information

Accessory Photogate ME-9204B
Photogate Stand ME-9805

Photogate & Pulley System

ME-6838A

Specifications:

Pulley Rotational Inertia: 1.8 x 10^{-6} kg m^2
Pulley Coefficient of Friction: < 7 x 10^{-3}
Pulley Diameter: 5 cm, mass 5.5 g
Photogate Width: 7.5 cm; fall time < 50 ns
Photogate Spatial Resolution: < 1 mm
Timing Resolution: 0.1 millisecond
Connector: Stereo phone plug

Order Information

Photogate & Pulley System ME-6838A

Time-of-Flight Accessory

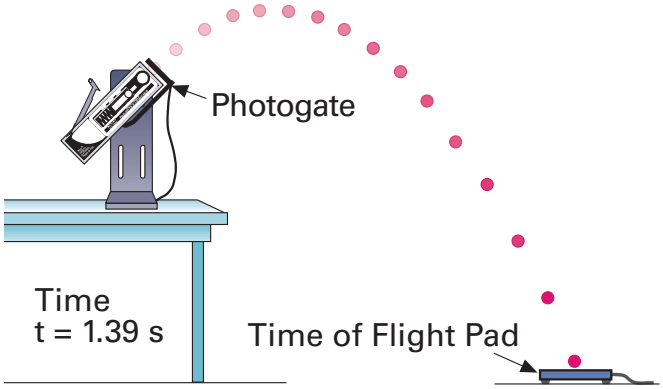
ME-6810A

Applications:

- Conduct freefall experiments
- Use with all PASCO launchers
- Horizontal Velocity is Constant
- Horizontal Distance (two Photogate Heads needed)
- Time-of-Flight Versus Initial Velocity

The Time-of-Flight Accessory is designed primarily for freefall or projectile experiments. When an object hits the plate, a signal is sent to the interface.

Note: When used with the Projectile Launcher, a photogate is used to start the timer and the 20' extension cable is recommended.



Order Information

Time-of-Flight Accessory ME-6810A

Phone Jack Extender Cable

PI-8117

This six meter phone jack-to-phone jack extension cord can be used with any Photogate/Timing accessory.

Order Information

Phone Jack Extender Cable (20' cable) PI-8117

Sound Sensor with Microphone

UI-5101

Also see the Wireless Sound Sensor on page 67.

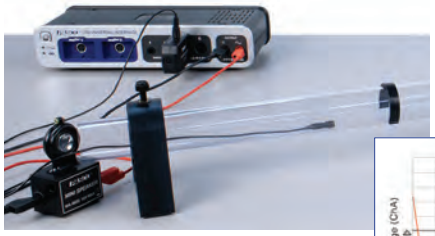
The Sound Sensor houses a sensitive microphone designed to measure the relative intensity of sound and display the audio waveforms of sound levels between 45 and 100 dB, when used in conjunction with the 550 or 850 Universal Interface and PASCO software.

Applications:

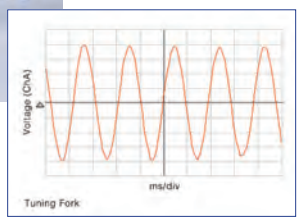
- Measure basic sound intensity
- Measure speed of sound measurement
- Measure beats
- Study the doppler effect
- Conduct voice studies
- Learn musical instrument overtones

Specifications:

Frequency Response: 20 to 9,000 Hz
Decibel Range: 45 to >100 dB
Signal-to-Noise Ratio: < 60 dB
Amplification: Two stages condition low-level signals
Pin Configuration: 8-pin DIN plug on case
Sensor ID: Auto-identification on 550/850 Interfaces



The included auxiliary microphone can be used to probe a resonance tube.



Includes:

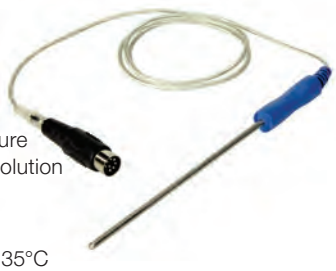
- Auxiliary Microphone (UI-5102)
- 8-Pin DIN Extension Cable
- Sensor Mounting Rod

Order Information

Sound Sensor with Microphone.....UI-5101
Replacement:
Auxiliary Microphone UI-5102

Temperature Sensor

CI-6605A



- Rugged sensor

PASCO's Stainless Steel Temperature Sensor offers a superior range, resolution and accuracy.

Specifications:

Temperature Range: -35°C to +135°C
Accuracy: ±0.5°C
Resolution: 0.05°C
Pin Configuration: 8-pin DIN plug

Order Information

Temperature Sensor CI-6605A

Basic Electrometer

ES-9078A

- For 550/850 and ScienceWorkshop Interfaces

The PASCO Basic Electrometer is a quantitative electroscope, measuring the polarity and magnitude of charged objects. With almost infinite input resistance (10^{14} ohm), the Electrometer is a high-impedance voltmeter, draining almost no charge from the object it is measuring.

Features:

- **Center-Zero Meter:** Polarity is indicated directly.
- **Switch-Selectable Ranges:** 3, 10, 30 and 100 VDC. LED lights indicate the range in use.
- **Zeroing Switch:** Removes all charge from the input and brings the meter to zero.
- **Automatic Shutoff:** Turns off about 3 hours after turned on (or used in any way).
- **Output Compatible with PASCO Interfaces:** The interface cable included with the electrometer connects directly to an analog channel on a ScienceWorkshop interface, and connects to a PASPORT interface through an Analog Adapter. This enables the output signal from the electrometer to be recorded, displayed, and analyzed by the data acquisition software.
- **Battery Operation:** 4 "AA" cells included. Range indicator lights flash when batteries need to be replaced.

Includes:

- Shielded input cable to connect the Electrometer to the Faraday Ice Pail or other source of charge
- Grounding cable with clip
- Interface cable
- Instruction and experiment manual

Order Information

Basic Electrometer.....ES-9078A

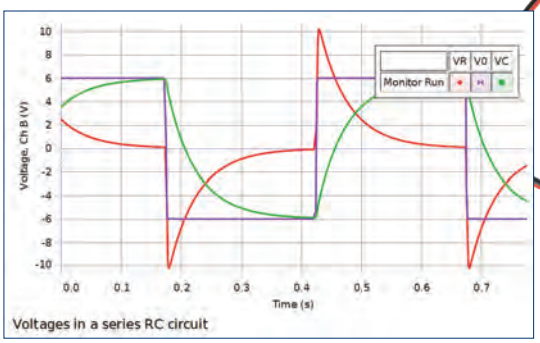
For 550/850 Interfaces and High Speed Sampling:

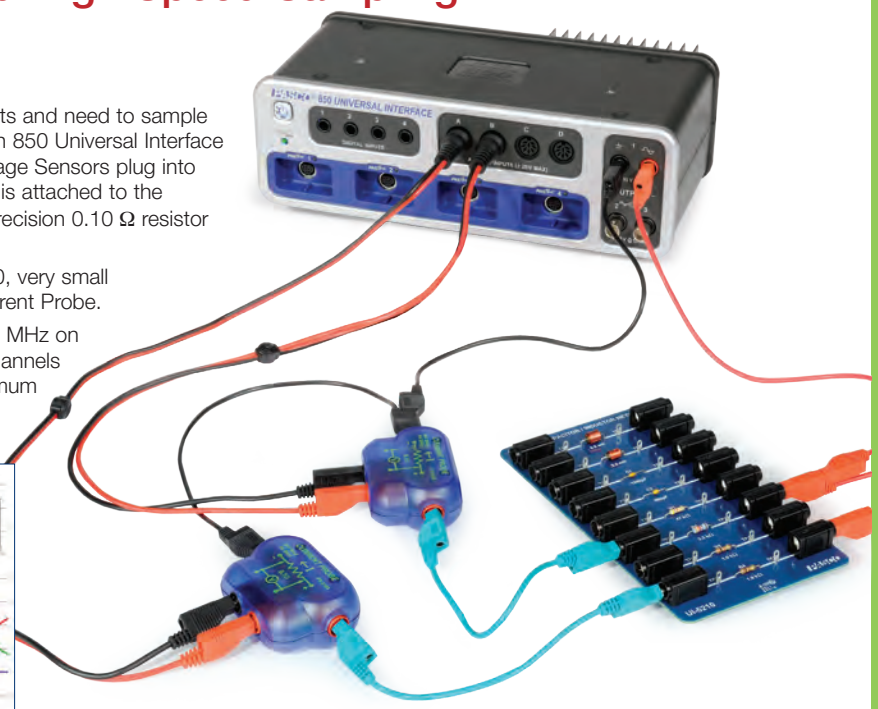
Voltage Sensor UI-5100/UI-5110
Current Probe PS-2184

When you're measuring voltage and current in AC circuits and need to sample fast, these sensors can sample as fast as 10 MHz on an 850 Universal Interface and up to 2 MHz on a 550 Universal Interface. The Voltage Sensors plug into the analog ports of these interfaces. The Current Probe is attached to the Voltage Sensor to measure the voltage drop across a precision 0.10 Ω resistor and outputs the resultant current calculation.

Since the 850 Interface analog gain can be set to x1000, very small currents (0.024 mA resolution) can be read with the Current Probe.

The 850 Universal Interface can measure at a rate of 10 MHz on two channels simultaneously; 1 MHz on three or four channels simultaneously. The 550 Universal Interface has a maximum sample rate of 2 MHz on one channel; 1 MHz on two channels simultaneously.





The high speed of the 850 Universal Interface, in Scope Mode, allows the examination of time varying voltages in an RC circuit to verify that Kirchhoff's loop theorem holds even when voltage is not constant.

Voltage Sensor

UI-5100 (unshrouded)

UI-5110 (shrouded)

This voltage sensor plugs into any analog channel on a ScienceWorkshop Interface, the 850 Universal Interface, and the 550 Universal Interface. The voltage range and frequency response depend on the interface. When the Voltage Sensor is plugged into either the 550 or 850 Universal Interface, the sensor is automatically recognized.

Specifications:

Voltage Range with 850 Interface: ±20 V AC/DC (850 Interface)

Voltage Range with other interface: ±10 V AC/DC (other than 850)

Product Pin Configuration: 8-pin DIN plug. Probe ends are standard banana plugs. Two alligator clip adapters included.

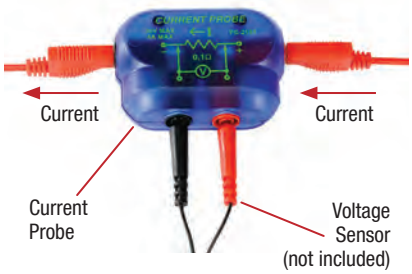
Order Information

Voltage Sensor (unshrouded) UI-5100

Voltage Sensor (shrouded) UI-5110

Current Probe

PS-2184



The PS-2184 attaches to any PASCO voltage sensor to allow the measurement of current between -4 A and +4 A. The probe contains a precision 0.10 ohm resistor and allows the precise measurement of the voltage drop across the resistor.

Specifications:

Resistor: 0.10 Ohm, 3.0 W, 1.0%

Maximum Current: 4 A

Maximum Voltage Without Damage: 30 V

Terminals: 4 mm Banana Jacks

Maximum Sample Rate: Depends on interface

Order Information

Current Probe PS-2184

Current Sensor

CI-6556

The Current Sensor determines the current through it by measuring the voltage across the internal 1.00 Ω resistor. Up to 1.5 A can be measured.

Specifications:

Maximum Current Input: 1.5 A*

Maximum Differential Voltage: 1.5 V*

Maximum Common Mode Voltage: 10 V

Resolution: 5 mA (1X gain), 0.5 mA

Pin Configuration: 5-pin DIN on box

*DC or AC RMS (root mean square)

Order Information

Current Sensor CI-6556

Light Sensor

CI-6504A

Applications:

- Measure relative light intensities in daylight (even monitor a solar eclipse)
- Compare light intensity vs. distance
- Study interference/diffraction/polarization

PASCO's Light Sensor is ideal for indoor and outdoor relative light intensity experiments. It can be used in a lighted room for most experiments.

Specifications:

Sensing Element: Si PIN photodiode
Spectral Response: 320 nm to 1100 nm
Gain Levels: 100x, 10x, 1x, switch-selectable
Output Voltage: 0 V to 5 V
Pin Configuration: 5-pin DIN plug on case
Maximum Light Intensity Levels (lux): Approximate Lux 5, 50, 500
Resolution: 0.0001 lux maximum

Order Information

Light Sensor CI-6504A

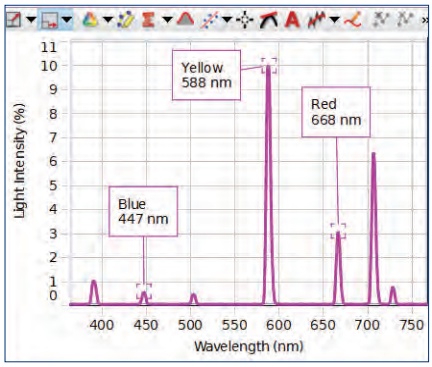
High-Sensitivity Light Sensor

CI-6604

Applications:

- Spectrophotometry
- Interference and diffraction patterns
- Measure light intensity vs. distance

The High-Sensitivity Light Sensor is designed for experiments involving low light level conditions.



Helium spectrum recorded using the High Sensitivity Light Sensor and the OS-8539 Educational Spectrophotometer System.

Specifications:

Sensing Element: Si PIN photodiode
Spectral Response: 320 nm – 1100 nm
Gain Levels: 100x, 10x, 1x, switch-selectable
Resolution: 10 µlux at the highest gain level.
Maximum Sample Rate: Interface dependent
Output Voltage: 0V to 5V

Order Information

High-Sensitivity Light Sensor CI-6604

Magnetic Field Sensor

Also see the Wireless 3-Axis Magnetic Field Sensor on page 69.

CI-6520A

- Measures radial or axial fields
- High sample rate

PASCO's Magnetic Field Sensor is sensitive enough to detect Earth's magnetic field. Its application in the physics lab includes measuring and plotting fields in single or Helmholtz coils, solenoids, electromagnets and magnets.

Features

- **Measures radial or axial fields:** Two switch-selectable Hall Effect sensors measure either radial or axial fields.
- **Tare button:** Zeroing or nulling out existing fields is accomplished by just pushing the Tare button.
- **Three switchable ranges of sensitivity:** Full scale ranges of 10, 100 and 1,000 gauss.
- **7.5 cm Probe:** Sensors are mounted at the end of a fully encapsulated 7.5 cm long probe.

Specifications:

Sensitivity:
± 10 gauss (100X Gain),
50 mG resolution, 1 G Accuracy
± 100 gauss (10X Gain),
50 mG resolution, 10 G Accuracy
± 1000 gauss (1X Gain),
500 mG resolution, 100 G Accuracy
Measurement Modes: Axial and Radial
Probe Length: 7.5 cm
Pin Configuration: 8-Pin DIN plug on case

Order Information

Magnetic Field Sensor CI-6520A
Replacement:
Zero Gauss Chamber EM-8652

Zero Gauss Chamber

EM-8652

This double-walled, high permeability metal chamber produces a zero gauss field within the chamber. By placing the Magnetic Field Sensor probe into the chamber and pushing the "Tare" button, the sensor may be zeroed. Highly recommended for measurement of Earth's magnetic field.

Order Information

Zero Gauss Chamber EM-8652

Digital PASPORT Sensor Index

PASPORT Sensors:

- Have digital outputs that allow multiple measurements per channel with reduced noise
- Compatible with all current PASCO interfaces, as well as discontinued PASPORT interfaces

PASPORT Sensor Extension Cable

PS-2500

The PASPORT Sensor Extension Cable extends the distance a PASPORT sensor can reach by 2 m. Two cables CANNOT be connected together or used on a sensor that already has a cable.

Order Information

PASPORT Sensor Extension Cable PS-2500

8-Pin DIN Extension Cable

UI-5218

The 1.8 m long Extension Cable allows ScienceWorkshop Sensors to be used further away from the interface. Multiple cables can be used in series. It is compatible with the 500, 750 (discontinued), and 850 Interfaces.

Order Information

8-Pin DIN Extension Cable UI-5218

PASPORT Digital Adapter

PS-2159

The Digital Adapter is required when photogates, timing and counting sensors are used with any PASPORT interface. Each Digital Adapter accommodates two sensors at once. Each port on the Digital Adapter automatically detects a connection and initiates a selection of pre-configured or user-defined options. Several Digital Adapters can be used simultaneously when required.

Order Information

PASPORT Digital Adapter.....PS-2159

Smart Gate *It's four photogates in one!*

PS-2180

- Dual Photogate beams
- Photogate Tape Slot
- Daisy-chain auxiliary Photogate or Time-of-Flight

Also see the Wireless Smart Gate on page 64.

The Smart Gate connects directly to any PASPORT interface, and has an auxiliary port to daisy-chain to an additional Photogate. Can be used with a Cart Picket Fence, Clamp-On Super Pulley, and flexible Photogate Tape.

High Resolution Photogate Tape

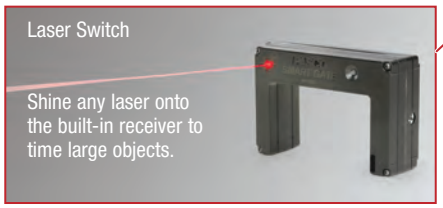
ME-6666

Flexible picket fence tape can be cut to any length.

Slot for Photogate Tape

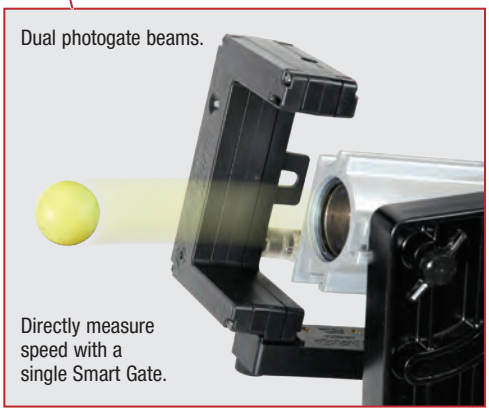
Auxiliary port for Time-of-Flight or other photogates

Connects directly to a PASPORT interface.



Laser Switch

Shine any laser onto the built-in receiver to time large objects.



Dual photogate beams.

Directly measure speed with a single Smart Gate.

Includes:

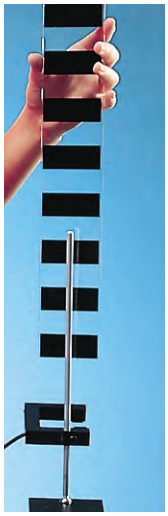
- Smart Gate
- PASPORT Cable
- Interface Cord

Order Information

Smart Gate	PS-2180
Recommended:	
Time-of-Flight Accessory	ME-6810A
Photogate Tape, High Resolution (30 m)	ME-6666
Required:	
PASPORT Interface	

Picket Fence

ME-9377A



Conduct freefall experiments by dropping this Picket Fence through the PASCO Photogate.

The distance from the leading edge of each black bar to the leading edge of the next black bar is 5.0 cm. The Picket Fence has eight black bars and is 40 cm long.

Order Information

Picket Fence ME-9377A

Cart Picket Fences (2 Pack)

ME-9804

Order Information

Cart Picket Fences (2 Pack) -- IDS ME-9804

Picket Fences (Smart Timer) (Set of 2)

ME-8933

See Smart Timer on pages 126-127.

Order Information

Picket Fences (Smart Timer) ME-8933

Photogate Tape, High Resolution (30 m)

ME-6666

This flexible Mylar picket fence tape can be cut to any length. Tape slides into a Smart Gate to more accurately measure the motion of a cart.

Slide the photogate tape through the slot to measure position, velocity, and acceleration. The band spacing on the tape is 1 cm from edge to edge.

Order Information

Photogate Tape, High Resolution (30 m) ME-6666
Recommended:
Smart Gate PS-2180

Phone Jack Extender Cable

PI-8117

This six meter phone jack-to-phone jack extension cord can be used with any Photogate/Timing accessory.

Order Information

Phone Jack Extender Cable..... PI-8117

Photogate Head

ME-9498A

The Photogate Head monitors the motion of objects passing through its gate, counting events as the object breaks the infrared beam.

Specifications:

Photogate Width: 7.5 cm
Fall Time: < 50 ns
Spatial Resolution: < 1 mm
Timing Resolution: 0.1 millisecond
Connector: Stereo phone plug

Order Information

Photogate Head ME-9498A
Recommended:
Photogate Stand ME-9805

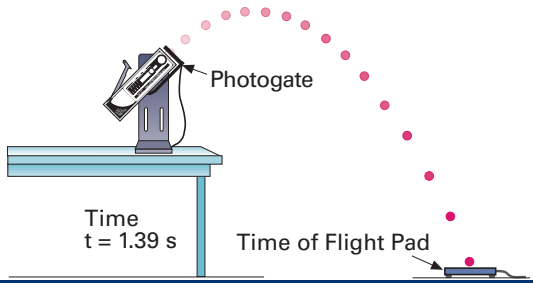
Time-of-Flight Accessory

ME-6810A

The Time-of-Flight Accessory is designed primarily for freefall or projectile experiments. When an object hits the plate, a signal is sent to the interface. Note: When used with the Projectile Launcher, a photogate is used to start the timer and the 20' extension cable is recommended.

Applications:

- Conduct freefall experiments
- Use with all PASCO launchers
- Horizontal Velocity is Constant
- Horizontal Distance (two Photogate Heads needed)
- Time-of-Flight Versus Initial Velocity



Order Information

Time-of-Flight Accessory ME-6810A

Super Pulley with Mounting Rod

ME-9499

This Super Pulley is mounted on a rigid plastic mounting rod (12.7 mm diameter, 14 cm long) and fits most standard laboratory clamps.

Order Information

Super Pulley with Mounting Rod ME-9499

PASPORT Motion Sensor

PS-2103A

The PASPORT Motion Sensor is used to measure the position, velocity, and acceleration of a target. The Motion Sensor can be set on a desktop, mounted to a rod stand, or attached to a PASCO Dynamics Track.

Features:

- Measures position, velocity, and acceleration
- False Target Rejection Technology collects clean data
- Switch-selectable short range and long range settings
- Snaps onto PASCO dynamics tracks
- Mounts to rods for easy positioning
- 360° pivoting head

Specifications:

Minimum Range: 0.15 meters

Maximum Range: 8 meters

Resolution: 1 mm

Maximum Sampling Rate: 250 Hz

Transducer Rotation: 360°

Narrow Near/Far Switch Settings: For distances up to 2 meters to reject false target signals or ignore air track noise.

Standard Near/Far Switch Settings: For longer distances up to 8 meters.

Cable Length: 1.8 meter

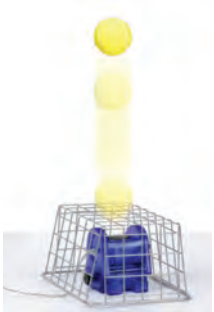
Mounting Options: Non-skid rubber feet for table mount

Order Information

PASPORT Motion Sensor	PS-2103A
Recommended:	
Motion Sensor Guard	SE-7256
Motion Sensor Bracket	PS-2546
Cart Adapter Accessory	ME-6743

Motion Sensor Guard

SE-7256



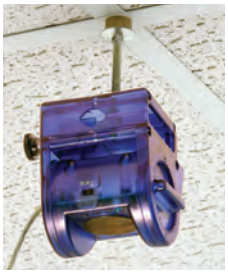
Use this wire guard to protect the Motion Sensor when dropping objects from above.

Order Information

Motion Sensor Guard	SE-7256

Motion Sensor Bracket

PS-2546



This magnetic bracket allows a Motion Sensor to be easily hung from a drop ceiling. Simply screw the bracket into the 1/4"-20 threads on the sensor and use the included adjustment nut to hold the sensor in the desired orientation.

Order Information

Motion Sensor Bracket	PS-2546

Cart Adapter Accessory

ME-6743

The Cart Adapter Accessory allows the Motion Sensor and many other sensors to be mounted to a Dynamics Cart or a PAScar.

Order Information

Cart Adapter Accessory	ME-6743

PASCO *MatchGraph!*

- Students feel the motion firsthand and learn how to interpret motion graphs! Watch your students compete to get the best match score.
- The sample graphs to match include both Position vs. Time and Velocity vs. Time.
- The student moves back and forth in front of a motion sensor in an attempt to match the motion represented on the graph.

FREE *MatchGraph!*™ Software

MatchGraph!™

Go to **pasco.com/downloads** and click on MatchGraph.

Now works with all Motion Sensors and Smart Carts!

See page 90 for more info.

MatchGraph!™

Download FREE *MatchGraph!* software for Mac® and Windows® computers at **pasco.com**. Download the free iPad® or Android™ app on the App Store or Google Play.

Download on the App Store

ANDROID APP ON Google play

Order Information

Required:		
Wireless Motion Sensor	PS-3219	p. 63
OR		
PASPORT Motion Sensor	PS-2103A	
OR		
Motion Sensor II	CI-6742A	p. 32
*Requires a USB or Bluetooth interface; see pages 60-61.		
OR		
Smart Cart (Red)	ME-1240	p. 62

PASPORT Rotary Motion Sensor

PS-2120A

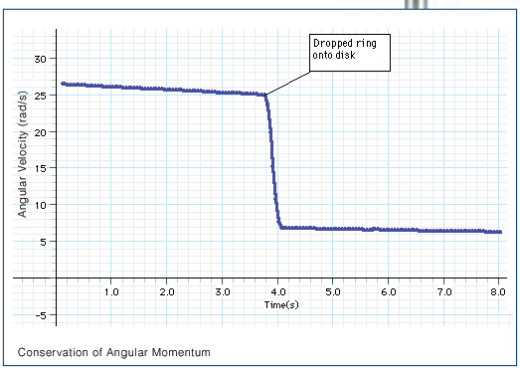
The PASPORT Rotary Motion Sensor is used to measure position and motion during physics labs. It measures position, velocity, and acceleration, both angular and linear, with incredible resolution and accuracy. The maximum spin rate of 30 rev/sec and bi-directional orientation enable the PASPORT Rotatory Motion Sensor to facilitate the performance of most motion experiments.

How it Works: The 6.35 mm diameter, dual ball-bearing shaft extends from both sides of the unit, providing an excellent platform for rotational experiments. The rod clamp, which can be attached to three sides of the sensor, allows the unit to be mounted in almost any orientation. A three-step pulley and a mount for the PASCO Super Pulley make torque experiments easier than ever before.

Specifications:

Three-step Pulley: 10 mm, 29 mm, and 48 mm diameters
Sensor Dimensions: 10 cm x 5 cm x 3.75 cm, 6.35 mm diameter shaft
Rotary Motion Resolution: 0.09° (0.00157 rad)
Linear Motion Resolution: 0.0078 mm
Maximum Rotation Rate: 30 revs/sec
Rotary Motion Optical Encoder: Bidirectional to indicate the direction of motion; 4000 divisions/rev

Conservation of Angular Momentum



The angular speed of the disk decreases when the ring is dropped onto the disk.

Order Information

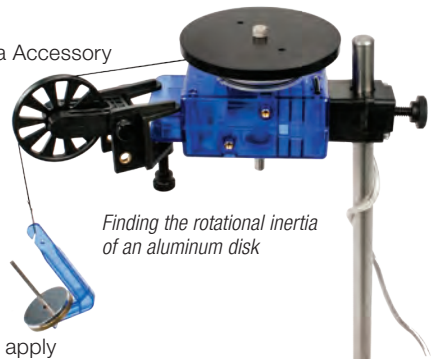
PASPORT Rotary Motion Sensor PS-2120A
Recommended:
Linear Motion Accessory CI-6688A
3-Step Pulley for Rotary Motion Sensor CI-6693

Rotational Inertia Accessory

ME-3420

- Ring and Disk have same mass and outer diameter.
- Alignment Guide centers the ring on the disk.

Add the Rotational Inertia Accessory to any PASCO Rotary Motion Sensor to study the oscillations of a pendulum, the rotational inertia of a disk, a steel ring and a metal rod, as well as the conservation of momentum during a rotational collision. The clamp-on Super Pulley allows students to apply a torque by hanging a mass over the pulley.



Finding the rotational inertia of an aluminum disk

Specifications:

Disk Mass: 100 g
Ring Mass: 100 g
Disk Diameter: 8.9 cm
Ring Diameter: 8.9 cm O.D., 7.9 cm I.D.
Rod Mass: 28 g
Rod Dimensions: 0.8 cm diameter, 38 cm long
Brass Masses: 75 g
Alignment Guide Mass: 2 g

Includes:

- Ring And Disk Set (ME-3419)
- Pendulum Accessory (ME-8969)
- Super Pulley with Clamp (ME-9448B)

Order Information

Rotational Inertia Accessory ME-3420
Also available:
Ring And Disk Set ME-3419
(Includes ring, 2 disks, and 3 alignment guides)

Linear Motion Accessory

CI-6688A

Includes:

- Rod Clamp
- Solid aluminum rack

Order Information

Linear Motion Accessory CI-6688A

PASPORT High Resolution Force Sensor

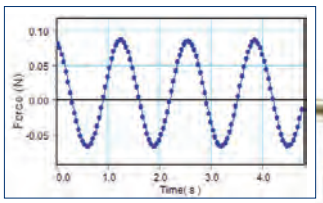
PS-2189

- 0.002 N resolution
- Dynamic over-sampling

The PASPORT High Resolution Force Sensor offers a higher resolution than the PS-2104. It features a variable over-sampling rate that reduces measurement noise at lower sampling rates. The digital design minimizes drift, ensuring that the tare holds for hours. You can use this force sensor as a pan balance for long-term experiments, such as investigating the evaporation of liquids, like alcohol or liquid nitrogen, and the sublimation of dry ice.

Specifications:

Range: ±50 N
Measurement Resolution: 0.002 N
Zero (Tare) Function: Push-button
Max Sample Rate: 1000 Hz; 5000 Hz for the 550 and 850 interfaces
Force Overload Protection: Up to 75 N



Graph shows force data for the oscillation of a mass and spring system.

The High Resolution Force Sensor has 10 times the resolution of the PS-2104, and can measure changes in force of less than 0.01 N.

The digital design of the PS-2189 results in very little drift, ensuring that the tare will hold for hours. You can use this force sensor as a pan balance for long-term experiments, like investigating the evaporation of liquids such as alcohol or liquid nitrogen, and the sublimation of dry ice!

Order Information

PASPORT High Resolution Force Sensor PS-2189
Shown in use with:
Mass and Hanger Set..... ME-8979 p. 207
IDS Spring Kit ..... ME-8999 p. 177

Force Sensor Balance Stand

CI-6460

Includes:

- Metal Force Sensor Stand
- Pan Balance

Order Information

Force Sensor Balance Stand CI-6460

PASPORT Force Sensor

PS-2104

- Binocular force beam minimizes side force measurements

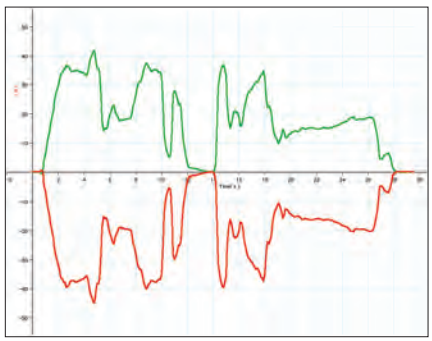
The sensor includes an overload stop in the force beam and a polycarbonate, plastic case to protect it from damage. Finger holes are provided for handheld use, but the sensor can also be mounted directly to a PASCO Dynamics Cart or a 0.5" rod stand.

Applications:

- Measure force exerted by an oscillating mass
- Measure force during elastic and inelastic collisions
- Measure force of a swinging pendulum

Specifications:

Range: ±50 N
Resolution: 0.03 N
Zero (Tare) Function: Push-button
Max Sample Rate: 1000 Hz; 5000 Hz for the 550 and 850 interfaces
Force Overload Protection: Up to 75 N without damage



This graph displays Newton's Third Law during a "Tug of War" experiment.

Order Information

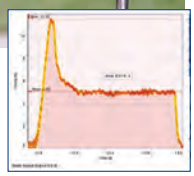
PASPORT Force Sensor PS-2104

Rocket Engine Test Bracket

ME-6617

- A perfect supplement for rocketry studies

With the Rocket Engine Test Bracket attached to a Force Sensor (ScienceWorkshop or PASPORT), students can measure and graphically display the impulse of Estes™ and other model rocket engines. A perfect supplement for rocketry studies. Accommodates rocket engine sizes A, B, C and D.



Order Information

Rocket Engine Test Bracket.....ME-6617

Bumper Accessory Set

ME-9884

Includes:

- Stiff Spring
- Light Spring
- Empty Cup (2)
- Modeling Clay

Order Information

Bumper Accessory Set..... ME-9884

Magnetic Bumper Set

ME-9885A

Includes:

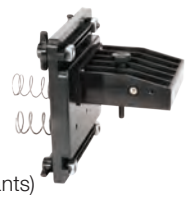
- Magnetic Bumper (2)

Order Information

Magnetic Bumper Set ME-9885A

Force Sensor Track Bracket

ME-6622



Includes:

- Spring Bumpers (2) (different spring constants)
- Magnetic Bumper
- Rubber Bumper
- Clay Cup for Inelastic Collisions (clay included)
- #0 Phillips Head Screwdriver (to attach to Force Sensor)

Order Information

Force Sensor Track Bracket ME-6622

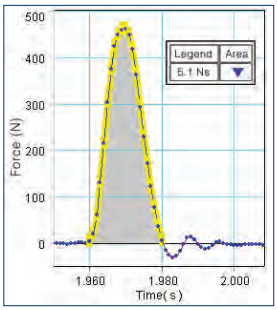
PASPORT Force Platform

PS-2141

Also see the Wireless Force Platforms on page 66.

- Rugged design
- Force overload protection
- Large jumping and landing surface

The sturdy, glass-filled nylon platform is supported by four force beams that measure the total force acting on the platform. You can use the Force Platform to measure the static weight of a structure or person, as well as the dynamic, vertical force created when moving or jumping. The platform can be placed on a floor or tabletop to measure vertical force, and mounted to a wall to measure horizontal force.



Impulse data for a bouncing playground ball.

Applications:

- Determine hang time by jumping from and landing on the platform.
- Measure impulse and maximum force.
- Measure the normal force acting on a person riding an elevator.
- Use two Force Platforms to investigate Newton's Third Law.
- Use a Motion Sensor and a ball to compare the impulse and change in momentum as the ball collides with the platform.

Specifications:

Range: -1100 N to +4400 N
Force Overload Protection: up to 6600 N (1500 lb, 1700 N or 375 lb per beam)
Platform Size: 35 cm x 35 cm
Zero (tare) Function: Push-button
Max Sample Rate: 1000 Hz (2000 Hz with the 850 Interface)
Resolution: 0.1 N
Mass: 4 kg (without handles)

Order Information

PASPORT Force Platform..... PS-2141
Recommended:
Handle Set, Force Platform..... PS-2548

PASPORT 2-Axis Force Platform

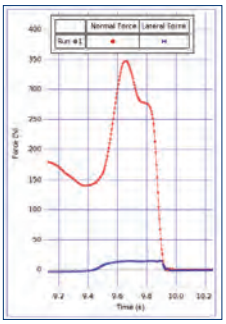
PS-2142

- Large jumping and landing surface

The 2-axis Force Platform has a second plate that rides on rollers along a base to measure the force parallel to the platform. There are a total of five force beams: four corner beams to measure the normal force and a fifth beam to measure the parallel (sideways) force.

Applications:

- Measure the sideways force during a broad jump.
- Measure the normal and parallel forces on a wall as a ladder leans against the wall.
- Measure the normal and parallel forces as a person walks or runs across the platform.
- Pull an object across the platform and measure the normal and frictional forces.



The normal and parallel forces are recorded as the girl jumps off the platform.

Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.

Specifications:

Range: -1100 N to +4400 N (in normal direction)
-1100 N to +1100 N (in parallel direction)
Platform Size: 35 cm x 35 cm
Platform Mass: 6.4 kg (without handles)
Zero (tare) Function: Push-button Force Overload Protection
Max Sample Rate: 1000 Hz (2000 Hz with the 850 Interface)
Resolution: 0.1 N

Order Information

PASPORT 2-Axis Force Platform..... PS-2142
Recommended:
Handle Set, Force Platform..... PS-2548

Handle Set, Force Platform

PS-2548

Confirm Newton's Third Law by pushing on a Force Platform using two sets of handles. The handles bolt onto the Force Platform and can be mounted on either side or both sides.

Includes:

- Sturdy metal handles (2)

A real-life statics problem can be analyzed by standing on a 2-Axis Force Platform while pushing against the wall with a 1-Axis Force Platform.

Order Information

Handle Set, Force Platform..... PS-2548

Force Platform Structure Bracket

ME-6988A

Includes:

- Brackets (2)
- Screws (4)

Order Information

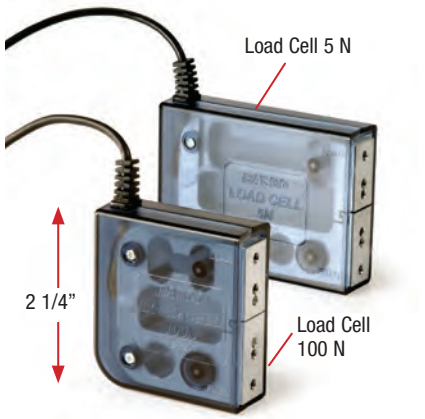
Force Platform Structure Bracket..... ME-6988A

Two ranges of Load Cells

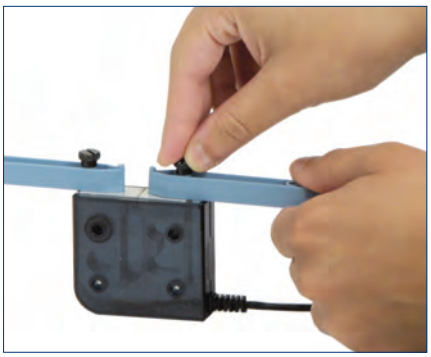
Load Cell 100 N
PS-2200

Load Cell 5 N
PS-2201

Also see the Wireless Load Cell on page 65.



Load Cells are available in two different ranges: ±100 N and ±5 N. Both types of Load Cells can be used with the same amplifier in any combination. The semi-transparent case lets students see the strain gauge and beam inside.



I-Beams key into the Load Cell and are fastened with thumbscrews.

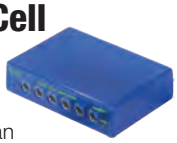
PS-2200 Specifications:
Range: ±100 N
Accuracy: ±1% (±1 N)
Resolution: 0.02 N
Safe Overload: ±150 N

PS-2201 Specifications:
Range: ±5 N
Accuracy: ±1% (±0.05 N)
Resolution: 0.001 N
Safe Overload: ±7.5 N

Order Information

100 N Load Cell	PS-2200
5 N Load Cell	PS-2201

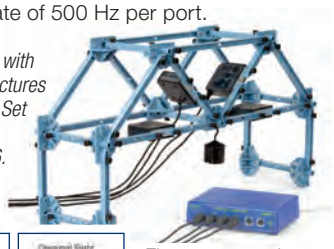
PASPORT Load Cell Amplifier



PS-2198

This Load Cell Amplifier can accommodate up to six Load Cells and utilizes a single PASCO interface port to connect to a computer's USB port. Students can insert up to six Load Cells at various points of their structures to extensively analyze their bridges. The Amplifier is compatible with both 5 and 100 N Load Cells, and features a maximum data sampling rate of 500 Hz per port.

Shown in use with PASCO's Structures System Truss Set (ME-6990). See page 156.



The top two numbers are the left and right diagonals and the bottom two numbers are the left and right horizontal forces.

Includes:
- PASPORT Load Cell Amplifier (PS-2198)
- Instruction manual

Order Information

PASPORT Load Cell Amplifier	PS-2198
Required:	
100 N Load Cell	PS-2200
5 N Load Cell	PS-2201

PS-2199 Includes:
- Load Cell Amplifier
- 100 N Load Cell (4)
- Instruction Manual

Order Information

Load Cell and Amplifier Set	PS-2199

PASPORT Dual Load Cell Amplifier

PS-2205

Includes:
- Dual Load Cell Amplifier
- 100 N Load Cell

PS-2206 Includes:
- Load Cell Amplifier (2-port)
- 100 N Load Cell

Order Information

PASPORT Dual Load Cell Amplifier	PS-2205
PASPORT Load Cell and Dual Amplifier Set	PS-2206

Measure bridge deflection with a Displacement Sensor

PASPORT Displacement Sensor
PS-2204

The Displacement Sensor measures the travel of a spring-loaded indicator as a bridge is loaded with weight. The PASPORT Sensor plugs into the included Digital Indicator, which has its own digital LED readout and can be used as a standalone device. To record your data, simply plug the PASPORT sensor into an interface.

Specifications:
Maximum Travel: 10 mm
Maximum Sample Rate: 5 Hz
Resolution: 0.013 mm (0.0005 in)

Includes:
- Sensor
- Bracket
- Dial Gauge

Order Information

PASPORT Displacement Sensor	PS-2204	
Shown in use with:		
Hooked Mass Set	SE-8759	p. 207
Small "A" Base	ME-8976	p. 196
Stainless Steel Rod, 60 cm Threaded	ME-8977	p. 196

PASPORT Absolute Pressure Sensor

PS-2107

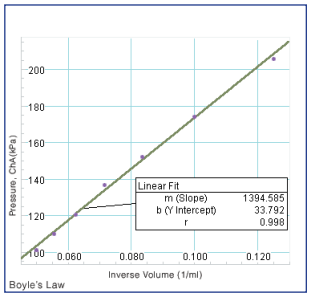
The Absolute Pressure Sensor measures the gas pressure in a container or the surrounding environment. Includes a 20 cc syringe and quick-connect tubing for investigating the Gas Laws. The sensor's wide range makes it an excellent general purpose pressure device.

Applications:

- Measure chemical reaction rates
- Verify Gas Laws (Ideal, Charles', Boyle's)
- Study Vapor Pressure vs. Temperature

Specifications:

Range: 0 to 700 kPa
Accuracy: ±2 kPa
Resolution: 0.1 kPa
Maximum Sample Rate: 200 Hz
Repeatability: 1 kPa



The Absolute Pressure Sensor is used in a Boyle's Law experiment in which a syringe is compressed.

Order Information

PASPORT Absolute Pressure Sensor PS-2107

PASPORT Dual Pressure Sensor

PS-2181

The Dual Pressure Sensor is capable of reading two absolute pressures, one gauge pressure, or one differential pressure. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.

Applications:

- Measure pressure in Heat Engine (TD-8572).
- Measure pressure drops in pipes.

Specifications:

Maximum Sample Rate: 1000 Hz

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Differential Pressure: ±100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Order Information

PASPORT Dual Pressure Sensor PS-2181

PASPORT Absolute Pressure/ Temperature Sensor

PS-2146

This combination sensor is specifically designed for studying the Ideal Gas Law. The included thermistor temperature probe has a fast response time and very low thermal mass.

Applications:

- Extrapolate absolute zero
- Explore Gas Laws (Ideal, Charles', Boyle's)

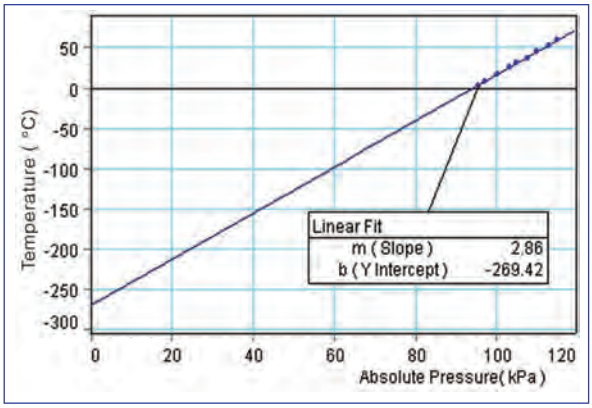
Specifications:

Pressure: 0 to 700 kPa with 2% accuracy, 0.5 kPa resolution (displays pressure in kPa, N/m^2, and psi)

Maximum Sample Rate: 100 Hz

Temperature with Included Fast Response Probe: -10 to 70°C with ±0.5°C accuracy (displays Temperature in °C, K and °F)

Sensor Extension Cable: Included



Extrapolating Absolute Zero

Measure the pressure and temperature of air in the sphere.

Order Information

PASPORT Absolute Pressure/Temperature Sensor	PS-2146	
Absolute Zero Sphere	TD-8595	p. 216
Ideal Gas Law Apparatus	TD-8596A	p. 216

PASPORT Temperature Sensor

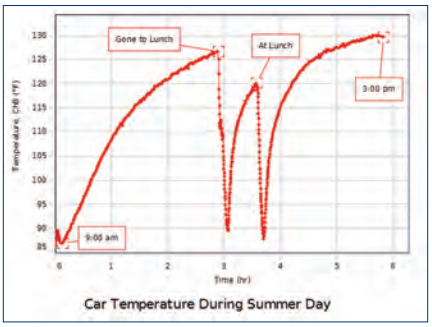
PS-2125

Also see the Wireless Temperature Link on page 68.

PASCO's Stainless Steel Temperature Sensor offers a superior range, resolution and accuracy. It reports temperature (in °C, °F, or K) whether it is immersed in liquids, held in the air, or touching a solid surface.

Applications:

- Conduct general temperature experiments
- Measure rapid temperature changes found in endothermic-exothermic reactions
- Conduct environmental studies



Capstone graph showing the temperature inside a parked car on a summer day. We turned on the air conditioning when we drove to lunch.

Specifications:

Range: -35°C to +135°C
Accuracy: ±0.5°C
Resolution: 0.0025°C
Maximum Sample Rate: 10 Hz
Displays: °C, K and °F
Repeatability: 0.1°C

Order Information

PASPORT Temperature Sensor PS-2125

PASPORT Quad Temperature Sensor

PS-2143

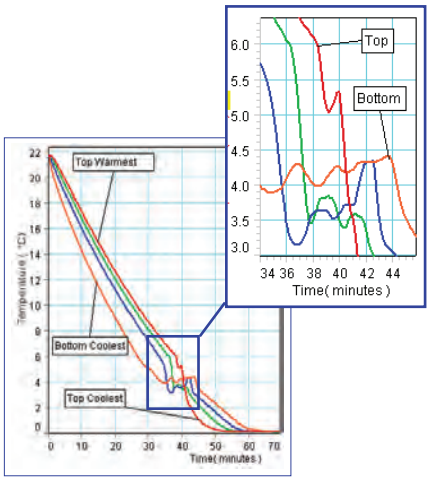
The PASPORT Quad Temperature Sensor can connect up to four Temperature Probes and can be used with our Stainless Steel, Fast Response, and Skin/Surface Temperature probes for a wider variety of temperature measurements in the classroom or field.

Applications:

- Thermal heat flow (one or two dimension)
- Compare body temperatures
- Side-by-side chemical reactions
- Solar radiation
- Properties of insulation

Specifications:

Accuracy: -35 to +135°C at ±0.5°C
Displays: °C, K and °F
Resolution: 0.0025°C
Maximum Sample Rate: 100 Hz



Four Fast Response Temperature Probes were used to study the temperature in a glass of water at four different levels as the water was cooled.

Includes:

- Two Stainless Steel Temperature Probes (2)
- Three Fast Response Probes (3)

Order Information

PASPORT Quad Temperature Sensor PS-2143

Temperature Probes

PASPORT Skin/Surface Temperature Probe

PS-2131

- Flat sensing element ideal for surfaces
- Quickly reaches equilibrium temperature with surface

Range:
-10 to +70°C

Make a temperature profile of the human hand.

Order Information

PASPORT Skin/Surface Temperature Probe PS-2131

PASPORT Fast Response Temperature Probe (3 pack)

PS-2135

- Accurately measures temperature changes in real time
- Ideal for small or hard-to-reach spaces
- Includes 10 adhesive patches
- Adhesive patches hold the Temperature Probe in place.

Range: -30 to +105°C

Order Information

PASPORT Fast Response Temperature Probe (3 pack) PS-2135

PASPORT Stainless Steel Temperature Probe

PS-2153

Range: -35 to +135°C

Order Information

PASPORT Stainless Steel Temperature Probe PS-2153

Order Information

**All of the probes above require one of the following temperature sensors:*

PASPORT Temperature Sensor PS-2125
PASPORT Quad Temperature Sensor PS-2143
Temperature Sensor ..... CI-6605A p. 34

PASPORT Non-Contact Temperature Sensor

PS-2197

- Non-contact
- -70°C to 380°C

The Non-Contact Temperature Sensor measures surface temperature by detecting the emitted infrared light. Record the temperature of objects without touching them!

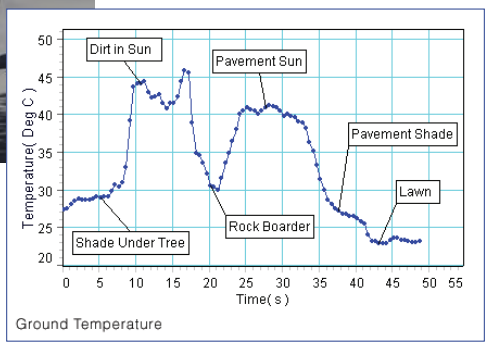
Applications:

- Compare temperature of hands, skin, face, and clothes
- Measure the temperature of different outdoor ground surfaces
- Map the temperature profile of an exterior wall

Specifications:

Range: -70°C to 380°C
Accuracy: ±0.5°C
Response Time: Less than 0.1 s
Maximum Sample Rate: 200 Hz
Field of View: ±35°

The student measures the late-morning ground temperature over four distinct surfaces. Starting in the shade under the distant tree, she then crosses bare dirt (in sun), a rock border, pavement, and lawn.



Ground Temperature

Order Information

PASPORT Non-Contact Temperature Sensor PS-2197
Shown in use with:
PASCO Capstone Software ..... pp. 84-87

PASPORT Temperature Type K Sensor

PS-2134

- Extra-long probe

The PS-2134 is a single channel sensor that uses a Type K thermocouple probe to measure temperatures ranging from -200 to +1000°C. Includes one Type K Thermocouple.

Applications:

- Measure temperatures down to -200°C
- Measure temperatures in hard-to-reach places
- Use in high temperature applications where the narrow tip of the probe can be applied without burning the insulation cover (such as a candle flame)

Specifications:

Temperature Range: -200°C to +1000°C
Maximum Sample Rate: 10 Hz
Accuracy: ±3°C or 3%, whichever is greater

The Type K Temperature Sensor can be used to measure the temperature of a flame. Works with any industry standard Type K thermocouple.

Order Information

PASPORT Temperature Type K Sensor PS-2134
Recommended:
Type K Thermocouple PS-2155

PASPORT High Sensitivity Light Sensor

PS-2176

- Ideal for low light experiments

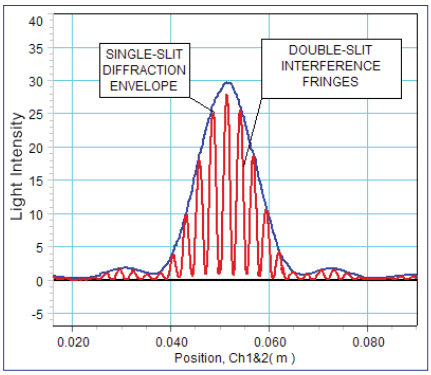
The High Sensitivity Light Sensor supports studies of visible light, ranging from early explorations of sunlight to low intensity spectral studies. Built-in automatic variable oversampling reduces noise.

Applications:

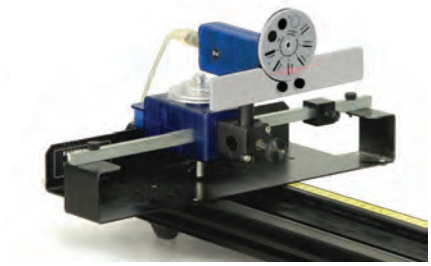
- Spectrophotometry
- Interference and diffraction patterns
- Measure light intensity vs. distance

Specifications:

Sensing Element: Si PIN photodiode
Spectral Response: 320 nm to 1100 nm
Gain Levels: 10,000x, 100x, 1x, switch selectable
Approximate Lux Ranges: 0 to 1, 0 to 100, 0 to 10,000
Maximum Sample Rate: 1000 Hz
Resolution: ±0.01 Lux at 1000 Hz on 0 to 100 scale; ±0.0005 Lux at 5 Hz on 0 to 100 scale



Computer scan of a single-slit and double-slit having the same slit width.



Order Information

PASPORT High Sensitivity Light Sensor PS-2176

PASPORT Infrared Light Sensor

PS-2148

- For heat studies

The Infrared Light Sensor is sensitive in the infrared portion (up to 40,000 nm) of the spectrum, but also detects the visible spectrum. It can detect the radiation from a person's hand. The response is linear over its entire frequency range.

Applications:

- Measure blackbody radiance
- Perform Leslie's Cube experiments
- Measure solar radiance
- Evaluate heat flow into or out of the sensor
- Simulate a non-contact temperature sensor

Specifications:

Measure Intensity: in Watts/Meter
Maximum Sample Rate: 100 Hz
Spectral Response: 580 to 40,000 nm
Built-in Thermistor: to measure the temperature of the "cold" side of the thermopile in °C, °F or K

Order Information

PASPORT Infrared Light Sensor PS-2148

PASPORT Broad Spectrum Light Sensor

PS-2150

- For use with Spectrophotometer
- Ideal for Blackbody Spectrum

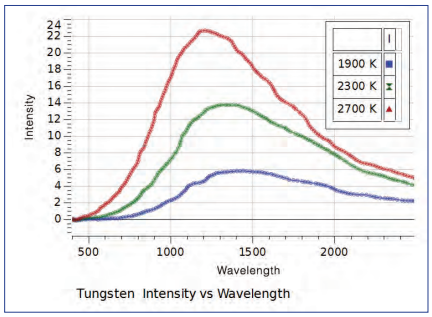
The Broad Spectrum Light Sensor is designed specifically for use with our Educational Spectrophotometer System OS-8539 and Prism Spectrophotometer Accessory OS-8543 for Blackbody experiments. The Broad Spectrum Light Sensor uses a thermopile and window combination that respond to both the near infrared and visible light necessary for the Blackbody experiment.

Applications:

- Blackbody Experiment

Specifications:

Sensing Element: BaF_2 window, xenon gas-filled thermopile
Spectral Response: 300 to 10,000 nm
Maximum Sample Rate: 100 Hz



The classic textbook diagram of the intensity versus wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is lowered.

Order Information

PASPORT Broad Spectrum Light Sensor PS-2150

PASPORT Voltage-Current Sensor

PS-2115

Also see the Wireless Current and Voltage Sensors on page 70.

The PASPORT Voltage-Current Sensor combines voltage and current sensors in one case. It can simultaneously measure voltage, current, and power, then display the collected data in the form of a digital display or graph. An audible beep can be heard when overload protection shuts down the sensor, alerting teachers and keeping students safe. The sensor will automatically reset after the high current is removed.

Applications:

- Study circuit properties for both circuits in series and parallel
- Ohm's Law
- Measure power used by an electrical device
- Indirectly measure the resistance of any circuit element
- Measure the voltage and current associated with RC and LRC circuits

Specifications:

Voltage Range: ±10 V
Voltage Resolution: 0.005 V
Current Range: ±1 A
Current Resolution: 0.5 mA
Current Channel Series Resistance: 0.6 ohms, < 0.9 ohms at room temperature
Maximum Common Mode Voltage: 10 V
Maximum Sample Rate: 1000 samples/sec
Voltage Input Impedance: 2 MΩ

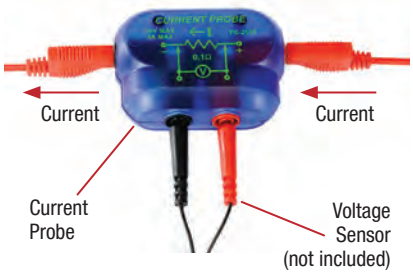
Order Information

PASPORT Voltage-Current Sensor	PS-2115	
Recommended:		
Alligator Clip Leads (Set of 10)	EM-8634	p. 237

PASPORT Current Probe

PS-2184

The PS-2184 attaches to any voltage sensor to allow the measurement of current between -4 A and +4 A. The probe contains a precision 0.10 ohm resistor and allows the precise measurement of the voltage drop across the resistor.



Specifications:

Resistor: 0.10 Ohm, 3.0 W, 1.0%
Maximum Current: 4 A
Maximum Voltage Without Damage: 30 V
Terminals: 4 mm Banana Jacks
Maximum Sample Rate: Depends on interface

Order Information

Current Probe	PS-2184	

PASPORT High Current Sensor

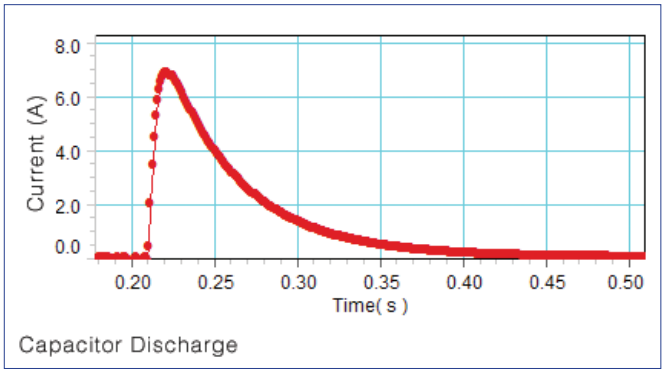
PS-2193

- 10 Amp
- Over-current LED

The High Current Sensor has a low (0.01 Ω) resistance sensing element, can measure up to 10 A, and has an LED over-current indicator. Dynamic variable over-sampling greatly reduces the measurement noise at low sample rates.

Specifications:

Current Range: ±10 A, resolution of 0.5 mA
Sensing Element Series Resistance: 0.01 Ω
Maximum Common Mode Voltage: 10 V
Maximum Continuous Current Without Damage: 12 A
Maximum Continuous Overvoltage Without Damage: ±40 V
Maximum Sample Rate: 1000 samples/second



The capacitor is charged with a power supply to 10 volts, and then discharged through the Air Core Solenoid. The graph of the data shows the effect of the coil's inductance on the rise time of the current.

Order Information

PASPORT High Current Sensor	PS-2193	
Recommended:		
Capacitor (0.025 F, 2 Pack)	EM-8632	p. 239
Knife Switches	EM-8815	p. 237
Air Core Solenoid	SE-7585	p. 247

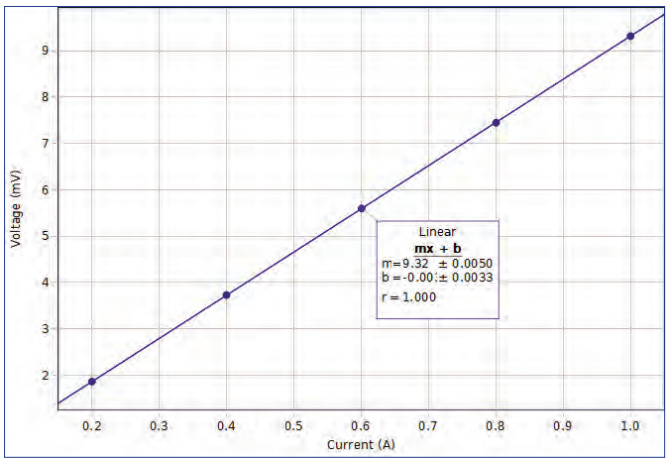
PASPORT Galvanometer

PS-2160

The Galvanometer Sensor is designed to measure small voltages with high resolution. It includes dynamic variable over-sampling, which greatly reduces the measurement noise at low sampling rates. Shunt resistors are included to allow measurement of current.

Specifications:

Voltage Range: ±2000 mV, resolution of 0.1 mV
Maximum Sample Rate: 1000 Hz with other interfaces
Input Impedance: 1 MΩ



Galvanometer Sensor can measure the voltage drop across a short piece of wire. A linear fit of voltage versus current yields the resistance of 0.0093 Ω for the wire.

By using a shunt resistor, the Galvanometer Sensor can be used to measure current.

Includes:

- BNC-to-banana plug cable
- BNC-to-banana jack adapter
- 0.1 Ω and 10 Ω resistors

Order Information

PASPORT Galvanometer	PS-2160	
Recommended:		
Alligator Clip Leads (Set of 10)	EM-8634	p. 237

PASPORT Charge Sensor

PS-2132

- Ideal for Electrostatics

The Charge Sensor is designed for experiments in electrostatics such as inductive charging, charge production/distribution, and charge on a capacitor. The sensor features automatic scaling, eliminating the need for a gain switch. Designed with highly efficient input over-voltage protection, the Charge Sensor is virtually "blow-out" proof and will provide many years of use in the student lab.

When used with the Faraday Ice Pail, the Charge Sensor can measure the total charge on an object by the induction method.

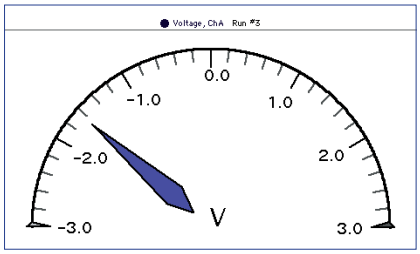
The Charge Sensor can also be used as a high impedance voltmeter (10^{12} Ω). It includes a 0.9 m shielded cable with alligator clips to eliminate stray fields.

Applications:

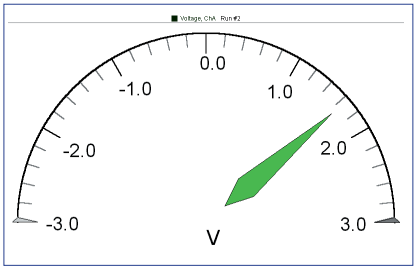
- Measure charge by induction
- Quantify the charge on a capacitor plate
- Discover the charge distribution on a conducting sphere

Specifications:

Charge Range: ±0.1 µC
Voltage Range: ±10 V
Input Resistance: 10^{12} Ω
Maximum Input Voltage: 150 V
Maximum Sample Rate: 100 Hz
Input Connector: BNC
Input Cable: 0.9 m length; shielded with alligator termination



The Charge Sensor measures equal yet opposite charges on two objects.



Order Information

PASPORT Charge Sensor	PS-2132	
Recommended:		
Faraday Ice Pail	ES-9042A	p. 225

PASPORT Magnetic Field Sensor

PS-2112

Also see the Wireless 3-Axis Magnetic Field Sensor on page 69.

The Magnetic Field Sensor provides magnetic field measurement in a compact package. The sensor at the tip of the probe measures magnetic field strength along the axis of the probe.

Applications:

- Study the field strength of bar magnets and electromagnets
- Understand the field strength of a solenoid
- Measure the field strength of a Helmholtz coil

Specifications:

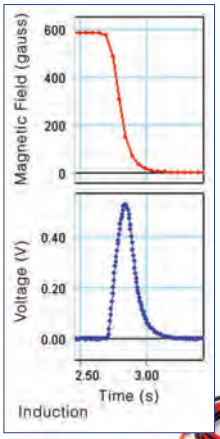
Range: ±1000 gauss

Accuracy: ±3 gauss or 5% of reading, whichever is greater at 25°C (after four minute warm-up)

Resolution: 0.1 gauss (0.01% full-scale)

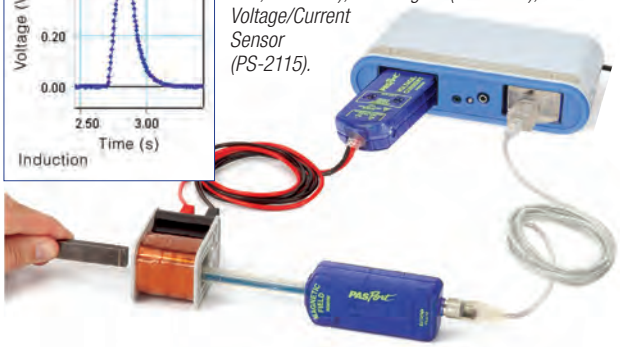
Maximum Sample Rate: 20 Hz

Repeatability: 0.05%



As the magnet is removed from the coil, a voltage is induced in the coil. The graph shows both the sudden decrease in magnetic field, as well as the voltage curve using a Voltage/Current Sensor.

Shown with: SPARKlink Air (PS-2011), Coil (3200 turn; SF-8613), Bar Magnet (EM-8620), and Voltage/Current Sensor (PS-2115).



Order Information

PASPORT Magnetic Field Sensor PS-2112
Recommended:
Zero Gauss Chamber EM-8652

Zero Gauss Chamber

EM-8652

This double-walled, high permeability metal chamber produces a zero gauss field within the chamber. By placing the Magnetic Field Sensor probe into the chamber and pushing the "Tare" button, the sensor may be zeroed. Highly recommended for measurement of Earth's magnetic field.

Order Information

Zero Gauss Chamber EM-8652

PASPORT 2-Axis Magnetic Field Sensor

PS-2162

- Measures radial and axial fields
- Tare button

Use the PASPORT 2-Axis Magnetic Field Sensor to measure radial and axial fields simultaneously. The built-in dynamic variable over-sampling greatly reduces noise at low sample rates.

Applications:

- Measure Earth's magnetic field.
- Measure magnetic field (magnitude and direction from a coil or a bar magnet).

Specifications:

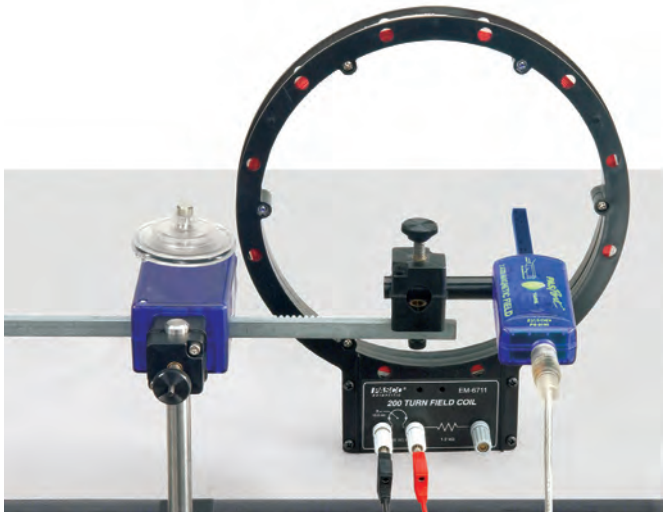
Range: ±1000 gauss

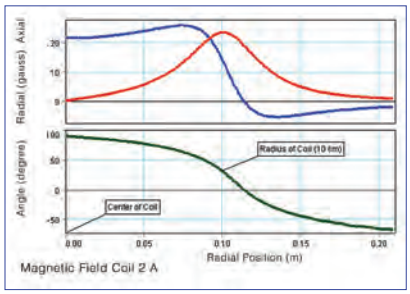
Accuracy: 5% of reading at 25°C (after four minute warm-up and Tare using Zero Gauss Chamber)

Resolution: 0.01 gauss at 10 Hz

Maximum Sample Rate: 1000 Hz

Repeatability: 0.05%





Magnetic field is measured from the center out to twice the radius of the coil. The angle of the resultant field is calculated.

Order Information

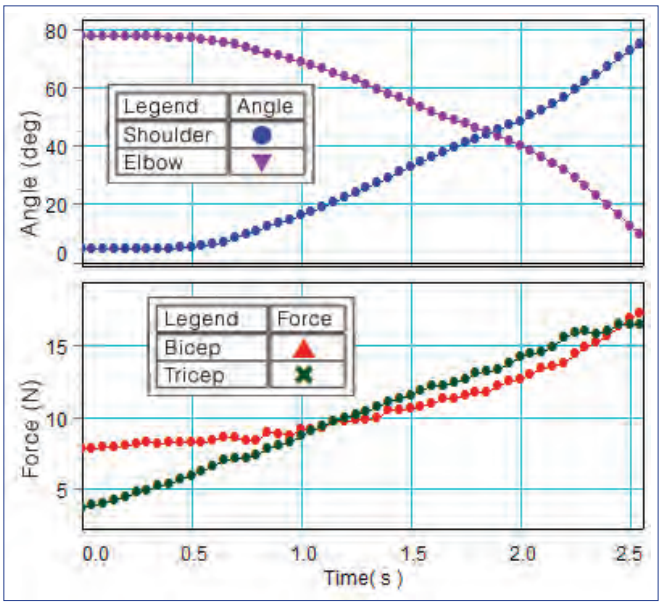
PASPORT 2-Axis Magnetic Field Sensor PS-2162
Recommended:
Zero Gauss Chamber EM-8652
Linear Motion Accessory ..... CI-6688A p. 41

Human Arm Model

PS-2611

- Working model of the human arm
- Associate tricep/bicep muscle action with arm motion
- Measure torque resulting from lifting weights
- Actually throws a ball

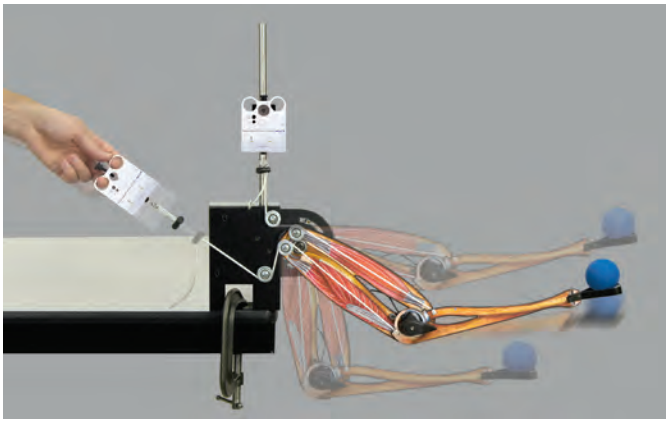
The Human Arm Model simulates the muscles and motion of an actual human arm. Students pull on the cord with a Force Sensor to activate the arm motion. Changes in position are measured at the shoulder and elbow using the two built-in potentiometers and the included Angle Sensor (PS-2139). From this information, the torque applied when lifting an object can be determined. Students may also evaluate the work done by the arm when throwing a ball and the resulting kinetic energy delivered to the ball.



Angles and Forces During Extension: *The upper graph shows the angles of the elbow (violet trace) and the shoulder (blue) as the arm is extended. Shown in the lower graph, the bicep tension (red) has little change at first and then rises sharply as the arm reaches out, while the tricep tension (green) rises steadily.*

Includes:

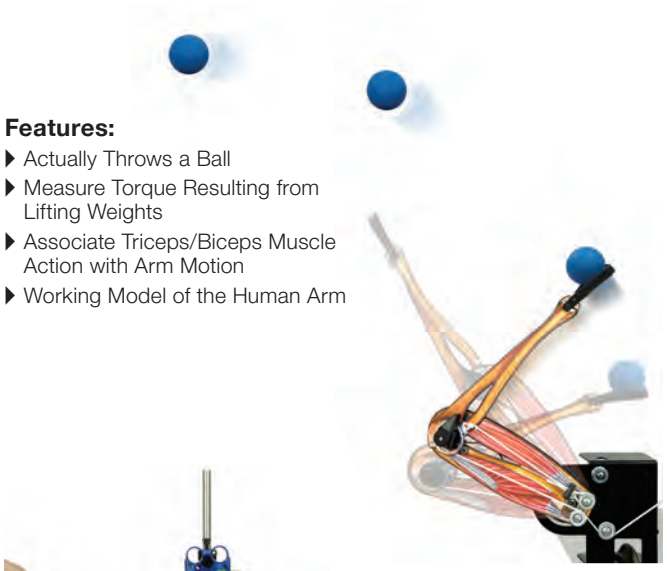
- Human Arm Model
- Angle Sensor
- Removable Mass
- Cord & Cord Locks
- Mounting Bracket with Rod
- Force Sensor Mounting Rod
- Rubber Ball

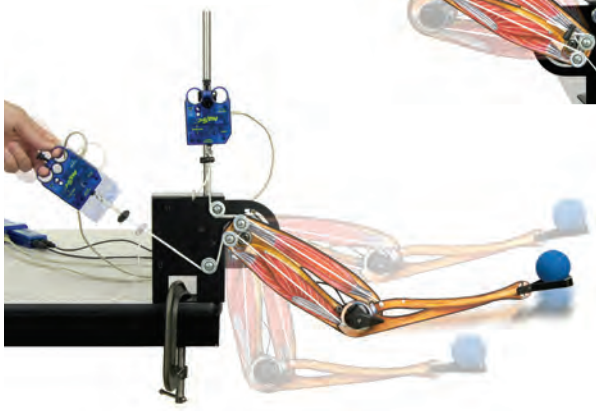


The Arm can perform many types of motion such as extending and lifting an object, curling, or throwing a ball overhand. Different arm muscles are activated depending on which pulleys are selected. Static force measurements can also be made to see how the muscle tension changes at various arm positions.

Features:

- Actually Throws a Ball
- Measure Torque Resulting from Lifting Weights
- Associate Triceps/Biceps Muscle Action with Arm Motion
- Working Model of the Human Arm





Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.

Order Information

Human Arm Model	PS-2611	
Human Arm Model Without Sensors	ME-6807A	
Required for force measurement:		
Wireless Force Acceleration Sensor	PS-3202	p. 65

PASPORT Breath Rate Sensor

PS-2187

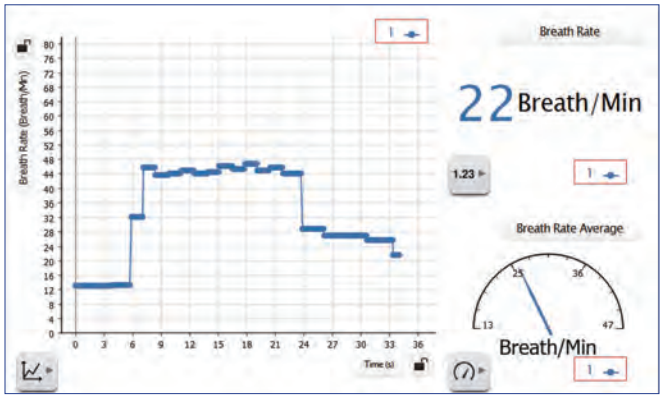
Also see the Wireless Blood Pressure Sensor on page 76.

- Works while exercising

The Breath Rate Sensor measures breath rate by sensing the pressure change within a standard, disposable dust mask. It generates consistently stable output, even when used during exercise. The sensor's tubing connects to the disposable pressure clips that fasten to the sides of the mask.

Applications:

- One reading every breath
- Running average over last four breaths



A graph showing a student's breath rate before, during, and after exercise

Includes:

- Sensor with Tubing
- Pressure Clips (10)
- Masks (10)

Order Information

PASPORT Breath Rate Sensor	PS-2187
Breath Rate Sensor Clips (10 pack)	PS-2568
Breath Rate Sensor Disposable Masks (10 pack)	PS-2567

PASPORT Goniometer Sensor

PS-2137

- Accurately measures joint movements
- Flexible mounting options for hip, knee, and elbow

The PASPORT Goniometer Sensor allows students to use their own bodies to contextualize physics. The Goniometer can be connected to knee, hip, or elbow joints to measure angle changes throughout a variety of movements. It can be used to measure the angular position, velocity, and acceleration of an arm or leg.

The PS-2137 includes one Angle Sensor (PS-2139) and one Goniometer Probe with a Velcro connection kit. An add-on Goniometer Probe (PS-2138) must be purchased to measure the motion of two joints simultaneously.

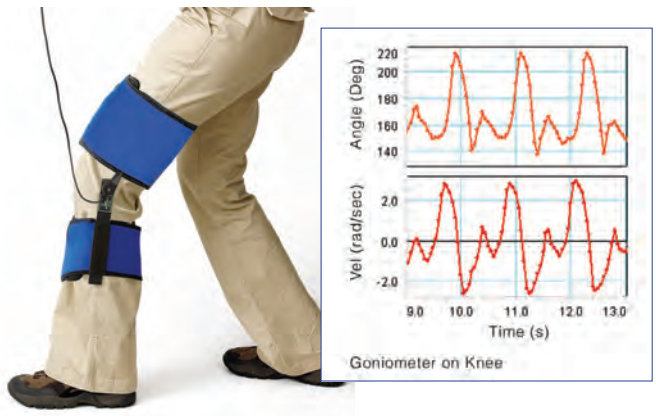
Specifications:

Range: 0 to 340°

Accuracy: ±1° (calibrated), ±3° (uncalibrated)

Resolution: 0.1°

Maximum Sample Rate: 500 Hz



Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.

See page 153 for more information.

Order Information

PASPORT Goniometer Sensor	PS-2137
Recommended:	
PASPORT Goniometer Probe	PS-2138

Also available separately:

PASPORT Angle Sensor

PS-2139

The Angle Sensor measures angle by measuring resistance. It has two ports to accept two Goniometers (PS-2137) or the two probes in the joints of the Human Arm (PS-2611).

Order Information

PASPORT Angle Sensor	PS-2139

PASPORT Thermocline Sensor

PS-2151

At last, students can measure temperature as a function of depth in local streams and lakes. PASCO's Thermocline Sensor measures depth automatically — no need to read markings on a cable and enter data manually. Weighted housing provides depth measurement stability in fast-flowing streams.

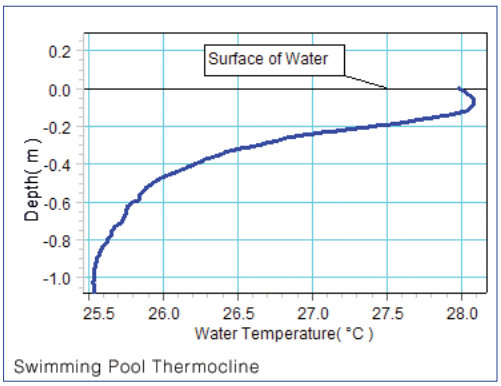
Applications:

- Study thermoclines in fresh and salt water environments
- Create depth profiles for streams, small rivers, shorelines, and swimming pools
- Study ocean tides

Specifications:

Depth-sensing Element Range: 0 m to 10.5 m
Depth-sensing Element Accuracy: 0.15 m
(in fresh water after barometric pressure compensation)
Depth-sensing Element Resolution: 0.03 m
Temperature-sensing Element Range: 0°C to 100°C
Temperature-sensing Element Accuracy: ±1.5°C
Temperature-sensing Element Maximum Sample Rate: 10 Hz

The temperature of the water in a pond is measured as a function of depth.



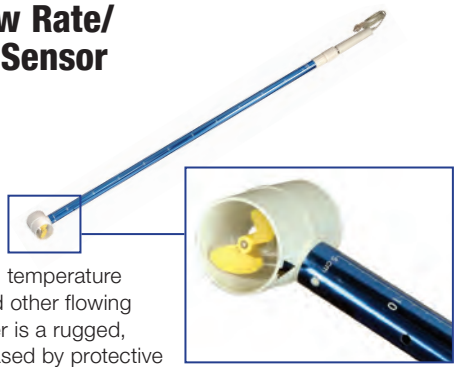
Swimming Pool Thermocline

Order Information

PASPORT Thermocline Sensor.....PS-2151

PASPORT Flow Rate/ Temperature Sensor

PS-2130



PASCO's Flow Rate Sensor allows students to measure the rate of movement and temperature of streams, rivers, and other flowing systems. The propeller is a rugged, single-piece unit encased by protective material — no more losing pieces at the bottom of the stream.

Applications:

- Determine sediment transport rate for a stream or other body of water
- Measure and compare flow rate at various locations in a stream
- Compare the characteristics of one stream to another

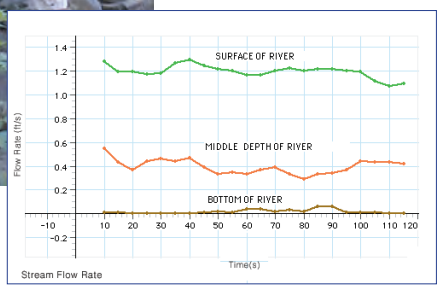
Specifications:

Flow Range: 0 m/s to 3.5 m/s
Accuracy: 0.1 ft/sec
Pulse Frequency: 8.62 pulse/linear foot
Unit Options: meter/sec; feet/sec; total pulses
Probe Length: 3 to 6 ft. with Telescoping Tube
(Probe is 6 ft when fully expanded)
Temperature Range: -10°C to 50°C
Maximum Length: 1.8 m (6 feet)
Telescoping handle to reach deep levels
Maximum Sample Rate: 20 Hz

Features:

- Built-in temperature sensor conveniently measures temperature at the same point as flow rate
- Revolutions of a magnet on the submersible impeller are counted and converted to linear flow rate measurements in ft/sec or m/s
- Telescoping Handle to reach deep levels

Graph shows the flow rates at the top (green), middle (orange), and bottom (brown) of a stream.



Stream Flow Rate

Order Information

PASPORT Flow Rate/Temperature Sensor.....PS-2130

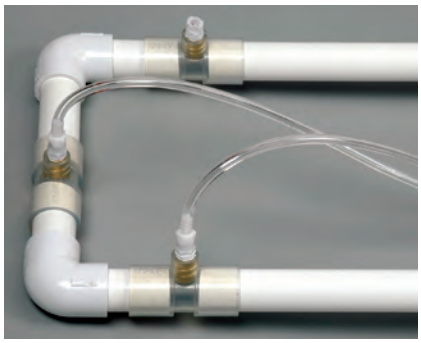
PASPORT Dual Pressure Sensor

PS-2181

The Dual Pressure Sensor is capable of reading two absolute pressures, one gauge pressure, or one differential pressure. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.

Applications:

- Measure pressure in Heat Engine (TD-8572A). See page 217.
- Measure pressure drops in pipes



Instrument your pipe network with the Pressure Taps connected to the Dual Pressure Sensor (PS-2181).

Specifications:

Maximum Sample Rate: 1000 Hz

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Differential Pressure: ±100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Order Information

PASPORT Dual Pressure Sensor	PS-2181

Pressure Taps (Set of 5)

ME-2224A

Order Information

Pressure Taps (set of 5)	ME-2224A

General Flow Sensor

PS-2222

The General Flow Sensor determines the fluid velocity of air or water by measuring the difference in pressure between the two input tubes. The Venturi Tube or Pitot Tube must be connected to the General Flow Sensor to collect data. The type of fluid (air or water) being used is selected using PASCO software.

Applications:

- The Venturi Tube is used in a pipe network carrying water or air.
- The Pitot Tube is used in an open water channel or air.

Specifications:

Pressure Range: 0 to 50 kPa

Pressure Accuracy: ±2.5% of Full Scale (0 to 85°C)

Resolution: 0.2% of Full Scale

Venturi Range: 0 to 84 gpm (water); 0 to 773 gpm (air)

Venturi Accuracy: ±2 gpm (water); ±2.5 cf/min (air)

Pitot Range: 0 to 9.98 m/s (water); 0 to 92.1 m/s (air)

Venturi Tube

ME-2220

The Venturi Tube is made of clear PVC so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor by the matching couplers. The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network.

Pitot Tube

ME-2221

The Pitot Tube is designed to be placed in the air flow or water flowing in a channel. The General Flow Sensor, connected to the Pitot Tube, measures the pressure difference between the fluid inlet and the static side taps of the Pitot Tube and the software calculates the fluid velocity from the pressure difference.

See pages 192-193 for more applications.

Order Information

General Flow Sensor with Venturi Tube	PS-2225
General Flow Sensor with Pitot Tube	PS-2226
Required:	
PASPORT Interface	p. 24-25
PASCO Capstone Software	p. 84-87
Also available separately:	
General Flow Sensor	PS-2222
Venturi Tube	ME-2220
Pitot Tube	ME-2221

PASPORT pH Sensor

PS-2102

Also see the Wireless pH Sensor on page 74.

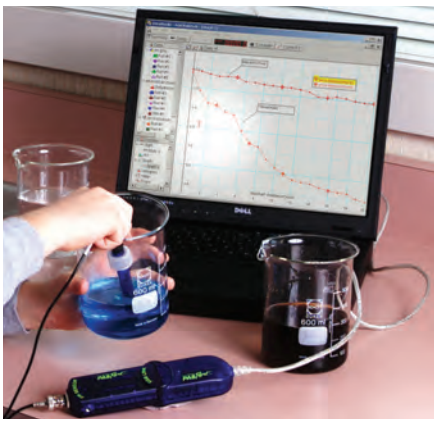
PASCO's pH Sensor measures the hydronium ion concentration in a solution and reports it as a pH value. This sensor is well-suited for a variety of activities where testing or monitoring acidity is important.

Applications:

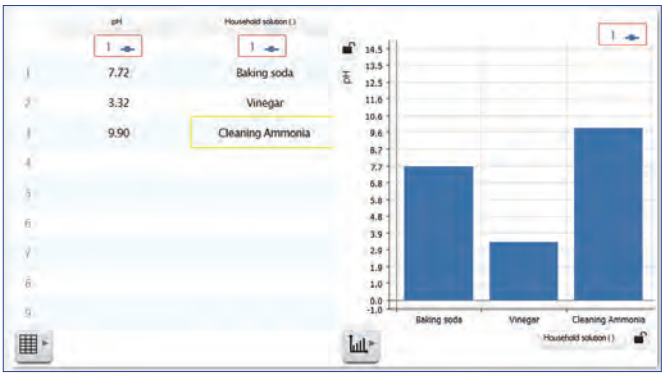
- Titrate an acid into a base
- Investigate the chemistry of buffers
- Monitor water quality

Specifications:

Range: 0 to 14 (probe-dependent)
Accuracy: ±0.1 (after calibration)
Resolution: 0.01
Electrode: Gel-filled Ag-AgCl combination electrode
Maximum Sample Rate: 50 Hz
Temperature Range: 5°C to 60°C



Below: Comparing the pH of different household chemicals.



Order Information

PASPORT pH Sensor	PS-2102
Recommended:	
pH Electrode	PS-2573

PASPORT Salinity Sensor

PS-2195

The PASPORT Salinity Sensor works with the 10X Salinity Sensor Probe to measure salinity, conductivity, and temperature. The sensor determines salinity based on electrical conductivity. A built-in calculation compensates for the change in conductivity due to temperature change, based on the Practical Salinity Scale (PSS).

The Salinity Sensor measures the electric current through a solution between the two platinized platinum electrodes in the Salinity Sensor Probe. The current through the solution is due to the movement of ions, so the higher the concentration of ions in the solution, the higher its conductivity. A voltage (AC) is applied across the two electrodes in the tip of the probe, and the measured current is proportional to the conductivity of the solution.

Applications:

- Explore the salinity of local water sources.
- Explore the interrelationship of salinity, temperature, and conductivity.
- Measure the change in the salinity of saltwater as the water evaporates.

Examples of Water Salinity:

Fresh Water: <0.5 ppt
Brackish Water: 0.5 to 30 ppt
Saline Water: 30 to 50 ppt
Ocean Water: 35 ppt
Brine: >50 ppt

Specifications:

Conductivity Range: 1,000 to 100,000 µS
Temperature Range: 0 to 50°C
Salinity Range: 1 to 55 ppt ±1% (with calibration)
Sample Rate (Maximum): 50 Hz
Temperature Compensation: ±0.5 ppt from 0 to 45°C at 33 ppt
Cell Constant: 10X

Order Information

PASPORT Salinity Sensor	PS-2195
Recommended:	
PASPORT Sensor Extension Cable	PS-2500

PASPORT Water Quality Colorimeter

PS-2179

This PASPORT Water Quality Colorimeter is designed specifically to support the chemical analysis of water samples using PASCO's ezSample Snap Vial water quality test kits (sold separately).

Includes built-in calibration curves for determining the concentration of ions in a solution (ions listed on this page). Simple to use in the field, and students avoid direct contact with chemicals!

Easily test water samples using ezSample Snap Vial Water Quality Test Kits. For general Colorimeter applications, see the Wireless Colorimeter and Turbidity Sensor (PS-3215).

Specifications:

Range: 0 to 100% transmittance

Wave Lengths: 660 nm (red), 610 nm (orange), 565 nm (green), 461 nm (blue)

Accuracy: ±0.5% transmittance

Resolution: 0.1% transmittance

Default Sample Rate: 1 Hz

Maximum Sample Rate: 5 Hz

Operating Temperature: 0° to 40°C

Measurable Ranges:

ezSample Snap Vials (Colorimetric)

Iron	1.5 to 8 mg/l
Nitrate*	0.25 to 2 mg/l
Ammonia	0.20 to 3 mg/l
Phosphate	0.20 to 8 mg/l
Chlorine	0.50 to 6 mg/l

ezSample Field Titrators

Total Hardness	20 to 200 mg/l
Dissolved CO_2**	10 to 100 mg/l
Alkalinity	10 to 100 mg/l

Includes:

- PASPORT Sensor Extension Cable

Order Information

PASPORT Water Quality Colorimeter	PS-2179
Available Test Kits: (30 tests per kit)	
ezSample Snap Vials (Colorimetric):	
ezSample Snap Vial - Iron	EZ-2331
ezSample Snap Vial - Nitrate*	EZ-2333B
ezSample Snap Vial - Ammonia	EZ-2334A
ezSample Snap Vial - Phosphate	EZ-2337
ezSample Snap Vial - Chlorine	EZ-2339A
ezSample Field Titrators	
ezSample Field Titrator - Total Hardness	EZ-2338
ezSample Field Titrator - Carbon Dioxide**	EZ-2341
ezSample Field Titrator - Alkalinity	EZ-2340

* **WARNING!** This product can expose you to chemicals including ethylene glycol, which is known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

** **WARNING!** This product can expose you to chemicals including phenolphthalein, which is known to the State of California to cause cancer, and methanol, which is known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

PASPORT Ethanol Sensor

PS-2194

The PASPORT Ethanol Sensor measures the concentration of gaseous ethanol up to 3%. In biology and environmental science labs, students can learn about anaerobic respiration by measuring the production of ethanol by bacterial or yeast fermentation. Physics and chemistry students can begin to explore combustion and thermodynamics. Connect your students to the study of respiration and alternative energy sources with the PASPORT Ethanol Sensor.

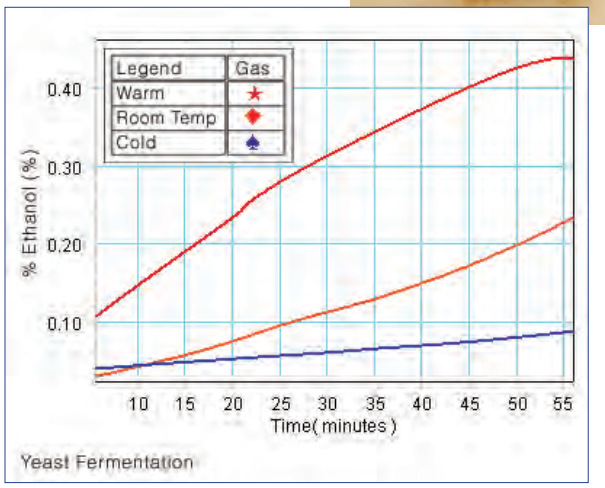
Note: This is a gas sensor – it should not be submerged into liquids. If exposed to gases with ethanol concentrations above the recommended maximum of 3% the sensor element will be depleted.

Students can vary environmental conditions such as temperature and determine the impact on the rate and type of cellular respiration taking place. In this example, as the temperature increases, the rate of ethanol production also increases.

Specifications:

Accuracy: 20% of reading

Range: 0% to 3% gaseous ethanol



Order Information

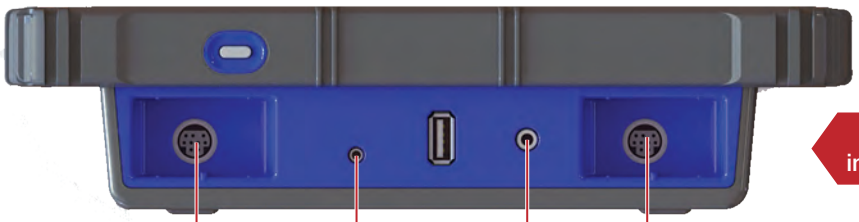
PASPORT Ethanol Sensor	PS-2194
Shown in use with:	
EcoChamber	ME-6667
Heater Stirrer	PS-3401

SPARK LXi2 Datalogger

Built for student use both indoors and outdoors.

PASPORT sensors connect directly to the LXi2.

SPARK LXi2
PS-3600B



PASPORT Sensor Port

Voltage Port

Temperature Port

PASPORT Sensor Port

The LXi2 also has built-in ports for the included temperature and voltage probes.

Simultaneously connect up to five PASCO Wireless Sensors.

SPARK LXi2 Datalogger

PS-3600B

Rugged and rechargeable, the SPARK LXi2 is a handheld datalogger that lets students collect and display sensor data, generate graphs, and analyze results.

The SPARK LXi2 simultaneously supports up to five Wireless Sensors. It also includes ports for two PASPORT sensors, as well as ports for the included Voltage and Fast Response Temperature Probes. With the SPARK LXi2, students can make measurements using the built-in GPS and accelerometer, or document their experiments using the built-in microphone, speaker, and front camera. It works seamlessly with PASCO's Wireless Sensors, PASPORT sensors, SPARKlink Air Interface, and 550 Universal Interface.

Designed with students in mind, the SPARK LXi2 features a slightly tilted screen that makes it easy to connect sensors, while reducing glare. Each device also comes pre-loaded with our award-winning SPARKvue, MatchGraph, and Spectrometry apps.

The SPARK LXi2 includes tools for data export, allowing students to save and transfer their files via USBA or USBC for use in third-party applications. When paired with a Bluetooth-enabled monitor or TV, the SPARK LXi2 can screencast data in real time for class demonstrations and data analysis.

Features:

- 8-hour battery life (standard use)
- Ruggedized, water resistant case for use indoors and outdoors
- 8” full-color capacitive touchscreen (1280 x 800 pixels)
- Simultaneously connects up to 5 PASCO Wireless Sensors
- Includes 2 PASPORT ports
- Includes Voltage Probe and port
- Includes Fast Response Temperature Probe and port
- Internal GPS, accelerometer, microphone, speakers/line out, and front camera
- Supports an additional five PASPORT sensors when used with the AirLink, SPARKlink Air, or 550 Universal Interface
- Installed software: PASCO SPARKvue, MatchGraph, and Spectrometry
- Android operating system
- WiFi, Bluetooth®, and USB connections
- Tools for data export: graphs, files, and images

Scan to learn more:

pasco.com/lxi2

Order Information

SPARK LXi2 Datalogger PS-3600B

AirLink Interface

PS-3200

The AirLink Interface connects PASPORT sensors to a Mac or Windows computer, Chromebook, iPad, tablet, or smartphone via Bluetooth or USB connection. The USB cable is included for charging ideally through a usb charging block and data connection to your computer.

Includes: USB cable

Specifications:

Bluetooth: 4.0
Bluetooth Range: 30 m (unobstructed)
Approximate Mass: 59 g

Order Information

AirLink Interface PS-3200

SPARKlink® Air Interface

PS-2011

The SPARKlink® Air allows students and teachers to connect any of our 70+ PASPORT sensors to their device via USB or Bluetooth®. This device allows students to collect data using a desktop or laptop running SPARKvue or PASCO Capstone software, or with a Bluetooth iOS or Android device running the SPARKvue app.

Includes:

- AC Adapter
- USB Cable
- Fast Response Temperature Probe
- Voltage Probe

Order Information

SPARKlink Air Interface PS-2011
Requires:
PASCO Capstone Software ..... p. 84-87

SPARKlink Air Charging Station

PS-2577

Conveniently store and charge up to five SPARKlink Air interfaces with a single power source.

Order Information

SPARKlink Air Charging Station PS-2577

PASPORT Digital Adapter

PS-2159

- Required for counting and timing sensors
- Allows digital ScienceWorkshop sensors to be used with PASPORT interfaces

The Digital Adapter is required when photogates, timing and counting sensors are used with any PASPORT interface. Each Digital Adapter accommodates two sensors at once. Each port on the Digital Adapter automatically detects a connection and initiates a selection of pre-configured or user-defined options. Several Digital Adapters can be used simultaneously when required.

Specifications:

Resolution for Counting and Timing Devices: 2 µs
Resolution for Motion Sensors: 1 µs
Input: Two 1/4" stereo phone jacks

Order Information

PASPORT Digital Adapter PS-2159

PASPORT Analog Adapter

PS-2158

- Use your black ScienceWorkshop sensors with blue PASPORT interfaces
- No need to buy new sensors

Use an Analog Adapter to connect ScienceWorkshop sensors with an 8-pin or 5-pin DIN connector such as:

- Colorimeter (CI-6747)
- Current (CI-6556)
- Force (CI-6537)
- Force, Economy (CI-6746)
- Infrared (CI-6628)
- Light (CI-6504A)
- Light, High-Sensitivity (CI-6604)
- Light, UVA (CI-9784)
- Magnetic Field (CI-6520A)
- Pressure Sensor-Absolute (CI-6532A)
- Sound (CI-6506B)
- Temperature (CI-6605A)
- Temperature, High Accuracy (CI-6525)

Order Information

PASPORT Analog Adapter PS-2158

PASCO Wireless Sensor Family

Our rugged, low-cost Wireless Sensors connect directly to computers, Chromebooks, laptops, tablets, and smartphones, allowing students to spend less time making measurements and more time on analysis and sense-making.

In Logging Mode, Wireless Sensors store data to their onboard memory for hours, days, weeks or even months at a time without needing to be connected to a computer, tablet, Chromebook or smartphone. When the experiment has concluded, simply connect the sensor to a device running PASCO software and download all the measurements for hassle-free analysis.

Wireless Physics Sensors

Wireless Chemistry Sensors

Wireless Biology/Environmental Sensors

Wireless Accessories

Does your Bluetooth need a boost?

USB Bluetooth Adapter

PS-3500

If you are using our Wireless Sensors and working on an older Mac (without Bluetooth 4.0 connectivity) or if you are using some Windows computers and Chromebooks, you will need a USB Adapter.

See pasco.com/compatibility if you have questions about Bluetooth connectivity.

Order Information

USB Bluetooth Adapter.....PS-3500

Smart Cart

ME-1240 (red) ME-1241 (blue)

U.S. Patent Number 10,481,173

- Your mechanics lab on wheels
- Built-in force sensor (±100 N)
- Built-in wireless force, position, and acceleration sensors
- Built-in 3-D acceleration sensor (±16 g)
- Optical encoder measures motion
- Data is transmitted wirelessly
- No interface required
- Rechargeable lithium-polymer battery

The patented Smart Cart is the ultimate tool for studying kinematics, dynamics, Newton's Laws, and more. It is based on a durable ABS body with nearly frictionless wheels, just like our high quality PAScars. Now, we've added built-in sensors that measure force, position, velocity, and acceleration. The versatile Smart Cart can collect measurements on or off a track and transmit the data wirelessly over Bluetooth. In essence, it is a wireless dynamics cart that combines all the necessary sensors, without requiring any additional hardware.

Smart Carts are ideal for studying mechanics topics, such as kinematics and dynamics. The built-in load cells enable two Smart Carts to visually demonstrate Newton's Third Law with ease. Additionally, built-in sensors for force and acceleration enable students to investigate Newton's Second Law in minutes. Smart Carts truly are a physics lab on wheels, and now you can own the most advanced physics cart ever created, all without the restrictions of cables.

The Smart Cart is used to record oscillation amplitude versus driving frequency in this Driven Damped Cart Oscillation experiment (EX-5551).

Features:

- Built-in ±100 N force sensor
- 3-axis accelerometer
- 3-axis rotational velocity sensor
- Bluetooth® connectivity
- Rechargeable battery
- Motion encoder measures position and velocity on or off the track
- Magnetic bumper for force sensor
- 3-position plunger
- Mass tray
- Velcro® tabs
- Force sensor hook and rubber bumper

Applications:

- Kinematics
- Newton's Laws
- Impulse
- Conservation of Momentum
- Elastic and Inelastic Collisions
- Conservation of Energy
- Simple Harmonic Oscillators
- Magnetic damping
- Determining g using acceleration on an incline
- And much more!

Specifications:

Force Range: ±100 N
Force Resolution: 0.1 N
Force Accuracy: ±1.0%
Force Maximum Sampling Rate: 2.0 kHz
Position Resolution: ±0.2 mm
Max Velocity: ±3.0 m/s
Velocity Max Sample Rate: 500 Hz
Acceleration Range: ±16 g
Acceleration Max Sample Rate: 500 samples/second
Max Rotational Speed Sampling Rate: 500 samples/second
Max Wireless Range: 30 m (unobstructed)
Maximum Measurable Rotation Rate (Gyro): ±245 deg/second
Mass Without Accessories: 245 g
Patent No.: 10,481,173
Magnetic Bumper Mass: 23.6 g

Includes:

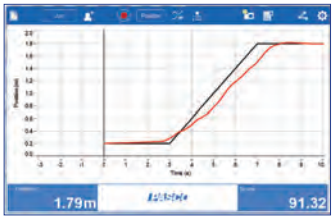
- Hook
- Rubber bumper
- Magnetic bumper
- USB cable for charging

Order Information	
Smart Cart (Red)	ME-1240
Smart Cart (Blue)	ME-1241

Wireless Motion Sensor

PS-3219

The Wireless Motion Sensor connects via Bluetooth or USB to your device, and uses ultrasound to measure the position, velocity, and acceleration of objects. This enables students to take turns measuring themselves, while the class observes their motion materializing as a graph in real time. The sensor can detect objects ranging from 15 cm to 4.0 m away, and without cables to get in the way, students can explore handheld and ceiling-mounted applications.



The Wireless Motion Sensor works with our free MatchGraph! software. It is an ideal way to teach the concepts of motion graphing, interpreting graphs, and rate of change or slope.

Specifications:

Range: 0.15 to 4 m
Resolution: 1 mm
Maximum Sample Rate: 100 Hz
Transducer Rotation Range: 180°
Rechargeable Battery: Lithium-polymer
Connectivity: Direct USB or via Bluetooth (Bluetooth 4.0)

Order Information

Wireless Motion Sensor PS-3219
Recommended:
MatchGraph! Software ..... p. 90
Also available:
Wireless Motion Sensor Pack* PS-3337
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Motion Sensor Guard

SE-7256

Use this wire guard to protect the Motion Sensor when dropping objects from above.

Order Information

Motion Sensor Guard SE-7256

Motion Sensor Bracket

PS-2546

This magnetic bracket allows a Motion Sensor to be easily hung from a drop ceiling. Simply screw the bracket into the 1/4"-20" threads on the sensor and use the included adjustment nut to hold the sensor in the desired orientation.

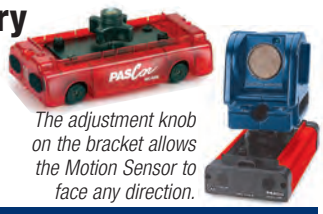
The bracket can also be used to hold the Motion Sensor on vertical surfaces such as filing cabinets and magnetic whiteboards.

Order Information

Motion Sensor Bracket PS-2546

Cart Adapter Accessory

ME-6743



The Cart Adapter Accessory allows the Motion Sensor and many other sensors to be mounted to a Dynamics Cart or a PAScar.

The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Order Information

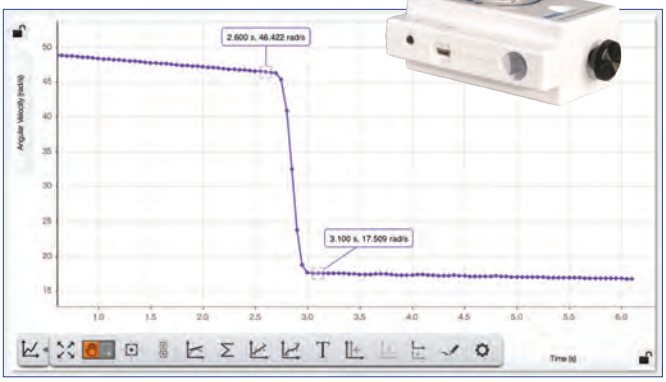
Cart Adapter Accessory ME-6743

Wireless Rotary Motion Sensor

PS-3220

The Wireless Rotary Motion Sensor measures angle, angular velocity, and angular acceleration, as well as their linear equivalents. The included three-step pulley can be rotated at different rates of acceleration to apply various torques. Use the included rod-mounting holes to position the sensor for different experiments. The Wireless Rotary Motion Sensor connects directly to your devices via Bluetooth or USB.

Show that angular momentum is conserved. The Wireless Rotary Motion Sensor records the angular velocity as a ring is dropped on a spinning disk.



Specifications:

Angle Resolution: 0.18° (0.00314 radian)
Linear Resolution: 0.0157 mm (with 5 mm pulley radius)
Three-Step Pulley: 10, 29, and 48 mm diameter
Shaft Diameter: 6.35 mm
Maximum Rotation Rate: 30 revolutions per second
Optical Encoder: 2000 divisions/rev, bidirectional
Rechargeable Battery: Lithium-polymer
Logging: Yes
Connectivity: Direct USB or via Bluetooth 4.0

Order Information

Wireless Rotary Motion Sensor PS-3220
Shown in use with:
Rotational Inertia Accessory ..... ME-3420 p. 184

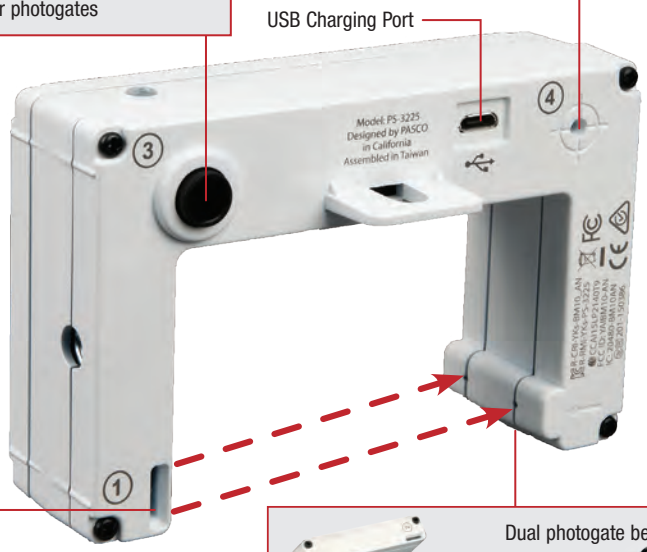
Wireless Smart Gate

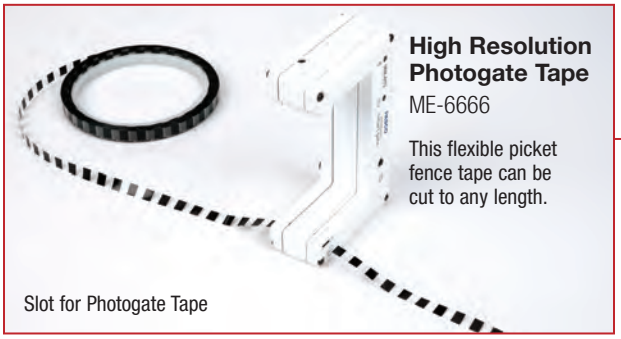
PS-3225

- Dual photogate beams
- Laser switch
- Photogate tape slot
- Auxiliary photogate/Time-of-Flight port
- USB and Bluetooth®
- Rechargeable

The Wireless Smart Gate is more than just a photogate. It has dual photogate beams spaced 1.5 cm apart to accurately measure speed. When used with a laser, students can use the built-in laser switch to time objects that are too large to fit through the photogate beams. It also includes a photogate tape slot for measuring the movement of objects and an auxiliary port for adding another photogate head or the Time-of-Flight Accessory.

We do not recommend using two Wireless Smart Gates in the same experiment unless the measured times are relatively long (greater than one-half of a second) since synchronization is limited to 2 ms.

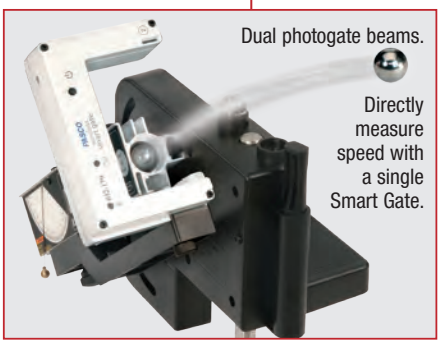


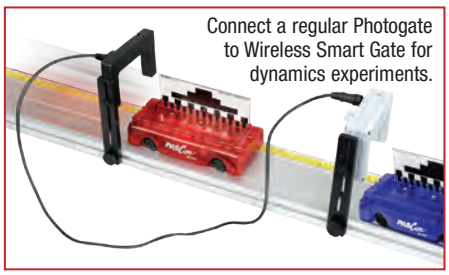


High Resolution Photogate Tape

ME-6666

This flexible picket fence tape can be cut to any length.





Specifications:

Logging: Yes

Battery: Rechargeable Lithium-Polymer

Connectivity: Direct USB or via Bluetooth 4.0

Order Information

Photogate Wireless Smart Gate	PS-3225
Recommended:	
Time-of-Flight Accessory	ME-6810A
Photogate Tape, High Resolution (30 m)	ME-6666

Wireless Smart Gate Dynamics System

NEW PRODUCT!

PS-3703

When used with a computer for data recording, display, and analysis, this photogate timing system provides a wide range of time, speed, and velocity measurements. The photogates mount to the Dynamics Track using the provided brackets. The provided Picket Fences mount directly to the Dynamics Carts.

Includes:

- Wireless Smart Gate: PS-3225
- Photogate Head: ME-9498A
- Photogate Brackets: ME-9806
- Picket Fences: ME-9804

Order Information

Wireless Smart Gate Dynamics System	PS-3703

Wireless Smart Pulley

NEW PRODUCT!

PS-3704

The Wireless Smart Pulley attaches directly to the Wireless Smart Gate, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.

Includes:

- Wireless Smart Gate: PS-3225
- Super Pulley: ME-9450A
- Super Pulley Rod

Order Information

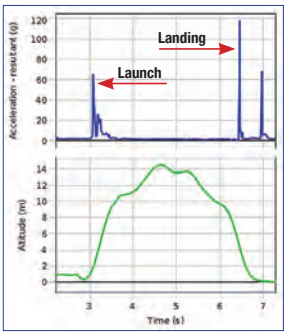
Wireless Smart Pulley	PS-3704

Wireless Acceleration/ Altimeter

PS-3223

- 3-axis accelerometer
- 3-axis gyroscope
- Altimeter
- Rubberized case

The Wireless 3-Axis Acceleration/Altimeter can remotely log acceleration in three dimensions and altitude, making it ideal for recording roller coaster rides.



The Wireless 3-Axis Acceleration/Altimeter is launched by a stretched rubber band that is connected to one of the many attachment holes in the rubberized case. The graph shows the resultant acceleration (measured in g's) and the altitude for the four-second flight.

Specifications:

Accelerometer Ranges: ±16 g, ±100 g, ±200 g, ±400 g

Measurements: Acceleration (3 axes and resultant); Altitude; Angular velocity (3 axes)

Logging: Yes

Battery: Coin Cell

Connectivity: Bluetooth 4.0

Order Information

Wireless Acceleration/ Altimeter..... PS-3223

Wireless Force Acceleration Sensor

PS-3202

- Eliminates wires
- Measures force, acceleration, and rotation

Capable of simultaneously measuring force, acceleration, and rotational velocity, this sensor is ideal for experiments involving rotating platforms, moving carts, spring oscillations, collisions, and impulse. The wireless design offers improved measurement accuracy by eliminating cords that affect data collection. Students can use the finger-holes for handheld applications, or mount it onto a cart or rod for more complex experiments.

Features:

- Bluetooth and USB connectivity
- Logging
- ±50 N force sensor
- 3-axis accelerometer (±16 g)
- 3-axis gyroscope
- Finger-holes
- Built-in rod clamp

Specifications:

Force Range: ±50 N

Force Resolution: 0.03 N

Accuracy: 0.1 N

Acceleration Range: ±16 g

Angular Rotation Rate Range: up to ±2000 degrees per second

Battery: Rechargeable lithium-polymer

Logging: Yes

Bluetooth: BT 4.0

Includes:

- Hook attachment
- Rubber bumper attachment
- Cart/bracket thumbscrew
- Rechargeable lithium-polymer battery
- USB cable

Order Information

Wireless Force Acceleration Sensor..... PS-3202

Also available:

Wireless Force Acceleration Sensor Pack*.....PS-3339

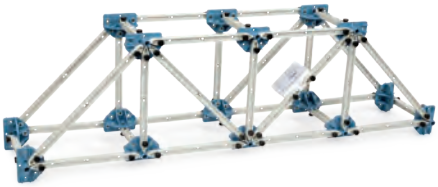
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Wireless Load Cell and Accelerometer

PS-3216

- Measures loads in structures
- Built-in 3-axis accelerometer measures bridge vibrations

The Wireless Load Cell and Accelerometer is designed to measure loads in PASCO's Structures System. It is particularly useful for measuring vibrations because it includes an accelerometer and has no wires to impede movement.



Learn more about PASCO Structures on pages 154-167.

Specifications:

Load Cell Range: ±50 N

Load Cell Resolution: 0.03 N

Load Cell Accuracy: 0.1 N

Load Cell Maximum Sample Rate: 2 kHz

Acceleration Range: ±16 g (three axis)

Acceleration Maximum Sample Rate: 500 Hz

Measurements: Force; Acceleration (3 axes and resultant)

Logging: Yes

Battery: Rechargeable Lithium-Polymer

Connectivity: Direct USB or via Bluetooth 4.0

Order Information

Wireless Load Cell and Accelerometer..... PS-3216

Shown in use with:

Building Better Bridges Kit ME-3581

Wireless Force Platform

PS-3229

The Wireless Force Platform builds on the success of our PASPORT Force Platform, offering users the same reliable performance with enhanced durability and a convenient, wireless connection.

The new design features a sturdy, glass-filled nylon platform and four supporting force beams that measure the forces acting normal to the platform's surface. Along the bottom of the platform are four adjustable feet that make leveling quick and easy, while also ensuring stability between the force beams and the surface below. Students can measure the force applied to each beam independently or the overall resultant force acting on the surface of the platform (up to 5200 N). With its new wireless design, the Wireless Force Platform is easier to use than ever, providing both special flexibility and custom sample rates for high speed sampling over Bluetooth Low Energy (up to 10 kHz).

The Wireless Force Platform can be used to measure the static weight of a structure or person, the dynamic vertical forces created when moving or jumping, or the forces associated with the impact of falling objects. Simply place the platform on a floor or tabletop to measure vertical force, or mount it to a wall to measure horizontal force.

Applications:

- Measure impulse and maximum force
- Determine hang time by jumping from and landing on the platform
- Measure the normal (vertical) force acting on a person riding an elevator
- Use two Force Platforms to investigate Newton's Third Law
- Use a Motion Sensor and a ball to compare the impulse and change in momentum as the ball collides with the platform

Features:

- Improved ruggedized design with increased maximum force range (up to 5200 N, resultant)
- Wide surface for jumping, standing, and walking
- Mechanical force over-limit protection
- Burst sampling option for high-speed wireless data collection
- Built-in handle for easy transport

Specifications:

Range: -1320 N to 5280 N (resultant)
Surface Dimensions: 35 cm x 35 cm
Maximum Sample Rate: 10 kHz
Resolution: 0.2 N
Force Over-Limit Protection: -500 N to 2000 N per beam

Order Information

Wireless Force Platform PS-3229

Wireless 2-Axis Force Platform

PS-3230

Building on the success of the PASPORT 2-Axis Force Platform, the Wireless 2-Axis Force Platform offers users the same reliable performance with enhanced durability and a convenient, wireless connection. The new design features a sturdy, glass-filled nylon platform with a sheet metal top and five force beams. Four vertical beams measure forces acting normal to the platform's surface, while a fifth beam, attached to the movable sheet metal top, measures forces acting parallel to the platform's surface. The platform also includes four adjustable feet that make leveling quick and easy, while ensuring a stable connection is made between the force beams and the surface below.

With its new wireless design, the Wireless 2-Axis Force Platform is easier to use than ever, providing both special flexibility and custom sample rates for high-speed sampling over Bluetooth Low Energy (up to 10 kHz). Students can measure the force applied to each beam independently or the overall normal force acting on the platform, with measurements up to 5200 N. They can also measure the normal and parallel forces acting on the platform simultaneously. Applications include determining the static weight of a structure or person, measuring forces associated with the impacts of falling objects, and determining the dynamic vertical and parallel forces that arise when moving or jumping. Simply place the platform on a floor or tabletop to measure vertical force, or mount it to a wall to measure horizontal force.

Applications:

- Determine hang time by jumping from and landing on the platform
- Use two Force Platforms to investigate Newton's Third Law
- Measure impulse and maximum force
- Measure the normal force acting on a person riding an elevator
- Use a Motion Sensor and a ball to compare the impulse and change in momentum as the ball collides with the platform
- Measure the sideways force during a broad jump
- Measure the normal and parallel forces on a wall as a ladder leans against the wall
- Measure the normal and parallel forces as a person walks or runs across the platform
- Pull an object across the platform and measure the normal and frictional forces

Specifications:

Range: -1320 N to 5280 N (resultant); ±1300 N parallel force
Surface Dimensions: 35 cm x 35 cm
Maximum Sample Rate: 10 kHz
Resolution: 0.2 N
Force Over-Limit Protection: -500 N to 2000 N per vertical beam; ±2000 N parallel beam

Order Information

Wireless 2-Axis Force Platform PS-3230

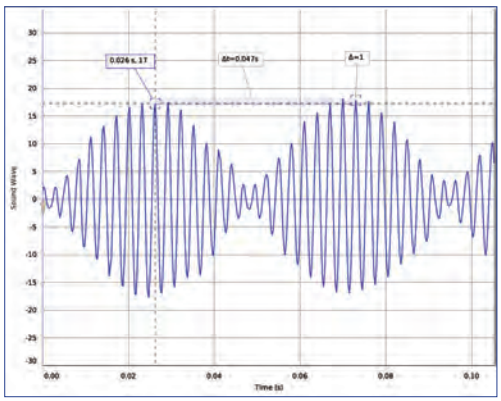
Wireless Sound Sensor

PS-3227

The PS-3227 Wireless Sound Sensor is two sensors in one wireless package: a sound wave sensor capable of measuring changes in relative pressure level as a function of time and a sound level sensor with both dBA and dBC weighted scales.

Sound Wave Sensor: The Sound Wave Sensor measures relative changes in sound pressure level as sound waves are incident on the sensor. With graphs of sound wave measurements versus time, students can explore and analyze wave properties like wave shape, wave speed, amplitude, frequency, wavelength, and much more. Students can use this sensor to explore superposition of waves and beat frequencies, while also exploring standing wave harmonics, and the presence of overtones. Sound wave measurements work beautifully with the scope and FFT displays in both SPARKvue and Capstone, and the Wireless Sound Sensor is capable of measuring sound wave data wirelessly at sample rates up to 100 kHz.

Sound Level Sensor: The Sound Level Sensor gives you true sound level (intensity) measurements with both dBA and dBC scales. The dBC weighting scale measures the intensity of sounds in a wide range of frequencies within, and outside the frequency range of human hearing. The dBA weighting scale filters some of the sound frequencies from a sound source to more closely match the frequency response of the human ear. The dBA scale is commonly used in the workplace to determine the sound level an employee will experience in typical working conditions. Sound level and noise pollution are key measurements in environmental science. This new sensor gives you a wireless solution to measure sound level with all the capability of a sound level meter, but adds the flexibility of recording data continuously as a function of time.



Easily observe and measure beat frequencies

Specifications:

Microphone Frequency Range: 100–15,000 Hz
Sound Wave Maximum Sampling Rate: 100 kHz
Sound Level Range: 50–110 dB
Accuracy: ±2 dB
Response: A or C weighted

Includes Sensor Handle

Order Information	
Wireless Sound Sensor	PS-3227
Also available:	
Wireless Sound Sensor Pack*	PS-3342

* Includes 8 sensors in a Gratnells® storage tray with custom insert.

//code.Node

PS-3231

The //code.Node is a turnkey coding solution that combines real-world sensor inquiry, Blockly coding, and live data displays to drive computational thinking in STEM learning. It includes six interactive sensors and four device outputs that measure and respond to phenomena using code created in SPARKvue or Capstone software.

Sensor Inputs:

- Temperature
- Motion
- Sound
- Light
- Magnetic Field

Device Outputs:

- Speaker
- RGB LED
- 5x5 LED array
- Software displays

Applications:

- Introduce computational thinking into science lessons.
- Explore science concepts using coding and data collection.
- Create a program to identify changes in your environment.
- Program songs, games, countdowns, alarms, and much more!

Specifications:

Light Level Sensor Range: Visible Spectrum (400 nm to 700 nm)
Light Level Sensor Sensitivity: Approximately 600 lx to 50,000 lx (not calibrated)
Sound Level Sensor Sensitivity: Approximately 70 dB to 100 dB (not calibrated)
Magnetic Field Sensor Range: ±50 gauss
Acceleration Sensor Range: 2-axes, ±8g
Ambient Temperature Range: -25°C to 40°C
Ambient Temperature Resolution: 0.05°C
Ambient Temperature Accuracy: ±1°C
Maximum Sample Rate: 50 Hz
Momentary Push Buttons (2): On/Off
Speaker Output Frequency Range: 10 Hz to 10,000 Hz
Multi-color LED: Independently adjust intensity of Red, Green, Blue

Order Information	
//code.Node	PS-3231
Also available:	
//code.Node Multi-Pack (Set of 8)*	PS-3311

* Includes 8 //code.Nodes, 8 holders, and 8 USB charging cables in storage box.

Wireless Pressure Sensor

PS-3203

The Wireless Pressure Sensor allows students to easily collect accurate gas pressure data for a wide range of applications. Included is a 60cc syringe, tubing, and connectors that facilitate experiments such as Boyle's Law or measuring pinch-grip strength. Within PASCO's software, students can easily select their desired units from a list containing kPa, mmHg, inHg, mbar, psi, atm, and torr.

Make accurate and consistent measurements of gas pressure, regardless of ambient conditions. Study the Empirical Gas Laws.

Specifications:

Range: 0-400 kPa
Resolution: 0.1 kPa
Accuracy: ±2 kPa
Logging: Yes
Max sample rate: 1000 Hz
Bluetooth: BT 4.0

Includes:

- Polyurethane Plastic Tubing, 2 ft
- Tube Connector
- Male Barbed Luer Locks (2)
- Female Barbed Luer Lock
- 60 cc Syringe
- Micro USB Cable (PS-3584)

Order Information

Wireless Pressure Sensor PS-3203
Also available:
Wireless Pressure Sensor Pack* PS-3333
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Wireless Temperature Sensor

PS-3201

Welcome to the modern thermometer. This sensor transmits live data and allows students to continuously monitor, log, and plot temperature measurements on nearly any device.

Features:

- Simply pair and go, no cables or adapters to manage
- Variable sampling rate for capturing small, fast changes or experiments that run for hours, days, or weeks
- Bluetooth wireless connectivity and long-lasting coin cell battery
- Logs temperature data directly onto the sensor for long-term experiments
- Dust, dirt, and sand-proof and water resistant (IP-X7 certified)

Specifications:

Range: -40°C to 125°C
Resolution: 0.01°C
Accuracy: 0.5°C
Logging: Yes
Bluetooth: BT 4.0

The versatile Wireless Temperature Sensor works well, both in the lab and outdoors.

Order Information

Wireless Temperature Sensor PS-3201
Also available:
Wireless Temperature Sensor Pack* PS-3330
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Wireless Temperature Sensor Link

PS-3222

- Accepts three types of thermistor temperature probes
- Includes Fast Response Temperature Probe

Specifications:

Battery: Coin cell (battery life >1 year)
Compatible Temperature Probes: Skin/Surface (PS-2131); Fast Response (PS-2135); Stainless Steel (PS-2153)
Range with included probe: -30°C to 105°C
Jack: 3.5 mm stereo
Logging: Yes
Connectivity: Bluetooth 4.0

Order Information

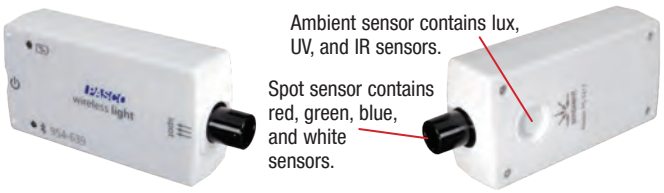
Wireless Temperature Sensor Link PS-3222
Compatible Temperature Probes:
PASPORT Skin/Surface Temperature Probe PS-2131
PASPORT Fast Response Temperature Probe (3 pack) PS-2135
PASPORT Stainless Steel Temperature Probe PS-2153

Wireless Light Sensor

PS-3213

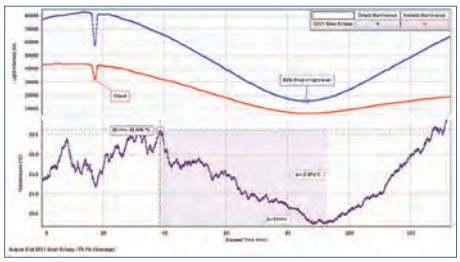
- Four sensors in one
- Ambient lux
- Ultraviolet and infrared
- Detects RGB colors separately
- Bluetooth 4.0 wireless
- New enhanced features measure PAR and irradient light!

The Wireless Light Sensor features two separate apertures - one for ambient light measurements and one for directional light measurements. The ambient sensor measures illuminance and UV Index, while the spot (directional) aperture measures light level and color intensity. Our software displays the relative intensities of Red, Green, and Blue light, then sums them to determine the level of White light. PAR and irradiance are also available as calculated measurements within PASCO Capstone (version 1.8 or later) and SPARKvue software (version 2.6 or later).



Using Wireless Sensors to collect eclipse data

On August 21, 2017, a total solar eclipse occurred and was visible, in some degree, over much of the continental United States. As the moon passed directly in front of the sun, the moon cast a shadow on Earth. Using PASCO Wireless Sensors, students across the United States viewed the total eclipse and measured the change in light level and temperature as the moon passed in front of the sun!



This eclipse data was collected at PASCO in Roseville, CA, on August 21, 2017.

For more info, see pasco.com/eclipse

Specifications:

Spectral Response: 300 nm to 1100 nm
Illuminance Range: 0 to 131,000 lux
Irradiance Range: 0 to 1362 W/m^2
PAR Range: 0 to 2400 µmol/m^2/s
UV Index Range: 0 to 12 (typical in daylight)
RGB and White Light Range: 0 to 100%
Maximum Sample Rate: 2 Hz (ambient); 20 Hz (spot)
Battery: Coin cell
Bluetooth 4.0: Yes

Order Information

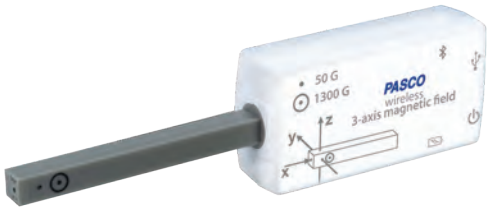
Wireless Light Sensor	PS-3213	
Also available:		
Wireless Light Sensor Pack*	PS-3338	

* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Wireless Magnetic Field Sensor

PS-3221

- Simultaneous measurements on three axes
- Dual range: ±50 G and ±1300 G
- Sensitive enough to measure the Earth's magnetic field
- Measure fields from bar magnets and coils



This 3-Axis Magnetic Field Sensor can sense the Earth's magnetic field and fields from coils and bar magnets. There are two ranges: ±50 gauss and ±1300 gauss. This sensor is primarily for static fields.

Wirelessly measure the magnetic field strength inside a solenoid as a function of current.

Specifications:

Ranges: ±50 G and ±1300 G
Resolution: ±0.01 G (50 G range); ±1 G (1300 G range)
Maximum Sample Rate: 100 Hz
Measurements: Magnetic Field Strength (3 axes and resultant)
Logging: Yes
Battery: Rechargeable Lithium-Polymer
Connectivity: Direct USB or via Bluetooth 4.0

Includes:

- 3-Axis Magnetic Field Sensor
- Sensor Mounting Rod
- USB Charging Cable

Order Information

Wireless Magnetic Field Sensor	PS-3221	
Recommended:		
Zero Gauss Chamber	EM-8652	p. 51

Wireless Current Sensor

PS-3212

The Wireless Current Sensor's wide current range enables introductory and advanced explorations of the fundamental concepts of electricity and basic circuits.

Features:

- **Two Ranges:** ±1.0 A and ±0.1 A
- **Resolution:** 0.2 mA at ±1 A range and 0.02 mA at ±0.1 A range
- **Bluetooth® sampling rate of 1.0 kHz**
- **High-speed sampling via USB**
- **Remote logging**
- **Variable sampling rate** for recording small, fast changes or experiments that run for hours, days, or weeks

Includes:

- USB Cable
- Red, Banana-to-alligator-clip
- Black, Banana-to-alligator-clip
- Wireless Current Sensor

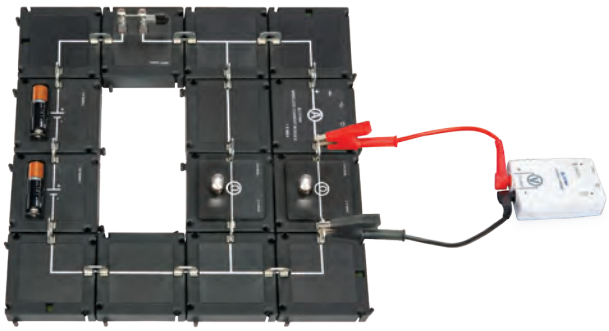
Order Information

Wireless Current Sensor PS-3212
Also available:
Wireless Current Sensor Pack* PS-3336
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Wireless Voltage Sensor

PS-3211

The Wireless Voltage Sensor is ideal for exploring the fundamental concepts of electricity, voltage, and basic circuits. Complete with built-in overload protection, this sensor measures voltages up to ±15 V, and features high-speed sampling rates when connected via USB. When combined with the Wireless Current Sensor, students can use it to explore Ohm's Law, circuits in series and parallel, and much more.



Features:

- **Two Ranges:** ±15 V, ±5 V
- **Resolution:** 7 mV (±15 V range); 2 mV (±5 V range)
- **Bluetooth® sampling rate of 1.0 kHz**
- **High-speed sampling via USB**
- **Remote logging**

Includes:

- Wireless Voltage Sensor
- USB Cable
- Red, Banana-to-alligator-clip
- Black, Banana-to-alligator-clip

Order Information

Wireless Voltage Sensor PS-3211
Also available:
Wireless Voltage Sensor Pack* PS-3335
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Wireless Current Sensor Module

EM-3534

Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components.

Specifications:

Two ranges: ±1 A, ±0.1 A
Resolution: 0.2 mA (±1 A range); 0.02 mA (±0.1 A range)
Bluetooth® sampling rate of 1 kHz
Higher speed sampling via USB
Includes remote logging

Order Information

Wireless Current Sensor Module EM-3534
Required:
Modular Circuits ..... pp. 228-229

Included in *Essential Physics* Modular Circuits Kit EM-3536 on pages 228-229.

Wireless Geiger Counter

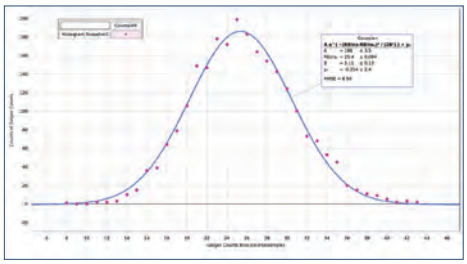
PS-3238

The PASCO Wireless Geiger Counter counts beta, gamma and alpha radiation particles as they enter the Geiger–Müller detector tube inside the counter. Designed for easy mounting, the Geiger Counter provides superior position control in inverse square law labs, as well as an audible beep to indicate the detection of ionizing radiation. The front plastic snout fits conveniently inside the NU-3344 Sample Holder stand (available separately), which stabilizes the front of the counter's detector tube exactly 1 cm from the first slot in the holder.

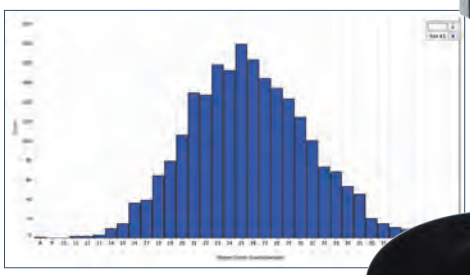
With the Wireless Geiger Counter, students can wirelessly control the high voltage supplied to the Geiger-Müller tube inside the counter, enabling them to make measurements of counts/interval for different tube voltages. They can also plot counts/interval versus tube voltages to experimentally observe the Geiger plateau characteristics of the tube.

Features:

- Built-in metal mesh screen to protect the delicate mica window in the front of the Geiger-Müller detector tube
- Audible beep to indicate count can be easily switched on or off
- **Versatile positioning options:** either in the NU-3344 Sample Holder, hand-held, or mounted on a rod stand
- Convenient design natively fits the PASCO NU-3344 Sample Holder
- Provides wireless control over the high voltage supplied to the Geiger–Müller tube inside the counter for Geiger plateau experiments



Demonstrates the statistical (gaussian or poisson) nature of counts/interval measured from a radioactive source with a long half-life.



Includes:

- Wireless Geiger Counter
- Micro USB Cable (PS-3584)
- Threaded handle for mounting the sensor to a ring stand

Order Information

Wireless Geiger Counter.....PS-3238

Applications:

- Observe the inverse square law
- Measure the Geiger plateau associated with a Geiger–Müller tube
- Demonstrate the shielding properties of different materials and different types of ionizing radiation

Specifications:

Sensitivity:
Alpha, Beta, Gamma

Count Detection:
Switchable audio signal

Gas Filling: Ne +Halogen

Effective Tube Diameter:
9.1 mm

Window Thickness:
1.5 to 2.0 mg/cm^2

High Voltage Control Range:
150 VDC to 650 VDC

Standard Operating Voltage:
500 VDC

The NU-3344 Sample Holder stand is not included with the PS-3238 Wireless Geiger Counter, but is available separately. See below.

Geiger Counter Sample Holder

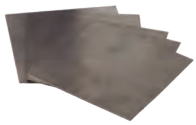
NU-3344

The PASCO Geiger Counter Sample Holder makes it easy to mount and position the PS-3238 Wireless Geiger Counter for inverse square law labs, radiation shielding labs, and other radiation labs. The front plastic snout on the Wireless Geiger Counter is designed to fit conveniently inside the Sample Holder stand, which stabilizes the front of the counter's detector tube exactly 1 cm from the first slot in the holder.

The stand includes a radioactive sample holder tray and 5 pieces of 7 cm x 7 cm aluminum shielding material. The stand has eight slots designed to hold the included radioactive sample holder tray or shielding material. Each slot in the holder is spaced 1 cm apart to make changing the spacing between the Geiger Counter, radioactive sample, or shielding materials quick and easy.

Features:

- Includes 1x radioactive sample holder and 5 pieces of 7cm x 7cm aluminum shielding
- 8 slots for holding radioactive samples or shielding materials, each spaced 1 cm apart
- Designed to hold the PASCO Wireless Geiger Counter exactly 1 cm from the first slot in the holder



Includes:

- Stand with 8 slots
- Radioactive sample tray
- 7cm x 7cm aluminum shielding material (5)

Order Information

Geiger Counter Sample Holder NU-3344

UV-Vis Spectrometer

SE-3607

- Uses PASCO's award-winning Spectrometry software
- Spectral scans from 180 to 1050 nm
- Easy to calibrate

The SE-3607 is an easy-to-use, wide range UV-Vis spectrometer that delivers fast, accurate and reliable performance for routine analyses in chemistry and biochemistry teaching labs. With USB connectivity and cross-platform Spectrometry Software, the PASCO UV-Vis Spectrometer improves collaboration between lab members, enabling data collected on a computer or laptop to be analyzed on tablets, iPads, and Chromebooks*.

* Chromebooks are not compatible with the PASCO UV-Vis Spectrometer for data collection (analysis only).

Specifications:

Wavelength Range: 180–1050 nm
Light Source: Deuterium (UV) Tungsten (Vis)
Detector: 2048 CMOS linear (0.3nm reporting interval)
Grating: 500 lines/mm
Signal to Noise: 2000:1
Optical Resolution: 1.5 nm
Wavelength Accuracy: 1.0 nm
Photometric Accuracy: ±5%
Photometric Range (best accuracy): 0.1–1.0 (reports full range 0.0 to 3.0)
Typical Scan Time (depends on integration): 4 ms–10 s
Connectivity: USB only
Power Consumption: 2.5 A startup, 350 mA continuous
Power Supply: 100–240 VAC to 24VDC @ 2.5A
Warranty: 5 year limited on hardware, 1 year on lamps
Dimensions: 19.5 x 24.5 x 7.0 cm

Applications:

- Determination of solution concentrations
- Identification of unknown substances
- Measurement of reaction rates or rate of decay
- Colorimetric assays (e.g., BCA, Bradford, Lowry)
- Purity testing of synthesized compounds
- Determination of the equilibrium constant
- Determination of molar absorption coefficients
- Quality testing (e.g., fermentation mediums, food adulteration, QA levels)

Includes:

- Semi-Micro Volume Cuvettes (Qty. 10)
- Cuvette Rack (EC-3590)
- USB-A to USB-B Cable
- External AC Adapter, 24 V Power Supply
- Foam Lined Carrying Case (ABS)
- Spectrometry Software

Order Information

UV-Vis Spectrometer	SE-3607
Recommended:	
UV Quartz Cuvettes (Qty. 2)	SE-3611
UV-Vis Fiber Optic Kit	SE-7182

Disposable UV Semi-Micro Volume Cuvettes (Qty. 10)

SE-3610

Includes:

- Disposable UV Semi-Micro Volume Cuvettes (10)
- Cuvette Rack (EC-3590) (2)

Order Information

Disposable UV Semi-Micro Volume Cuvettes (Qty. 10)	SE-3610

UV Quartz Cuvettes (Qty. 2)

SE-3611

Includes:

- UV Quartz Cuvette (2)
- Teflon Cuvette Cap (2)

Order Information

UV Quartz Cuvettes (Qty. 2)	SE-3611

UV-Vis Fiber Optic Kit

SE-7182

Enhance the capabilities of your PASCO UV-Vis Spectrometer (SE-3607) for the analysis of emission sources, external samples, and the classification of lasers with the UV-Vis Fiber Optic Kit. This complete kit includes a quartz core cable (50-cm quartz core, 0.2-mm diameter) and a front surface mirror, reflective cuvette. Other applications include: analysis of external absorption spectra, measurement of electronic transition energies, calculation of the Rydbergh constant, and determination of light source energies.

Includes:

- Quartz core cable with attached reflective cuvette

Order Information

UV-Vis Fiber Optic Kit	SE-7182

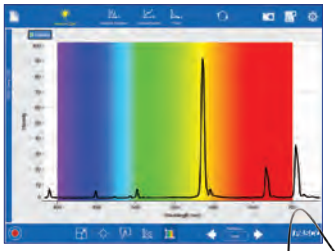
Wireless Spectrometer (VIS)

PS-2600A

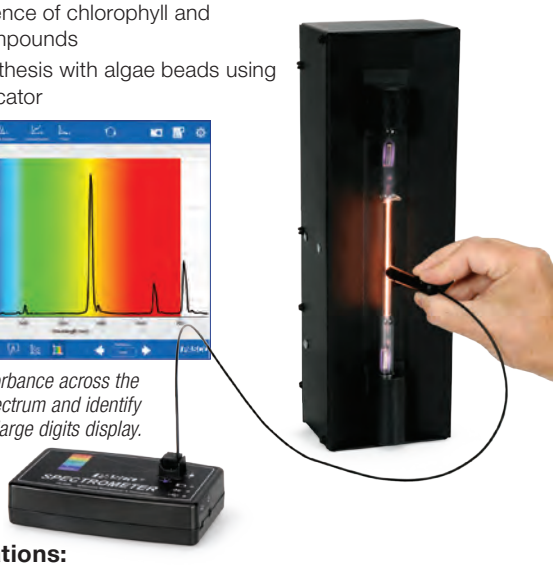
The award-winning PASCO Wireless Spectrometer is specifically designed for modern chemistry, biology, and physics labs. It connects to student devices via USB or Bluetooth Low Energy and includes free Spectrometry software with built-in tools for spectral analysis. Scan times are fast, enabling students to collect a full spectrum of data in less than a second. Three plots are provided for common applications, including Wavelength vs. Absorbance (or emission), Concentration vs. Absorbance (Beer's law), or Absorbance vs. Time (kinetics).

Applications:

- Photosynthesis with DPIP
- Absorption spectra of plant pigments
- Rate of an enzyme-catalyzed reaction
- Absorption spectrum of chlorophyll
- Emission spectra of light from flame tests or other sources
- Easily identify peak wavelengths for concentration data
- Study the relationship between concentration and absorbance (Beer's Law)
- Reaction Kinetics
- Fluorescence of chlorophyll and other compounds
- Photosynthesis with algae beads using a pH indicator



Visualize absorbance across the full visible spectrum and identify peaks with a large digits display.



Specifications:

Resolution: 2–3 nm FWHM
Detection Range: 390–950 nm
Fluorescence Excitation Wavelengths: 405 nm and 500 nm
Light Source: LED-boosted tungsten
Bluetooth: Bluetooth Low Energy

Includes:

- Cuvettes (10)
- Spectrometry Software

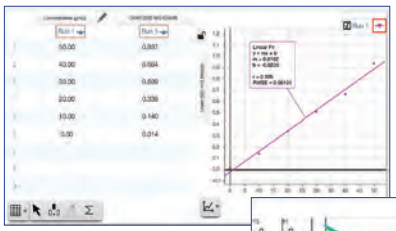
Order Information

Wireless Spectrometer (VIS)	PS-2600A	
Recommended:		
Fiber Optics Cable	PS-2601	p. 302

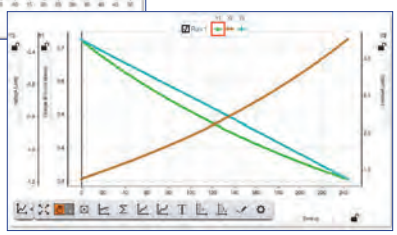
Wireless Colorimeter & Turbidity Sensor

PS-3215

The Wireless Colorimeter & Turbidity Sensor simultaneously measures the absorbance and transmittance of six different wavelengths. The sensor can be used to study Beer's Law (absorbance vs. concentration), enzyme activity, photosynthesis, and the rates of chemical reactions (absorbance vs. time). After a simple calibration, students can quickly begin viewing live measurements as they materialize across the visible spectrum at 650 nm (red), 600 nm (orange), 570 nm (yellow), 550 nm (green), 500 nm (blue), and 450 nm (violet). This sensor also functions as a high-quality turbidimeter for water quality analysis.



Create Beer's Law plots to help students understand the relationship between absorbance and concentration.



Graphically analyze how a reaction changes over time.

Specifications:

Color Detection/Peak Wavelengths: 650 nm (red), 600 nm (orange), 570 nm (yellow), 550 nm (green), 500 nm (blue), 450 nm (violet)
Detector Ranges: ±25 nm from peak
Absorbance: 0-3 Abs units; useful range (0.05-1.5 Abs)
Transmittance: 0-100%
Turbidity Range: 0-400 NTU
Accuracy: ±5% NTU

Includes:

- USB charging cable
- Cuvettes and Caps (9)
- Cuvette Rack (2)
- 100 NTU Calibration Cuvette

WARNING! This product can expose you to chemicals including Formaldehyde, which is known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Order Information

Wireless Colorimeter & Turbidity Sensor	PS-3215
Also available:	
Cuvettes and Caps	SE-8739
100 NTU Calibration Cuvette	SC-3512
Cuvette Rack	EC-3590
Wireless Colorimeter & Turbidity Sensor Pack*	PS-3334

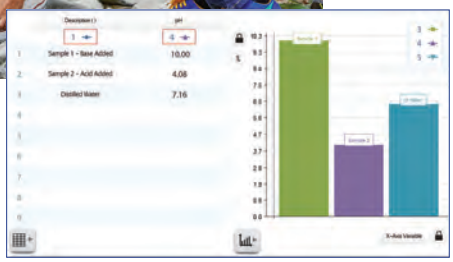
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Wireless pH Sensor

PS-3204

The Wireless pH Sensor is a must-have for any chemistry, biology, or environmental science course. Equally capable in the lab or field, the sensor eliminates the hassle of cables, reducing spills and improving safety. Don't worry about charging, the sensor has a coin-cell battery that lasts for 2-3 years in most labs and costs about one dollar to replace. The sensor can transmit data in real-time, or store data for hours or days when continuous monitoring is required. The Wireless pH Sensor can perform countless experiments, including acid-base titrations, investigating household chemicals, changes in pH during reactions, water quality studies, and much more.

With the Wireless pH Sensor, students can collect data anywhere!



Easily measure and compare the pH of common acids and bases.

Features:

- Simply pair and go, no cables or interfaces to manage
- Compatible with ion-selective electrodes (ISE) and the oxidation reduction probe (ORP)
- Bluetooth® wireless connectivity and a long-lasting coin cell battery
- Logs pH data directly onto the sensor for long-term experiments

Specifications:

Range: 0-14 pH
Resolution: 0.02 pH
Accuracy: ±0.1 pH with calibration
Logging: Yes
Bluetooth: BT 4.0
Temperature Range: 5°C to 60°C

Includes:

- Coin cell battery
- Direct-connect BNC pH probe
- Probe storage bottle and solution

Order Information

Wireless pH Sensor PS-3204

Also available:
Wireless pH Sensor Pack* PS-3331
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Flat pH Probe

PS-3514

The Flat pH Probe gives you the freedom to measure what you want, where you want. Study pH levels in different kinds of foods, investigate the pH of common skin and hair care products, and easily collect pH data when doing soil analysis. Can be used on semi-solids by pressing the probe against a moist surface.

Includes:

- Soaker bottle

Order Information

Flat pH Probe PS-3514
Required:
Wireless pH Sensor PS-3204

Get even more measurements out of the Wireless pH Sensor by using these ORP or ISE electrodes.

Oxidation Reduction Potential Probe

PS-3515

Includes:

- 2m cable

Ion Selective Electrodes

Ammonium Ion

Carbon Dioxide Ion

Calcium Ion

Chloride Ion

Potassium Ion

Nitrate Ion

Includes:

- Cable

Order Information

Oxidation Reduction Potential Probe PS-3515
Ion Selective Electrodes
Ammonium Ion Selective Electrode PS-3516
Carbon Dioxide Ion Selective Electrode PS-3517
Calcium Ion Selective Electrode PS-3518
Chloride Ion Selective Electrode PS-3519
Potassium Ion Selective Electrode PS-3520
Nitrate Ion Selective Electrode PS-3521

Wireless Conductivity Sensor

PS-3210

The Wireless Conductivity Sensor measures the electrical conductivity of an aqueous solution. It is ideal for investigating the properties of solutions, including total dissolved solids (TDS) for water quality inquiry. Because it is temperature compensated, calibrations are less frequent and can be applied across a range of temperatures. With a range of 0 to 20,000 µS/cm, this sensor can be utilized for chemical, biological, and environmental studies.

Teacher tip: To measure brackish or marine samples, perform a dilution until the measurement falls within the range, then multiply to determine sample conductivity.

Features

- Measure conductivity and total dissolved solids
- Automatic temperature compensation
- Battery life >1 year
- Remote logging with built-in memory
- Dust-proof, sand-proof, and water-resistant (1 meter for 30 minutes)

Measure the conductivity of water and other water-based solutions.

Includes:

- Coin cell battery

Order Information

Wireless Conductivity Sensor PS-3210

Also available:
Wireless Conductivity Sensor Pack* PS-3332

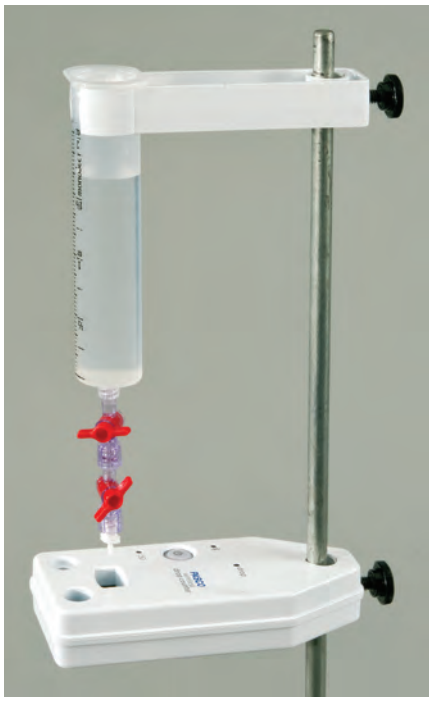
* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Wireless Drop Counter

PS-3214

The Wireless Drop Counter has a wider (18 x 13 mm) drop window for better drop detection and easier alignment with burettes. It works equally well with large or small, fast or slow drops.

Measures up to 10 drops per second with drops as small as 0.5 mm.



Includes:

- Wireless Drop Counter
- Micro Stir Bar
- Drop Dispenser with Stopcock
- Plastic Dispenser Rod Clamp

Order Information

Wireless Drop Counter PS-3214

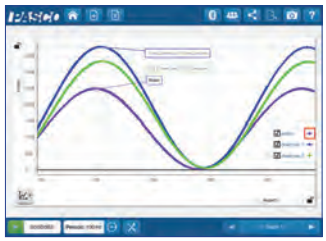
Wireless Polarimeter

PS-3237

PASCO's Polarimeter has both Bluetooth® and USB connectivity, so it works on your iPad®, Chromebook™, tablets, and computers. It is ideal for introductory Organic Chemistry and Biochemistry experiments with chiral compounds.

In this new device, plane polarized light is passed through a sample, which contains a chiral compound, to an analyzer and a detector. The degree of optical rotation of the plane polarized light is based on the type and amount of sample present.

Students can use the collected data to determine the concentration of compounds such as sugar.



Optical rotation of sucrose

Features:

- Bluetooth® and USB connectivity
- 589 nm LED light source
- ± 0.09° optical rotation accuracy
- SPARKvue and Capstone compatible
- Industry-standard, horizontal polarimeter sample cell (100 mm)

Includes:

- Sample Cell

Order Information

Wireless Polarimeter PS-3237

Wireless Blood Pressure Sensor with Standard Cuff

PS-3218

PASCO's Wireless Blood Pressure Sensor allows students to quickly and easily measure both systolic and diastolic arterial blood pressure (mmHg) as well as heart rate (pulse in bpm). Comparing the digits display for systolic and diastolic pressure with the display of blood pressure from the real-time graph helps students gain a contextual understanding of the physiology of blood pressure.

Applications:

- Determine effects of exercise on blood pressure and heart rate
- Compare the blood pressure and heart rate of different students in the class
- Explore effects of body position on blood pressure & heart rate

Specifications:

Heart Rate Units: beats per minute (bpm)
Heart Rate Range: 36 to 200 bpm
Heart Rate Accuracy: ±1 bpm
Heart Rate Resolution: 1 bpm
Blood Pressure Units: millimeters of mercury (mmHg)
Blood Pressure Range: 0 to 375 mmHg
Blood Pressure Accuracy: ±3 mmHg
Blood Pressure Resolution: 0.05 mmHg
Gauge Pressure Units: mmHg, N/m^2, kPa, atm, psi
Gauge Pressure Range: 0 to 375 mmHg
Gauge Pressure Accuracy: ±3 mmHg
Gauge Pressure Resolution: 0.05 mmHg

Includes:

- Wireless Blood Pressure Sensor
- Standard-size Arm Cuff
- Bladder and pressure release valve

Order Information

Wireless Blood Pressure Sensor with Standard Cuff..... PS-3218

Wireless Exercise Heart Rate Sensor

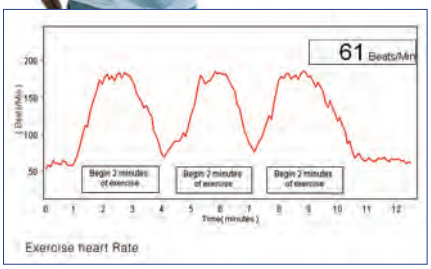
PS-3207

The Wireless Exercise Heart Rate Sensor has a chest strap and will transmit data wirelessly up to 10 m away! The electrode belt fits around the ribcage (worn against the skin for best results, but can be worn over a shirt if saline solution is applied under the electrodes) and wirelessly transmits the cardiac signal to the sensor.

Applications:

- Compare a student's heart rate before, during, and after exercise
- Calculate recovery rate after physical activity
- Determine the effects of mild stimulants (e.g. caffeine)
- Investigate how heart rate changes when a student sits, reclines, stands or moves suddenly

Graph shows the heart rate as a student alternates between exercising and resting.



Includes:

- Bluetooth® Heart Rate Module
- Coin Cell Battery
- Chest Strap (M-XXL)

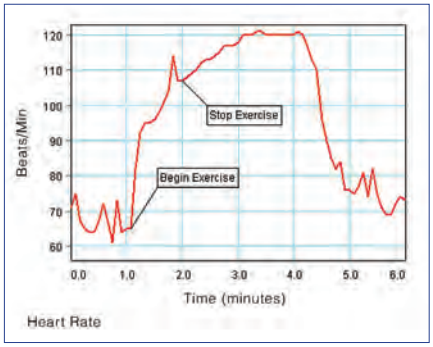
Order Information

Wireless Exercise Heart Rate Sensor..... PS-3207

Wireless Hand-Grip Heart Rate Sensor

PS-3206

With these wireless hand grips, conducting physiology labs on the cardiovascular system or homeostasis is easier than ever before. Continuously monitor heart rate during exercise, or use the sensor to take initial and final measurements with fast and reliable heart rate detection.



Includes:

- Hand Grips
- Bluetooth® Heart Rate Module
- Coin Cell Battery

Order Information

Wireless Hand-Grip Heart Rate Sensor..... PS-3206

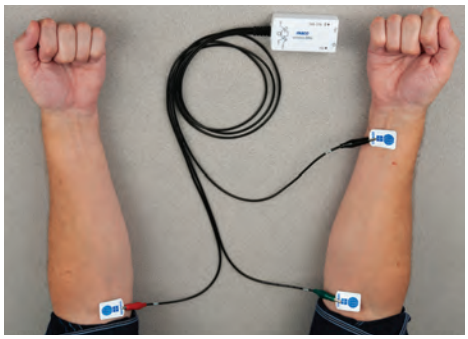
Wireless EKG Sensor

PS-3236

- Monitor heart rate and a live EKG trace
- Study nerve impulses and the dive response
- Use Blockly programming to produce a stimulus and measure reflex reaction times

The Wireless EKG Sensor measures electrical signals produced by contractions of the heart or muscles, and reports them in real-time on virtually any student device. The perfect sensor for fast-paced physiology courses, the EKG Sensor provides students with live feedback as they explore the effects of various stimuli on cardiac or muscular activity.

Heart Rate data is reported in beats per minute (BPM), while the voltage (mV) detected from cardiac contractions is intuitively displayed in an EKG trace. The sensor can also be used to study nerve impulses that affect muscles other than the heart, enabling students to study a wider range of physiological phenomena, including reflexes, muscle fatigue and more.



Leads on the (B) right wrist, (G) right elbow, and (R) left elbow allow the user to measure the heart's activity.

Applications:

- Investigate the effects of relaxation and exercise on heart rate
- Study the dive response and stimulus response reflexes
- Compare EKG traces between students at rest and students with their hands in ice water
- Perform in-depth reflex studies with the Wireless Force and Acceleration Sensor

Specifications:

Voltage Range: 0 to 4.5 mV
Voltage Resolution: 5 µV
Default Sample Rate: 250 Hz
Maximum Sample Rate: 1000 Hz
Heart Rate Range: 40 to 250 bpm
Heart Rate Resolution: 1 bpm

Includes:

- Electrode Patches (100)

Order Information

Wireless EKG Sensor	PS-3236
Recommended:	
EKG Sensor Electrode Patches	CI-6620

Wireless Spirometer

PS-3234

The PASCO Wireless Spirometer allows students to determine the volume of gas that passes through a tube during expiration, their total lung volume, and the factors that can affect it. Students can also estimate the amount of oxygen in their bloodstreams and the overall oxygen efficiency of their lungs by integrating data from a PASCO Wireless Oxygen or CO_2 Sensor.

The Wireless Spirometer Sensor makes it safe and easy for students to collect respiratory measurements, including flow rate, pressure, and lung volume. Ideal for studies in health and human physiology, the Wireless Spirometer Sensor streamlines experiments by providing students with real-time data, interactive graphs, and analysis tools on virtually any device. The disposable mouthpieces are designed for use with a single student and feature exchangeable filters that protect the sensor from particulates to ensure long-term hygienic use. Additional mouthpieces are available in convenient packs of ten.

Educational Use Only: This is not a medical device. PASCO products are designed for educational use only and should not be used in any apparatus involved with life support, medical testing, patient diagnosis, or industrial control/testing systems.

Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.

Includes:

- Pre-filters (3)
- Mouthpieces (3)

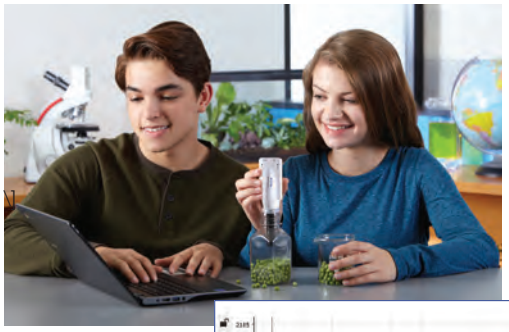
Order Information

Wireless Spirometer	PS-3234
Replacement Parts:	
Spirometer Mouth Piece Replacements (10)	PS-2522
Spirometer Mouth Piece & Pre-Filter	PS-3245

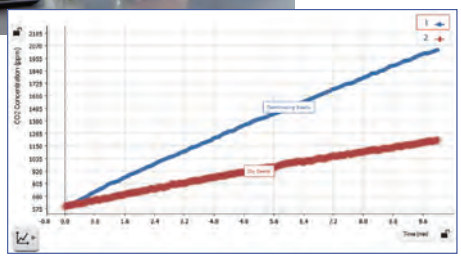
Wireless CO_2 Sensor

PS-3208

Measure changes in carbon dioxide (CO_2) gas levels quickly and easily with the Wireless CO_2 Sensor. The sensor is temperature compensated and can operate in high humidity environments, like the included 250-mL sample bottle. This sensor employs live data to make core labs, such as photosynthesis, cellular respiration, and metabolism experiments engaging and impactful. With the ability to store more than 55,000 data points, this sensor enables studies to run overnight or throughout an entire weekend for long-term carbon cycling investigations.



Easily compare respiration/ metabolism rates at different conditions.



Includes:

- 250-mL Sampling Bottle
- USB Charging Cable

Order Information

Wireless CO_2 Sensor PS-3208

Also available:

Wireless CO_2 Sensor Pack* PS-3341

* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Dissolved CO_2 Waterproof Sleeve

PS-3545

The Wireless CO_2 Sensor can be equipped for aqueous measurements using this semipermeable sleeve. The sleeve is waterproof but allows CO_2 gas to pass through the membrane, creating a headspace around the sensor. Monitor photosynthesis and respiration of aquatic plants or animals with the sample bottle or with other chambers. (Please note: Improper use will void sensor warranty.)

Includes:

- Sleeves (5)
- O-rings (5)

Order Information

Dissolved CO_2 Waterproof Sleeve PS-3545

Wireless Oxygen Gas Sensor

PS-3217

The Wireless Oxygen Gas Sensor measures gaseous O_2 concentration as well as humidity and air temperature for a range of biology, environmental science, and physiology activities.

The Wireless Oxygen Gas Sensor is accurate and easy to use, making it an ideal tool for studies of photosynthesis, respiration, and oxygen cycling. With remote logging, experiments can go beyond the lab period and easily give students hours or days of data for analysis. The Wireless Oxygen Gas Sensor also contains sensors to measure ambient temperature and humidity as well as oxygen gas levels.

Includes:

- USB Charging Cable
- 250-mL Sampling Bottle

Order Information

Wireless Oxygen Gas Sensor PS-3217

Also available:

Wireless Oxygen Gas Replacement Sensor PS-3606

Wireless Oxygen Gas Replacement Sensor

PS-3606

This replacement sensing unit fits inside the Wireless Oxygen Gas Sensor.

Specifications:

Oxygen Percent Composition: within 1%

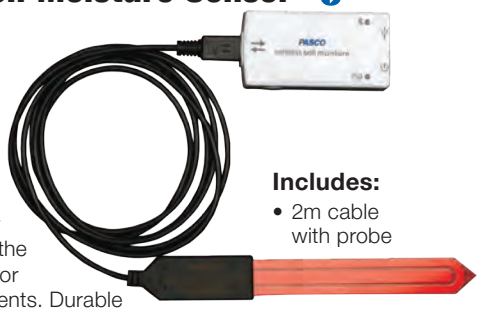
Oxygen Percent: 0 to 100%

Order Information

Wireless Oxygen Gas Replacement Sensor PS-3606

Wireless Soil Moisture Sensor

PS-3228



The Wireless Soil Moisture Sensor measures the volumetric water content (%VWC) of soil, reporting data in real time or storing it onboard the sensor's memory for long-term experiments. Durable and easy to use, the Wireless Soil Moisture Sensor is the perfect tool for monitoring controlled experiments in the classroom and long-term experiments outdoors. From experiments in evaporation and soil composition to water consumption and plant competition, the Wireless Soil Moisture Sensor makes it easy for students to investigate a wide array of topics both inside and outside of the classroom.

Includes:

- 2m cable with probe

Specifications:

Range: 0 to 45% water by volume

Accuracy: ±5%

Resolution: 0.1%

Power: 3 mA at 5 V DC

Operating Temperatures: -40 to 60°C

Probe Cable Length: 2m

Order Information

Wireless Soil Moisture Sensor PS-3228

Replacement Probe PS-3228-PRB

EcoZone™ System ME-6668

EcoChamber ME-6667

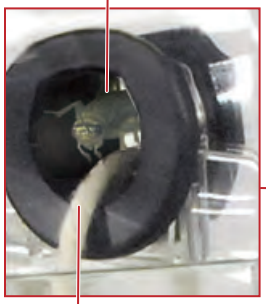
- Three interconnected EcoChambers (ME-6668) or one stand-alone EcoChamber (ME-6667)
- Designed for sensor-based measurements

PASCO's EcoZone System is designed to help students model and understand the complex interactions within, and among, different ecosystems. The three clear acrylic EcoChambers are specially designed to accommodate PASCO sensors, making qualitative and quantitative measurements as easy as observing.

With three interconnected chambers, students can model interactions between three different ecosystems. Choose the traditional terrestrial, aquatic, and decomposition arrangement or create unique biomes to model and measure. Decouple the system for isolated investigations. How does the availability of light affect the ecosystem? Students can create two identical ecosystems and monitor one in light conditions and one in dark.

Keep the system closed during chemical testing. Use the included syringe to extract water, or inject pollutants into the system and see how the ecosystem responds.

Opening connects the chambers to allow interaction between the living and non-living components of each unique ecosystem.



The included cord efficiently wicks water between the chambers.

Terrestrial Chamber

Aquatic Chamber

Decomposition Chamber

Cleanup is easy, and the chambers are durable enough to use again and again. The unique design of the PASCO EcoZone System allows you to use your sensors to actively measure a model ecosystem.

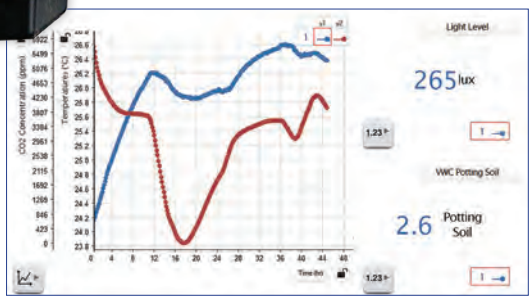
For information about compatible sensors and probes, see **www.pasco.com/ecozone** and scroll down to the Buying Guide.

ME-6667 Includes:

- Acrylic chamber
- Stoppers of various sizes (7)
- Probe stoppers (5)
- 20 cc calibrated syringe
- Sample tube with connector

ME-6668 Includes:

- Three individual EcoChambers with lids
- Custom tray for holding EcoChambers in a connected ecosystem
- Stoppers and connectors
- Cotton wick
- Syringe and plastic tubing



Observe the photosynthesis and respiration cycles of the simulated microclimate in the EcoZone and their effect on carbon dioxide.

Order Information

EcoZone System	ME-6668
EcoChamber	ME-6667

Wireless Optical Dissolved Oxygen Sensor

PS-3246

The Wireless Optical Dissolved Oxygen (ODO) Sensor is ideal for monitoring DO_2 in the lab or field. The Wireless Optical DO Sensor contains three different probes. In addition to the dissolved oxygen sensor, it also includes probes for measuring atmospheric pressure and water temperature. The optical technology is accurate, fast, and does not require stirring, filling solutions, warm-up, or frequent calibration.

A PASCO exclusive feature allows you to log data using the sensor's built-in memory. After collecting data for hours or even days, simply connect the sensor to your device and you're ready to download your data. With this powerful sensor, students can explore day and night nutrient cycles, changes in metabolic processes, seasonal changes in water quality, and more.

Note: The included waterproof probe is submersible to a depth of 2.5 m. The sensor box is not waterproof.

Applications:

- Teaching field sampling techniques
- Exploring how temperature influences dissolved oxygen concentrations
- Measuring net primary productivity
- Modeling ecosystems
- Monitoring water quality and investigating watersheds
- Investigating photosynthesis and cellular respiration in aquatic environments

Specifications:

Dissolved Oxygen Range: 0 to 20 mg/L, 0 to 300% saturation
Accuracy (with user calibration): ±0.2 mg/L or 1% (whichever is greater)
Accuracy (out of the box): ±0.5 mg/L or 3% (whichever is greater)
Response Time: 90% in 30 sec
Measurements:
Concentration (mg/L), Saturation (%), O_2 Gas (in air, qualitative) (%), Temperature (°C)
Waterproof Depth (probe): 2.5 m

Includes:

- USB Cable (for recharging and optional direct connection)
- Protective cover

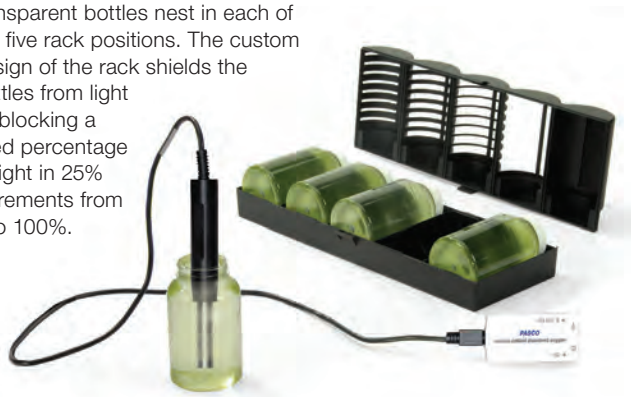
Order Information

Wireless Optical Dissolved Oxygen Sensor	PS-3246
Shown in use with:	
Photosynthesis Tank	PS-2521B

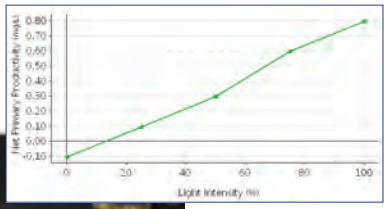
Aquatic Productivity Bottles

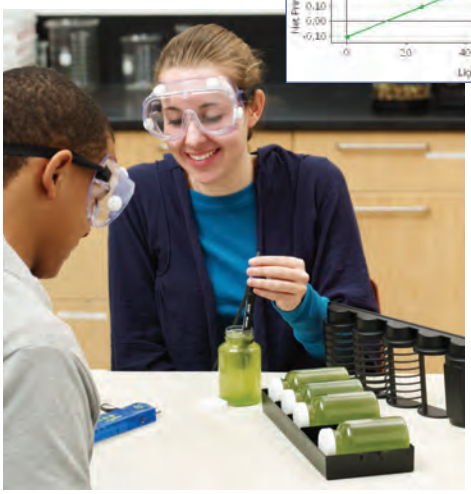
ME-6937

The Aquatic Productivity Bottles rest in a rack that provides consistent and reliable light control for quantitative aquatic productivity studies. The identical transparent bottles nest in each of the five rack positions. The custom design of the rack shields the bottles from light by blocking a fixed percentage of light in 25% increments from 0 to 100%.



The Aquatic Productivity Bottles were completely filled with algae solution and the initial dissolved oxygen (DO) concentrations of the solutions were determined with a DO sensor. The bottles were then placed into the rack and the specially molded, light-varying lid was locked into place over the bottles. After 24 hours of incubation in fluorescent light, the bottles were removed from the rack and the DO concentration was again determined with a DO sensor. Using the initial and final readings, students calculated Net Primary Productivity and Gross Primary Productivity.





Net Primary Productivity (mg/L) vs. Light Intensity (%): Notice that for the bottle in the dark, the Net Productivity is negative.

Includes:

- Plastic bottles w/lids (5)
- Case with slotted lid

Order Information

Aquatic Productivity Bottles	ME-6937
Shown in use with:	
Wireless Optical Dissolved Oxygen Sensor	PS-3246

Wireless Weather Sensor with GPS

PS-3209

The Wireless Weather Sensor is an all-in-one instrument for monitoring complex environmental conditions. It houses several sensing elements within a single unit to provide 19 different measurements. Use the sensor in logging mode with the Weather Vane Accessory for long-term monitoring, or use it as a handheld instrument to study microclimates and local phenomena. The collected data can be wirelessly exported to most devices, including classroom device dashboards, making it easier to support group activities that are constrained by time. Plus, with the built-in GPS, students can collect and analyze location data using the SPARKvue map display, powered by ESRI ArcGIS.

Measurements

Weather
1. Ambient Temperature
2. Barometric Pressure
3. Wind Speed
4. Wind Direction (true)
5. Relative Humidity
6. Absolute Humidity
7. Dew Point
8. Wind Chill
9. Heat Stress Index

Light
10. Ambient Light (lux)
11. UV Index
12. PAR
13. Irradiance

GPS
14. Latitude
15. Longitude
16. Altitude
17. Speed
18. Magnetic Direction
19. True Direction

Shown with optional Weather Vane Accessory, sold separately.

Weather data colored and viewed on one of several global base maps.

Specifications:

Water-resistant: IP-64 splash-proof

Battery: Rechargeable

(Please see pasco.com for detailed specifications.)

Includes:

- USB charging cable

Order Information

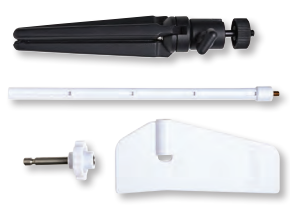
Wireless Weather Sensor with GPS	PS-3209
Suggested:	
Weather Vane Accessory	PS-3553
Also available:	
Wireless Weather Sensor with GPS Pack*	PS-3340

* Includes 8 sensors in a Gratnells® storage tray with custom insert.

Weather Vane Accessory

PS-3553

Equip your Wireless Weather Sensor for extended environmental monitoring with the Weather Vane Accessory. Once deployed the sensor will freely rotate to capture wind speed and direction, whether you are monitoring data in real time or using the sensor in logging mode to capture hours (or days!) of data for later analysis.



Includes:

- Tripod
- Tripod Adapter
- Weather Vane

Order Information

Weather Vane Accessory	PS-3553

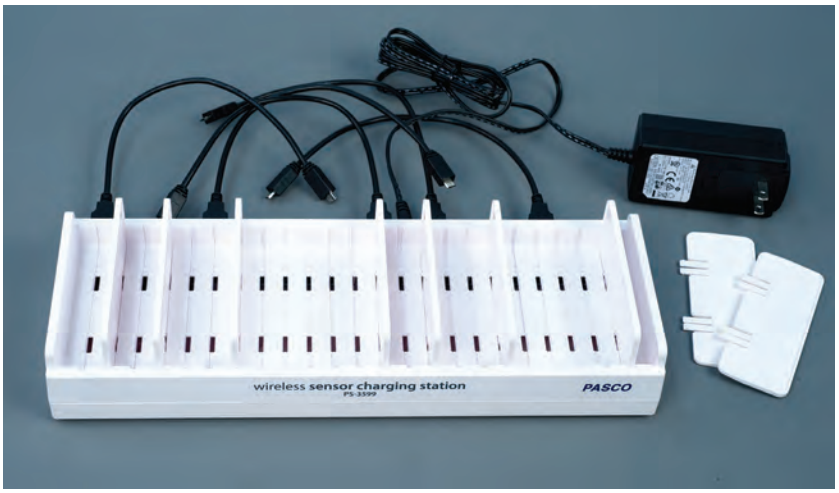
Wireless Charging Stations

Wireless Sensor Charging Station

PS-3599

- Charge all types of PASCO Wireless Sensors
- Remove partitions to resize sensor bays

This versatile charging station can be configured to fit any size sensor by adding or removing partitions.



Includes:

- Wireless Sensor Charging Station (13 cm x 35 cm)
- Power Adapter
- USB Charging Cables (10)
- Removable Partitions (9)

Order Information

Wireless Sensor Charging Station PS-3599

Smart Cart Charging Garage

ME-1243

Charge up to five Smart Carts at once. Provides storage for the carts and accessory bumpers. Includes power adapter.

Order Information

Smart Cart Charging Garage ME-1243

Wireless Sensor Storage Trays

- Each tray can store up to 10 Wireless Sensors.

Explore solutions for sensor storage at pasco.com/storage

Wireless Sensor Packs

- Includes 8 sensors in each Gratnells® storage tray

Wireless Conductivity Sensor Pack (PS-3332)

Wireless Temperature Sensor Pack (PS-3330)

Wireless Force Acceleration Sensor Pack (PS-3339)

Wireless Colorimeter & Turbidity Sensor Pack (PS-3334)

Wireless Sound Sensor Pack (PS-3342)

Also available:
Wireless pH Sensor Pack (PS-3331)
Wireless Pressure Sensor Pack (PS-3333)
Wireless Voltage Sensor Pack (PS-3335)
Wireless Current Sensor Pack (PS-3336)
Wireless Motion Sensor Pack (PS-3337)
Wireless Light Sensor Pack (PS-3338)
Wireless Weather Sensor with GPS Pack (PS-3340)
Wireless CO_2 Sensor Pack (PS-3341)

See all our Wireless Sensor Packs at pasco.com

Gratnells® Rolling Carts

EP-3574 (2-column) EP-3575 (3-column)

Gratnells Rolling Carts are the best way to store and transport PASCO sensors and equipment. They can be configured for trays of any size and include large casters with brakes for added stability.

Designed for Gratnells trays, these movable storage rack carts can store up to 8 (2 column) or 12 (3 column) Gratnells F2 trays (sold separately). Each cart comes with either 16 or 24 pairs of runners.

They can be used to store the equipment kits from the Essential Physics or Essential Chemistry curriculum, the storage trays we offer for Wireless Sensors, or any of the four sizes of empty trays that we offer for everything else you'd like to store.

Assembly is required. Trays not included.

EP-3574:
Stores up to
8 Gratnells F2 trays
24 pairs of runners
Dimensions: 107 cm high, 70 cm wide, 43.5 cm deep

EP-3575:
Stores up to
12 Gratnells F2 trays
16 pairs of runners
Dimensions: 107 cm high, 102 cm wide, 43.5 cm deep

Assembly is required. Trays not included.

Order Information

Gratnells Rolling Cart (2-column)	EP-3574
Gratnells Rolling Cart (3-column)	EP-3575

Gratnells® Storage Trays with Lids

These empty Gratnells storage trays with lids have a length of 427 mm and width of 312 mm. The depth of each follows:

F1: 75 mm
F2: 150 mm
F25: 225 mm
F3: 300 mm

F1 F2 F25 F3

Order Information

Storage Tray (F1) Shallow	PS-3326
Storage Tray (F2) Deep	PS-3327
Storage Tray (F25) X-Deep	PS-3328
Storage Tray (F3) Jumbo	PS-3329

Make the switch to PASCO capstone™ 2

The Most Advanced Data Collection Software in Science Education

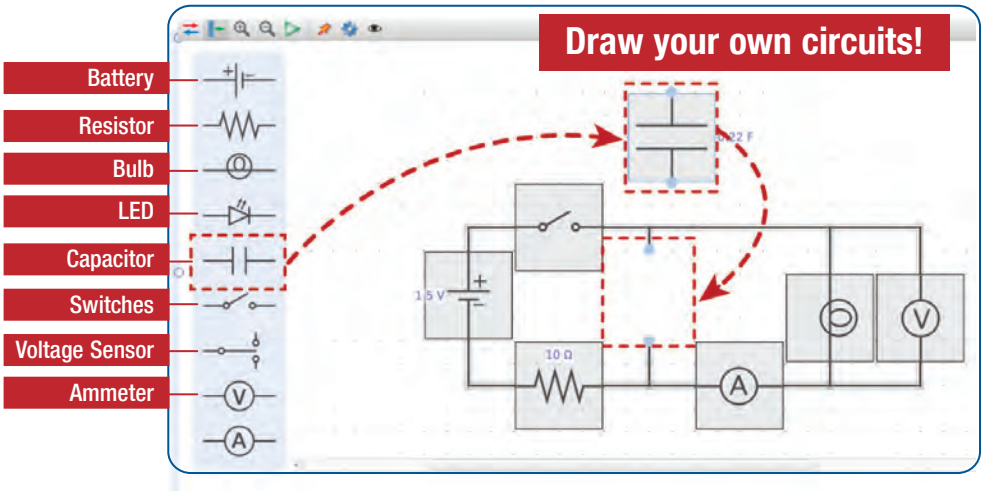
PASCO is pushing the limits of technology, so you can push your students to their potential. Working closely with educators, we continuously develop Capstone™, making improvements and enhancing the teaching features. Capstone is designed to handle large data sets, high-speed sampling, and customized preferences to fit the needs of your lab. The straightforward user interface is approachable for beginners, yet Capstone offers all the capabilities needed for even the most advanced users.

Features in PASCO Capstone 2

Visit **pasco.com/capstone** for more information.

Circuits Emulation

Reinforce circuit concepts and tackle student misconceptions using circuit visualization.



Combine real-world circuits with simulations, animations, and live measurements.

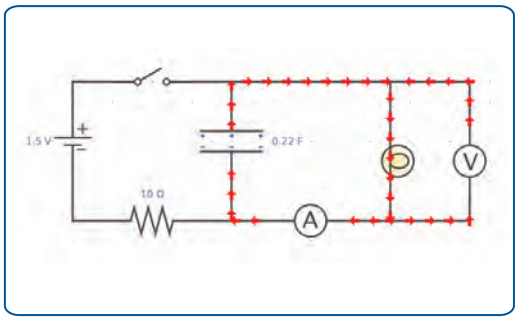
With this tool you can:

- Construct and modify circuits
- Show conventional current and electron flow animations
- Animate circuits with live sensor data

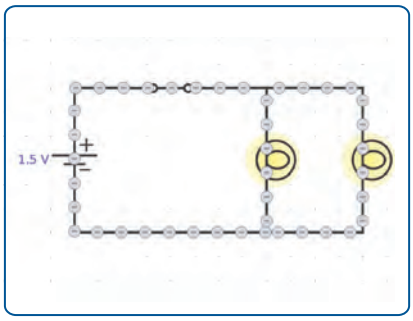
Build your own circuits in Capstone. Drag and drop components and draw wires to connect them.

- Demonstrate series and parallel
- Charge and discharge capacitors

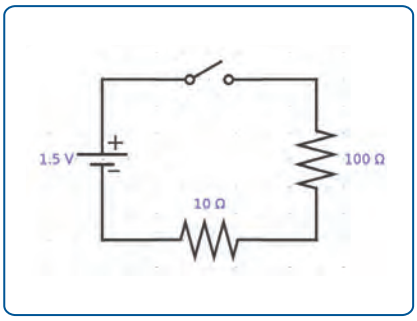
Examples of other circuit emulations



- Animate conventional current flow
- Animate a capacitor — charge or discharge
- Edit capacitor values



- Animate electron flow
- Connect components in parallel or series

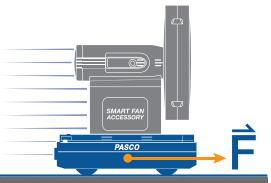


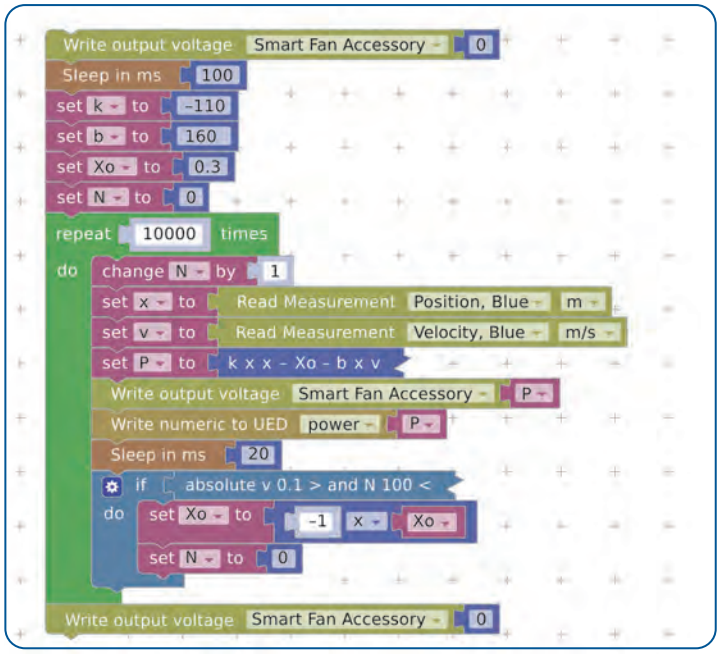
- Operate switches
- Edit voltage and resistor values

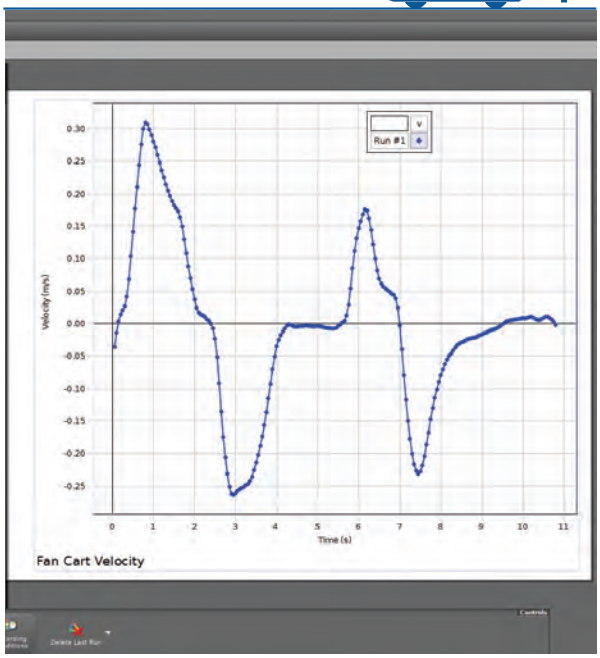
Blockly Block-based Coding

- Control all PASCO sensors and interfaces
- Create sense and control programs
- Control outputs from sensor inputs

Bring computational thinking into your science lab!



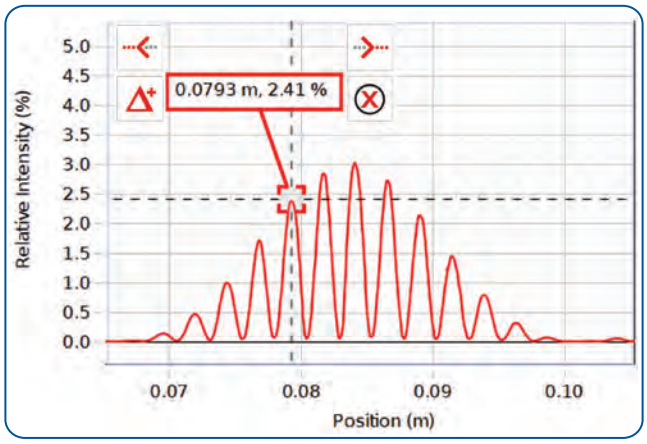




Visit **pasco.com/capstone** for more information.

Graph Pop-up Tools

Quick access to commonly used analysis tools



Capstone has all the software tools you need for data collection and analysis. And we continue to add more features, based on input from physics educators just like you!

- Exclude or delete selected data points from analysis.
- Create models using the calculator.
- Calculated columns in tables
- Error bars
- Weighted linear fit that takes into account error bars
- More complex curve fits such as damped sine, Gaussian, sine series, and user-entered fits
- Smooth data directly on a graph with slider tool.
- Global preferences settings

Order Information

PASCO Capstone
Single User License ..... UI-5401 or UI-5401-DIG

PASCO Capstone
Site License ..... UI-5400 or UI-5400-DIG

Download the Free Trial
www.pasco.com/Capstone
Requires Mac or Windows

PASCO Capstone 2

TOOLS

Configure PASCO Hardware
Works with PASPORT, ScienceWorkshop, and Wireless Sensors

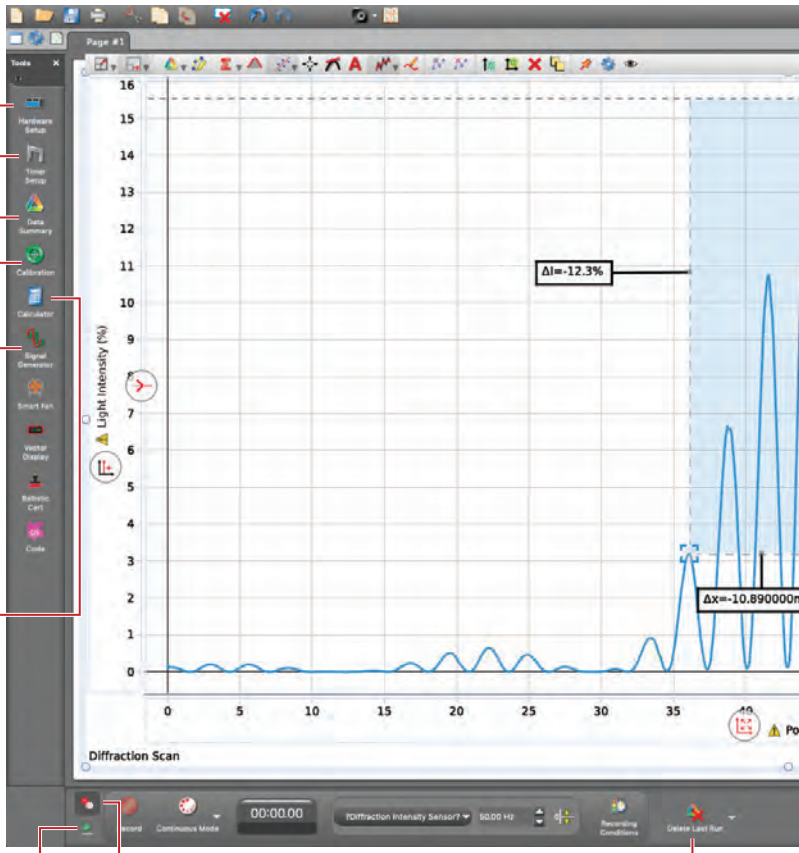
Photogate Timer Wizard
Easily configure photogates and timing measurements

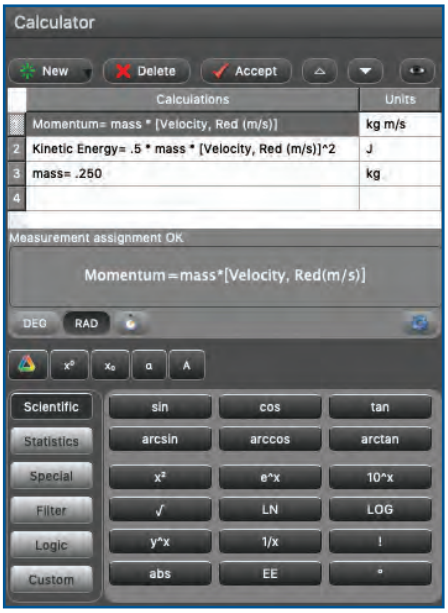
Data Summary
- Equations/calculations
- Fundamental constants
- Experimental constants
- Trials and runs

Sensor Calibration Wizard
- Step by step calibration
- Many calibration types

Signal Generator
- Scan through a range of frequencies
- Control signal output with a calculation

Calculator
- Graph modeling
- Create data sets using sensor data



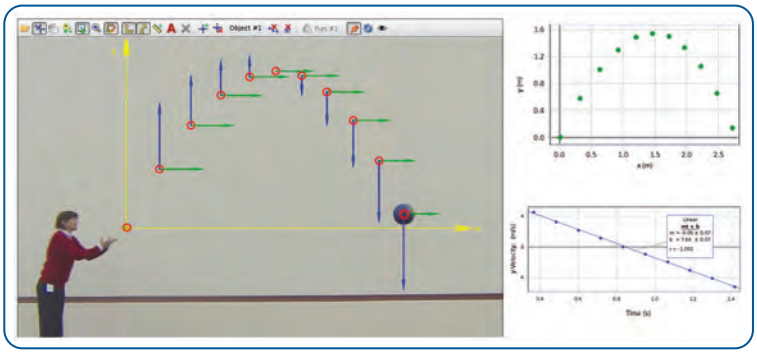


Sophisticated scientific calculator has statistics, calculus, filters, logic functions, and special operations such as amplitude and period.

Replay Your Data
- Change replay rate
- Increment by frame
- Loop playback

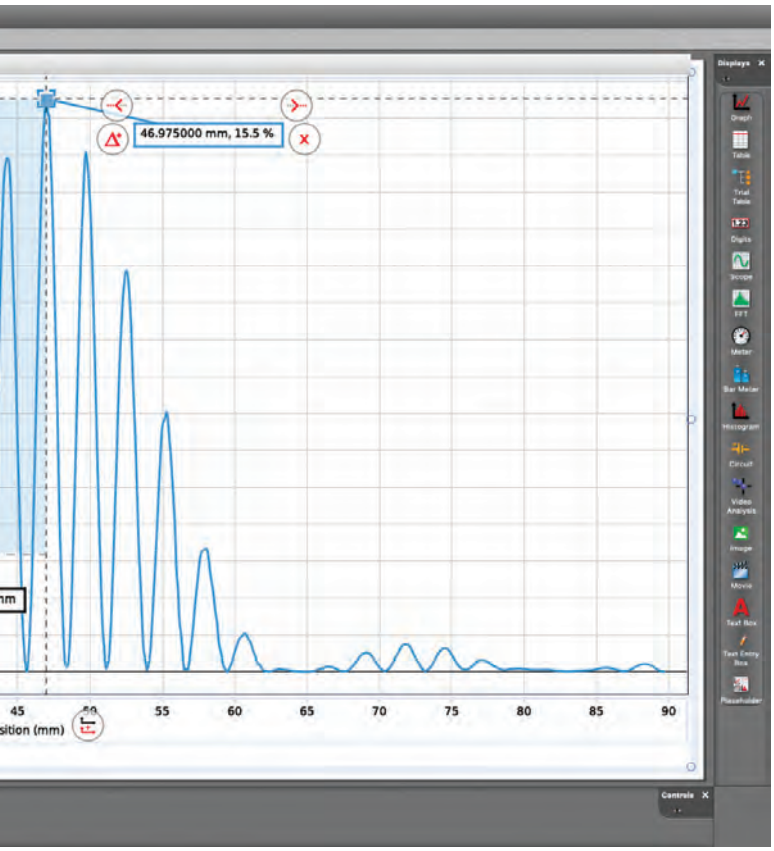
Sampling Options
- Continuous manual sampling
- Fast monitor mode
- Independent sensor sampling rates
- Start/stop conditions
- Zero sensor

Capstone 2 Includes Video Analysis



Import video and analyze the motion of objects to measure position, velocity, and acceleration. With this tool you can also:
- Show velocity and acceleration vectors
- Use magnifier to identify exact center of an object
- Use calibration ruler at any time
- And so much more!

PASCO's proximity in-app sensor pairing: U.S. Patent Number 10,356,594



DISPLAYS

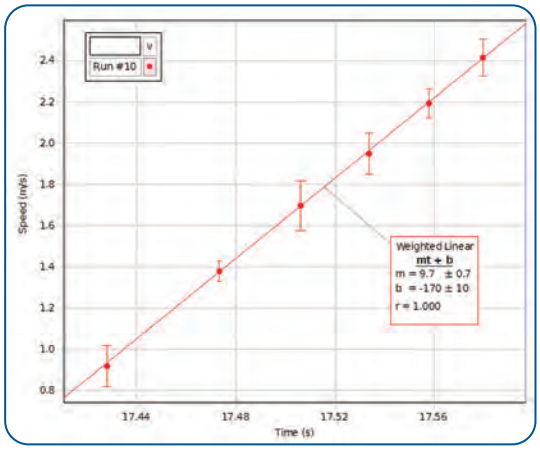
Display *Your* Data *Your* Way

▸ Graph ▸ Table ▸ Digits ▸ Scope ▸ FFT ▸ Meters

Graph Tools Include

- Draw predictions on graphs before taking data.
- Multiple *y*-axes and/or multiple plot areas
- Perform Quick-Calcs on the graph axis to linearize data.
- Curve-fits report the uncertainties in the parameters.
- Multi-coordinate tool gives *y*-values wherever it intersects data.

Error Bars and Weighted Linear Fits



Graph uncertainties using user-entered error bars, absolute error, or percent error. The weighted linear fit incorporates the error bars.

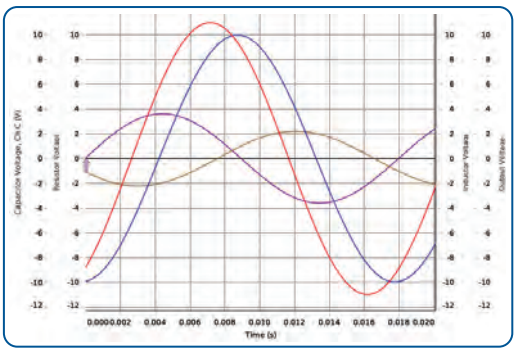
Visit **pasco.com/capstone** for more information.

Delete Runs

- Last run only
- Select from list
- All runs

Made a mistake?
Just hit
UNDO

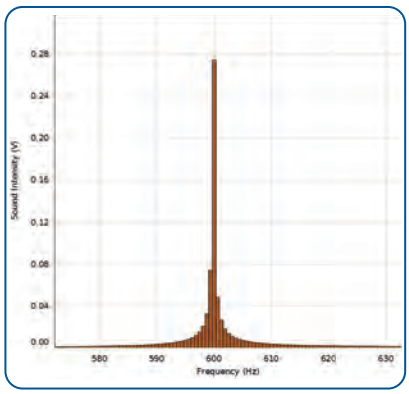
Oscilloscope Display



This display behaves like an authentic digital oscilloscope.

- Trigger
- Single trace collection
- Sample rate tied to time axis scale
- Set trace offset

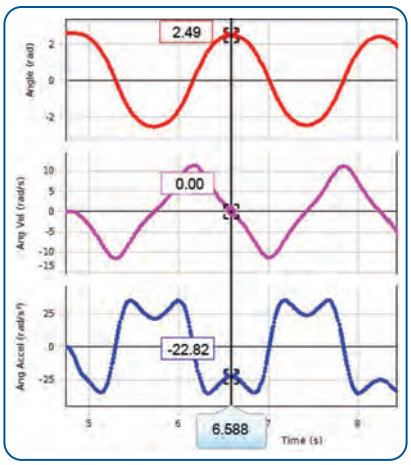
FFT



Display data in the frequency domain to find peak frequency and harmonics.

- Sample rate tied to axis scale
- Normalize data
- Adjust BIN width

Multi-Coordinate Tool



Easily show the relationship between multiple data plots by comparing data values across the time axis.

SPARKvue® 4 Software

Award-winning data collection and analysis software for any platform

SPARKvue is uniquely designed to deliver the features educators love within a framework students can easily use. It provides a powerful, all-in-one platform with intuitive tools for data collection, visualization and analysis, as well as features for block coding and collaboration. This all-in-one approach simplifies lab setups and data collection for science courses, while also equipping after-school programs with the tools they need to code, create, and explore. Visit us online to try it for free and see how SPARKvue can help you spark a lifelong love of science learning.

Designed for All Sciences

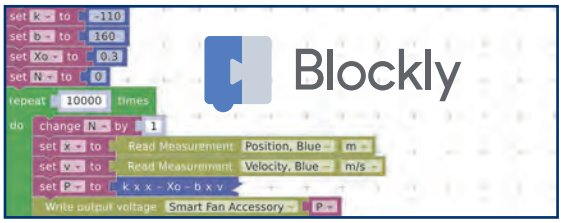
Collect data in real time using PASPORT or Wireless Sensors.

SPARKvue comes installed on every SPARK LXi2.

SPARKvue includes interactive data displays that are specific to your activity.

PASCO's proximity in-app sensor pairing: U.S. Patent Number 10,356,594

Data Collection:



- **Live Data Bar:** See sensor readings before recording
- **Periodic sampling:** Automatic sampling at a fixed rate
- **Manual sampling:** Saves data only when a user specifies
- **Blockly:** Use code to control sensor and interface data collection
- **Collaborate:** Start a shared session and stream results in real time

Data Displays:

- Graph displays with multiple plot areas and axes
- Digits
- Meter
- Data tables
- FFT
- Map Display
- Weather Dashboard
- Oscilloscope

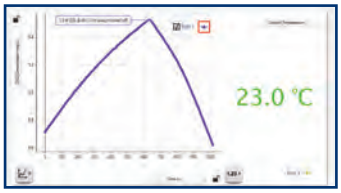
Try SPARKvue software for FREE. Get Started Today!

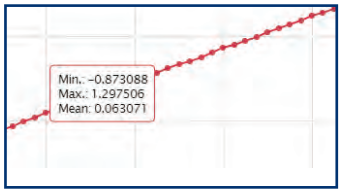
The complete version of SPARKvue is now available as a **FREE app** for Chromebook™, iPad®, Android™ tablets, and Apple® and Android™ smartphones.

Download on the App Store | Available in the Chrome Web Store | ANDROID APP ON Google play

We also offer free 60-day trials for Windows™ and Mac®*.
Visit www.pasco.com/downloads

Tools for Data Analysis:





- **Scale-to-fit:** Adjust axis for optimal data view
- **Data Selection:** Easily select a portion of data for analysis
- **Prediction Tool:** Visualize a prediction alongside the data
- **Smart Tool:** Find data coordinates and calculate delta values
- **Calculation Tools for Statistics:** Easily obtain statistics such as minimum, maximum, mean values and more
- **Slope Tool:** Find the slope of a point
- **Curve Fits:** Various curve fits with goodness of fit values
- **User Annotation:** Easily add text notes to runs or points
- **Axes:** Add another *y*-axis or a new plot with one button

SPARKvue Resources:

- Video Library: 330+ free videos featuring SPARKvue
- PASCO Blog: Dozens of fun applications for SPARKvue
- Experiment Library: 80+ free and downloadable SPARKvue labs
- FREE webinar training from PASCO professionals on our website
- Summer Institutes: Software and technology training
- Visit **www.pasco.com/training-and-development** for more information.

Cross-Platform Compatibility

SPARKvue

(single user license) PS-2401
(site license) PS-2400

Windows® and Mac®

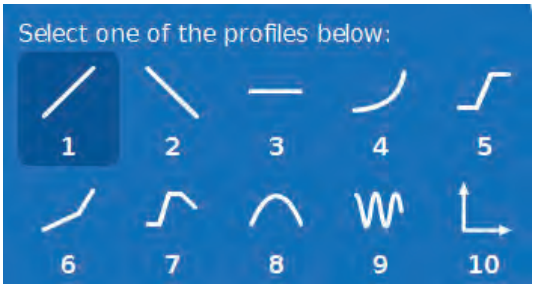
Order Information	
SPARKvue Single User License	PS-2401
SPARKvue Site License	PS-2400

PASCO *MatchGraph!*

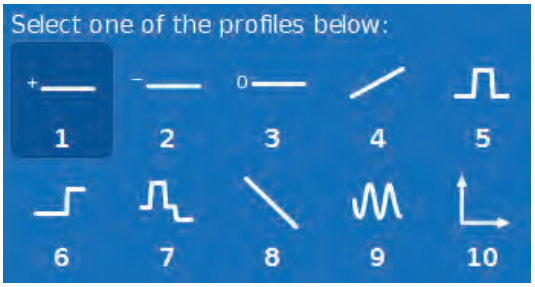
- Students feel the motion firsthand and learn how to interpret motion graphs! Watch your students compete to get the best match score.
- The sample graphs to match include both Position vs. Time and Velocity vs. Time.
- The student moves back and forth in front of a motion sensor in an attempt to match the motion represented on the graph.

High Score	
Name	Score
Lewis	90.78
Ann	90.46
James	75.47
Brett	70.24

Students learn while having fun competing for the highest score. The program keeps track of the scores for each profile.



There are nine position profiles to match. The tenth choice allows students to use the motion sensor without a profile on the graph.



The velocity profiles to match correspond to the position profiles.

The students get to see their motion for a few seconds before the matching starts so they can get lined up. Here the black line is the match profile and the red line is the student's attempt to match it.

Download FREE *MatchGraph!* software for Mac® and Windows® computers at **pasco.com**. Download the free iPad® or Android™ app on the App Store or Google Play.

Download on the App Store | ANDROID APP ON Google play

FREE *MatchGraph!™* Software

Go to **pasco.com/downloads** and click on MatchGraph.

Now works with all Motion Sensors and Smart Carts!

Order Information

Required:		
Wireless Motion Sensor	PS-3219	p. 63
OR		
PASPORT Motion Sensor	PS-2103A	p. 40
OR		
Motion Sensor II	CI-6742A	p. 32
*Requires a USB or Bluetooth interface; see pages 84.		
OR		
Smart Cart (Red)	ME-1240	p. 62

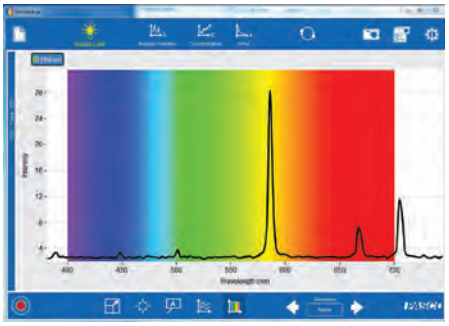
PASCO's FREE Spectrometry Software Puts Learning First

Our award-winning Spectrometry Software works on iOS®, Android™, Computers, and Chromebooks*

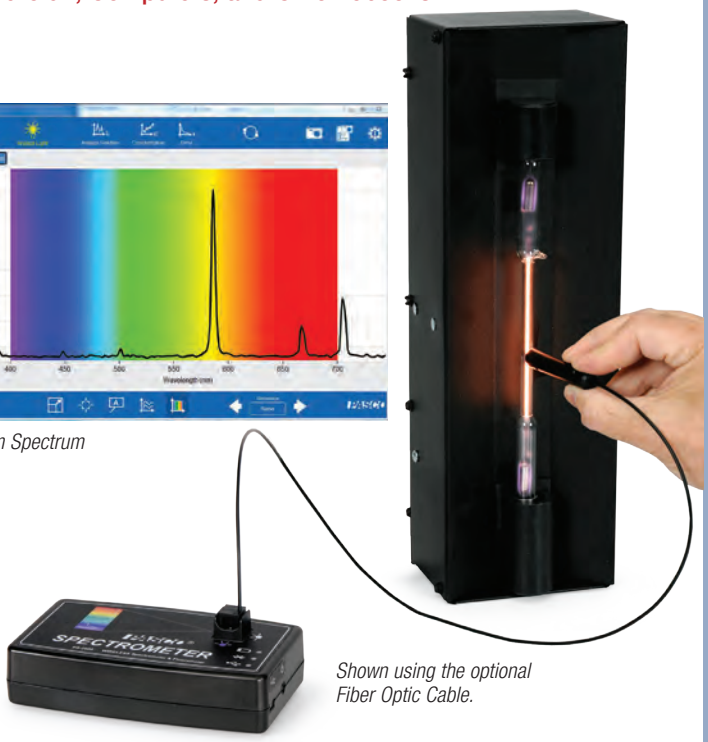
- Designed by teachers
- Specialized software specifically targets spectrometry activities
- Program guides students through the four common types of spectrometer uses
- Calibration routine is made obvious

The four specially targeted activities are:

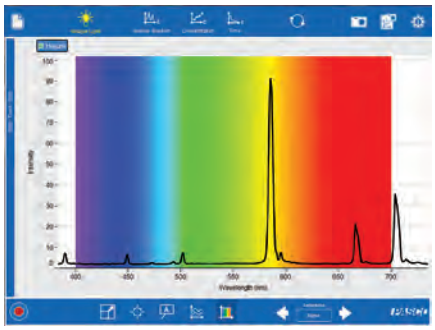
1. Analyze light sources with the optional Fiber Optic Cable.
2. Analyze the absorbance, transmittance, and fluorescence of colored solutions.
3. After the analysis wavelength is set, you can easily create calibration curves and determine the unknown concentration of a solution.
4. Observe the kinetics of a reaction involving a colored solution. Easily create the required graphs (ln(x), 1/x) to determine the order of the reactants.



Helium Spectrum



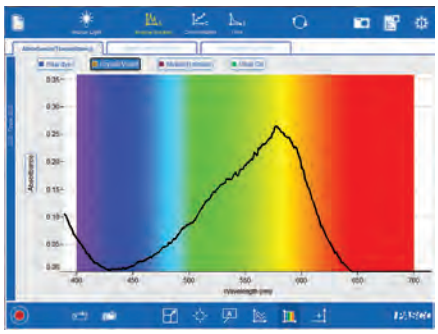
Shown using the optional Fiber Optic Cable.



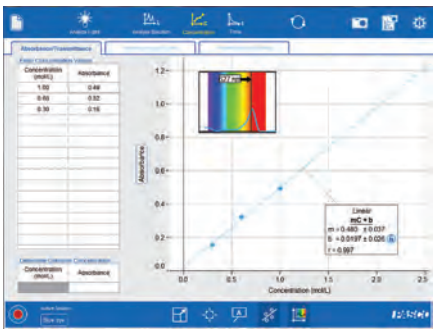
1. Analyze light sources with the optional Fiber Optic Cable.

The Wireless Spectrometer comes with **PASCO's award-winning Spectrometry software**.

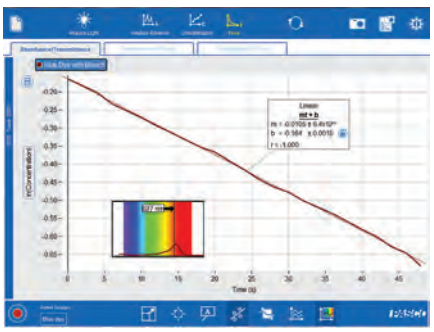
- Free software for iOS®, Android™, Windows®, and Mac®
- Available for Chromebooks™ with Google Play
- Designed specifically for introductory spectrometry experiments



2. Visualize absorbance across the full visible spectrum.



3. Create Beer's Law plots to relate absorbance and concentration.



4. Quickly plot calculations of concentration vs. time to determine the order of the reaction.

Works with PASCO's Wireless and UV-Vis Spectrometers.

PS-2600A Includes:

- PASCO Spectrometer
- Cuvettes (10)
- Spectrometry Software

SE-3607 Includes:

- Semi-Micro Volume Cuvettes (Qty. 10)
- Cuvette Rack
- USB-A to USB-B Cable
- External AC Adapter, 24 V Power Supply
- Foam Lined Carrying Case (ABS)

Order Information

Wireless Spectrometer (VIS)	PS-2600A
OR	
UV-Vis Spectrometer	SE-3607
Required for External Light Sources:	
Fiber Optics Cable	PS-2601 p. 302

Comprehensive 850 Physics System

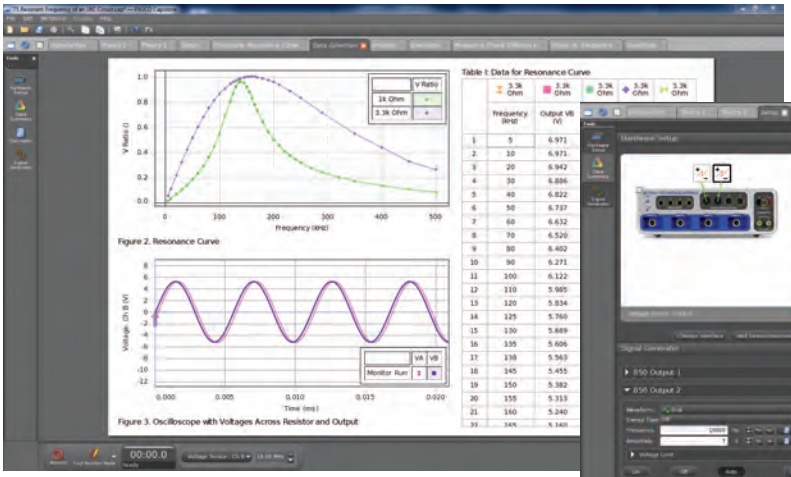
UI-5800D

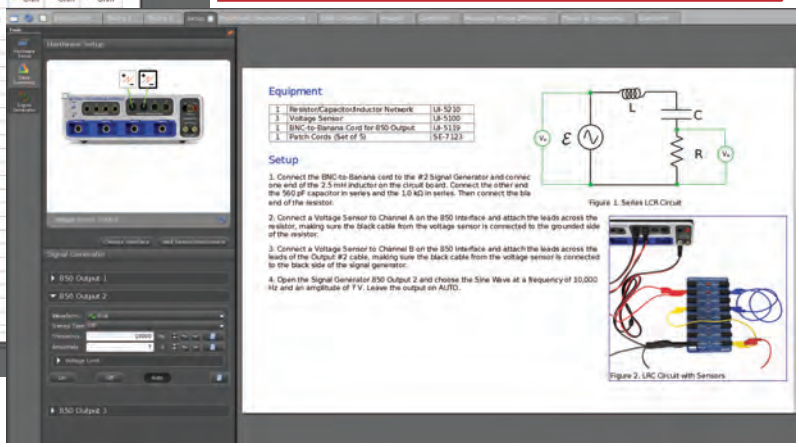
▶ Designed for the 850 Universal Interface and PASCO Capstone™ Software

NOTE: The 850 Universal Interface (UI-5000) is not included.

The 850 Comprehensive Physics System consists of 83 experiments and all the equipment and sensors needed to perform these experiments. The experiments cover topics, such as mechanics, waves, optics, thermodynamics, and electromagnetism. The included experiment manual contains instructions written in Word®, a PASCO Capstone electronic workbook, and sample data.

The key to a successful lab is a PASCO Capstone electronic workbook. These workbooks have step-by-step instructions with live, embedded displays, such as graphs, FFTs, oscilloscopes, and meters. They contain the theory, experiment set-up, procedure, data analysis, and questions designed to get students to think about their results. These electronic workbooks can be easily modified by teachers to fit their individual needs.





See page 94 for a list of experiments in the included manual. Download free experiments at **pasco.com/850experiments**

Comprehensive 850 Mechanics Bundle

UI-5801C

(Component of the 850 Comprehensive System UI-5800D)

Includes:

- Force Sensor Track Bracket ME-6622
- Cart Adapter Accessory ME-6743
- Compact Cart Mass (2) ME-6755
- Time-of-Flight Accessory ME-6810A
- Photogate Mounting Bracket ME-6821A
- Mini Launcher ME-6825B
- Dynamics Cart Magnetic Damping ME-6828
- Mini Ballistic Pendulum Accessory ME-6829
- Spring Cart Launcher ME-6843
- PAScar (Set of 2) ME-6950
- Super Fan Cart ME-6977
- Density Set ME-8569A
- Discover Friction Accessory ME-8574
- Large Rod Base ME-8735
- 45 cm Stainless Steel Rod ME-8736
- 90 cm Stainless Steel Rod ME-8738
- Picket Fences (Smart Timer) (2) ME-8933
- Dynamics Track End Stop (2) ME-8971
- Dynamics Track Feet (Pair) ME-8972
- Mass and Hanger Set ME-8979
- Elastic Bumper ME-8998
- IDS Spring Kit (12) ME-8999
- Picket Fence ME-9377A
- Large Table Clamp ME-9472
- 1.2 m Aluminum Dynamics Track ME-9493
- Photogate Head (2) ME-9498A

- Pendulum Clamp ME-9506
- Multi-Clamp (2) ME-9507
- Variable Speed Motorized Cart ME-9781
- Centripetal Force Pendulum ME-9821
- PASPORT Motion Sensor (2) PS-2103A
- PASPORT Rotary Motion Sensor PS-2120A
- PASPORT High Resolution Force Sensor (2) PS-2189
- Wireless Acceleration/Altimeter PS-3223
- Pulley Mounting Rod SA-9242
- No-Bounce Pad SE-7347
- Braided Physics String SE-8050
- Comprehensive 850 Physics System Experiment Manual UI-5813
- Rotational Inertia Accessory ME-3420

Order Information

Comprehensive 850 Physics System..... UI-5800D

Required:

850 Universal Interface ..... UI-5000 p. 26

PASCO Capstone™ Software..... pp. 84-87

Want Mechanics Only?

Comprehensive 850 Mechanics Bundle ... UI-5801C

Comprehensive 850 Waves, Optics and Thermodynamics Bundle

UI-5802A (Component of the 850 Comprehensive System UI-5800D)

Includes:

• Sound Sensor with Microphone	UI-5101
• Energy Transfer - Calorimeter	ET-8499
• Precision Diffraction Slits	OS-8453
• Green Diode Laser	OS-8458B
• Color Mixer Accessory Kit	OS-8495
• Color Mixer	OS-8496
• Basic Optics System	OS-8515C
• Red Diode Laser	OS-8525A
• Polarization Analyzer	OS-8533A
• Linear Translator	OS-8535A
• Adjustable Focal Length Lens	OS-8494
• PASPORT Absolute Pressure Sensor	PS-2107
• PASPORT Quad Temperature Sensor	PS-2143
• PASPORT High Sensitivity Light Sensor	PS-2176
• Sympathetic Resonance Box Set	SE-7345
• Banana Plug Cord - Red (5 Pack)	SE-9750
• Radiation Cans	TD-8570A
• Absolute Zero Sphere	TD-8595
• Ideal Gas Law Apparatus	TD-8596A
• Resonance Air Column	WA-9606
• String Vibrator	WA-9857A
• Mini Speaker	WA-9605

The experiments for this section require components of the 850 Comprehensive Mechanics UI-5801C.

See page 94 for manual. Download free experiments at **pasco.com/850experiments**

Comprehensive 850 Electromagnetism Bundle

UI-5803 (Component of the 850 Comprehensive System UI-5800D)

Includes:

• Alnico Bar Magnets (2)	EM-8620
• Zero Gauss Chamber	EM-8652
• AC/DC Electronics Laboratory	EM-8656
• Basic Electrostatics System	ES-9080B
• Field Mapper Kit	PK-9023
• PASPORT Current Probe (2)	PS-2184
• PASPORT 2-Axis Magnetic Field Sensor	PS-2162
• Banana Plug Cord Sets, 30 cm Length	SE-7123
• Plotting Compass Set (20)	SE-8680
• Dip Needle	SF-8619
• Voltage Sensor (unshrouded) (4)	UI-5100
• BNC Function Generator Output Cable (unshrouded)	UI-5119
• Resistor Capacitor Inductor Network	UI-5210

The experiments for this section require components of the 850 Comprehensive Mechanics UI-5801B.

See page 94 for a list of experiments in the included manual.

Comprehensive 850 Physics System (UI-5800D) Includes:

- Comprehensive Mechanics (UI-5801C)
- Comprehensive Waves, Optics, and Thermodynamics (UI-5802A)
- Comprehensive Electromagnetism (UI-5803)

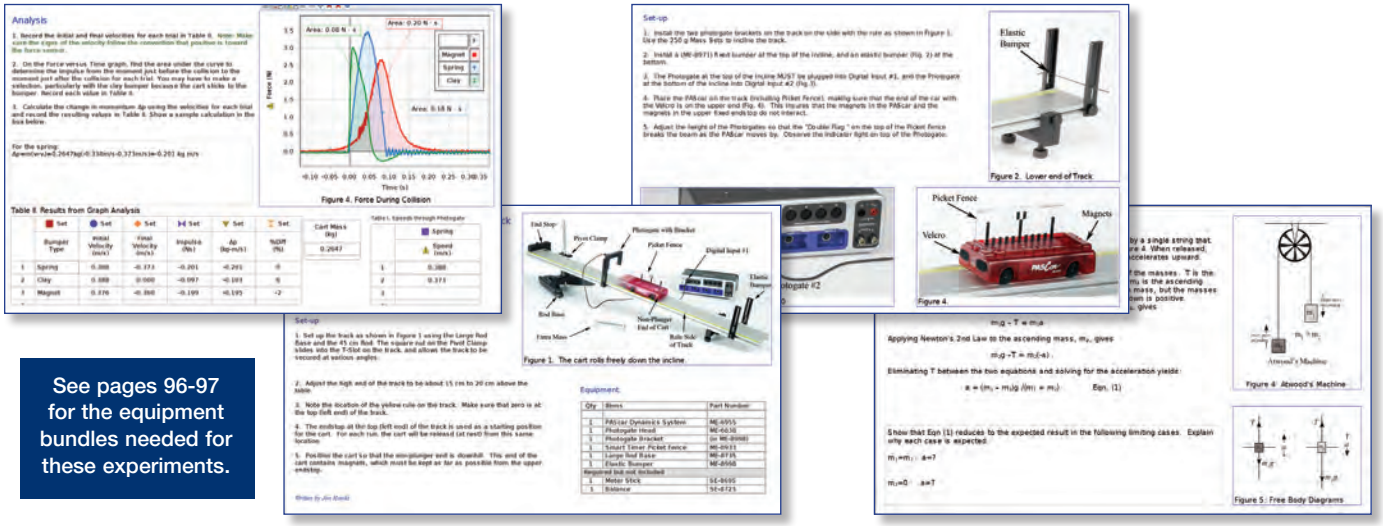
Order Information

Comprehensive 850 Physics System UI-5800D
Required:
850 Universal Interface ..... UI-5000 p. 26
PASCO Capstone Software ..... pp. 84-87
Also available separately:
Comprehensive 850 Mechanics Bundle UI-5801C
Comprehensive 850 Waves, Optics and Thermodynamics Bundle UI-5802A
Comprehensive 850 Electromagnetism Bundle UI-5803
Comprehensive 850 Physics System Experiment Manual UI-5813

Comprehensive 850 Physics System Experiment Manual

UI-5813

Designed for advanced high school and college-level physics, the Comprehensive 850 Physics System Experiment Manual includes dozens of digital experiments with preformatted Capstone workbook files. Each Capstone workbook file includes detailed step-by-step instructions, sample data, interactive displays, and intuitive analysis tools that help students conceptualize topics through data collection, visualization, and analysis.



See pages 96-97 for the equipment bundles needed for these experiments.

Comprehensive 850 Physics System Experiment List

Mechanics

(49 Experiments)

- Introduction to Measurement
- Uncertainty and Error Analysis
- Relative Motion in One Dimension
- Match Graph: Position and Velocity vs. Time
- Instantaneous and Average Speed
- Position and Velocity
- Velocity and Acceleration
- Equations of Motion
- Acceleration of a Freely Falling Ball
- Acceleration of a Freely Falling Picket Fence
- Acceleration on an Incline
- Projectile Motion
- Projectile Motion – Against a Wall
- Newton's First Law – No Net Force
- Newton's Second Law
- Force and Acceleration
- Inertia and Newton's Second Law
- Newton's Third Law
- External Forces and Newton's Third Law
- Atwood's Machine
- Acceleration Up an Inclined Plane
- Static Equilibrium
- Coefficients of Static and Sliding Friction
- Friction and Newton's Laws
- Magnetic Drag
- Terminal Velocity for Objects of Different Surface Areas and Masses
- Centripetal Force on a Pendulum
- Conservation of Energy on an Inclined Plane
- Gravitational Potential Energy
- Hooke's Law and Elastic Potential Energy
- Conservation of Energy for a Simple Pendulum
- Work-Energy Theorem
- Conservation of Momentum in Collisions
- Impulse and Change in Momentum
- Ballistic Pendulum
- Newton's Second Law for Rotation
- Rotational Inertia
- Rotational Kinetic Energy
- Conservation of Angular Momentum
- Simple Harmonic Motion – Mass on a Spring
- Oscillations of Cart and Springs
- Oscillation Equations of Motion
- Driven Harmonic Motion – Mass on a Spring
- Physical Pendulum
- Period of a Large Amplitude Pendulum
- Variable-g Pendulum
- Physical Pendulum Minimum Period
- Archimedes' Principle – Buoyant Force

Waves, Optics, and Thermodynamics

(22 Experiments)

- Heat and Temperature
- Transfer of Energy by Radiation
- Specific Heat
- Electrical Equivalent of Heat
- Boyle's Law: P and V of a Gas at Constant T
- Absolute Zero
- Behavior and Characteristics of Sound Waves
- Standing Waves on a String
- Resonant Modes of Sound in a Tube
- Speed of Sound in Air
- Superposition of Sound Waves
- Interference of Sound Waves
- Shadow and Color in Light
- Object and Image Distances for a Thin Lens
- Reflection and Refraction
- Focal Length of a Concave Mirror
- Optical Instruments: Telescope and Microscope
- Variation of Light Intensity
- Light Intensity vs. Distance
- Polarization: Verify Malus' Law
- Brewster's Angle
- Diffraction of Light

Electromagnetism

(16 Experiments)

- Electrostatic Charges
- Electric Field Mapping
- Ohm's Law
- Series/Parallel Circuits
- Kirchhoff's Laws: Resistors in Series and Parallel
- Capacitance
- RC Circuit
- Resonant Frequency of an LRC Circuit
- General Properties of Diodes
- Build a Rectifier
- Transistor 1 – The NPN Transistor as a Digital Switch
- Transistor 2 – Measure the Current Gain
- Earth's Magnetic Field
- Magnetic Field Mapping
- Induction – Magnet Through a Coil
- Magnetic Field in a Current-Carrying Coil

This manual is included in both the 850 Comprehensive Physics System UI-5800 and the 850 Comprehensive Mechanics System UI-5801.

Download free experiments at **pasco.com/850experiments**

Order Information

Comprehensive 850 Physics System Experiment Manual.....UI-5813
Word® files, PASCO Capstone files, and graphics are supplied on a flash drive.

Mechanics 850 System (Includes 850 Universal Interface)

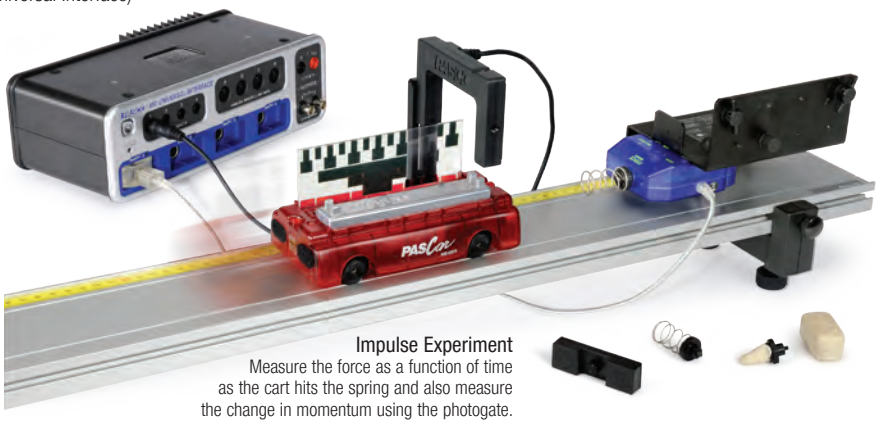
UI-5820

- Integrates probeware and physics equipment
- Includes 850 Universal Interface
- Perform a wide variety of mechanics experiments

When used together, PASCO's probeware and physics apparatus can help students learn the core concepts of mechanics more effectively. The Mechanics 850 System includes all the equipment students need to perform a wide variety of mechanics experiments.

The new manual features ten hands-on experiments that make full use of the system's components. This makes it an ideal solution for performing the key labs that are standard in all mechanics courses.

PASCO Capstone software (not included) enriches the labs with its interactive displays and analysis tools.



Impulse Experiment
Measure the force as a function of time as the cart hits the spring and also measure the change in momentum using the photogate.

Ten Experiments Included in Manual (UI-5821)

Title	Purpose	Sensors Used
Acceleration Down an Incline	Discover how the acceleration of an object down an incline depends on the angle of incline. Measure the acceleration due to gravity.	Photogate with picket fence
Newton's Second Law	Verify Newton's Second Law by varying the applied force and the mass.	Motion Sensor
Kinetic Friction I	Measure the kinetic coefficient of friction.	Motion Sensor
Kinetic Friction II	Study how the coefficient of kinetic friction depends on the velocity, acceleration, surface area, and weight of the object.	Photogate with pulley
Impulse and Momentum	Measure the impact force of a cart and compare the impulse to its change in momentum.	Force Sensor/ photogate
Conservation of Momentum in Explosions	Verify that momentum is conserved for two carts pushing off from each other.	Two photogates with picket fences
Conservation of Momentum in Inelastic Collisions	Verify that momentum is conserved in inelastic collisions and that kinetic energy is not conserved.	Two photogates with picket fences
Conservation of Momentum in Elastic Collisions	Verify that momentum is conserved in elastic collisions.	Two photogates with picket fences
Conservation of Energy	Show spring potential change into kinetic energy.	Motion Sensor/ photogate with picket fence
Simple Harmonic Motion	Measure the period of oscillation of a spring and mass system and compare it to the theoretical value. Evaluate the effect of changing the mass and spring constants.	Photogate and flag

Includes:

• 850 Universal Interface	UI-5000
• PASPORT High Resolution Force Sensor	PS-2189
• PASPORT Motion Sensor	PS-2103A
• Photogates and Fences Dynamics System	ME-9471A
• 1.2 m Aluminum Dynamics Track	ME-9493
• Discover Friction Accessory	ME-8574
• Force Sensor Track Bracket	ME-6622
• Mass and Hanger Set	ME-8979
• Super Pulley with Clamp	ME-9448B
• Plunger Cart	ME-9430
• Collision Cart	ME-9454
• Spring Cart Launcher	ME-6843
• Smart Fan Accessory	ME-1242
• Mechanics 850 System Lab Manual	UI-5821

Order Information

Mechanics 850 System.....UI-5820
Required:
PASCO Capstone Software.....pp. 84-87

Universal 550 Physics Experiment Bundle

UI-5830

The Universal 550 Physics System provides a complete set of labs for mechanics, heat, light, sound, and electromagnetism. Each lab consists of student instructions in a Word® document that the instructor can modify as they like, a PASCO Capstone setup file ready for data collection, a Capstone file with sample data, and all the lab equipment required for the experiment.

This system was designed to use both wireless and wired sensors, combined with the 550 Universal Interface that serves as a DC power supply and function generator.

Mechanics

Mechanics Includes:

- Rotational Inertia Accessory
- Red and Blue Smart Carts
- 1.2 m Aluminum Dynamics Track
- Friction Block
- Smart Fan Accessory
- Wireless Accelerometer/Altimeter
- Smart Cart Rod Stand Adapter
- Cart Mass (Set of 2)
- Pi Set
- Photogate Mounting Bracket
- Mini Launcher
- Mini Ballistic Pendulum Accessory
- Density Set
- Large Rod Base
- 45 and 90 cm Stainless Steel Rods
- Mass and Hanger Set
- Elastic Bumper
- Spring Kit
- Picket Fence
- Multi Clamps (2)
- Large Table Clamp
- Photogate Head (2)
- Pendulum Clamp
- PASPORT Rotary Motion Sensor
- No-Bounce Pad
- Braided Physics String
- Pulley Mounting Rod
- Bumper Accessory Set
- Super Pulley with Clamp
- Experiment Manual

Heat, Waves, Sound, and Light

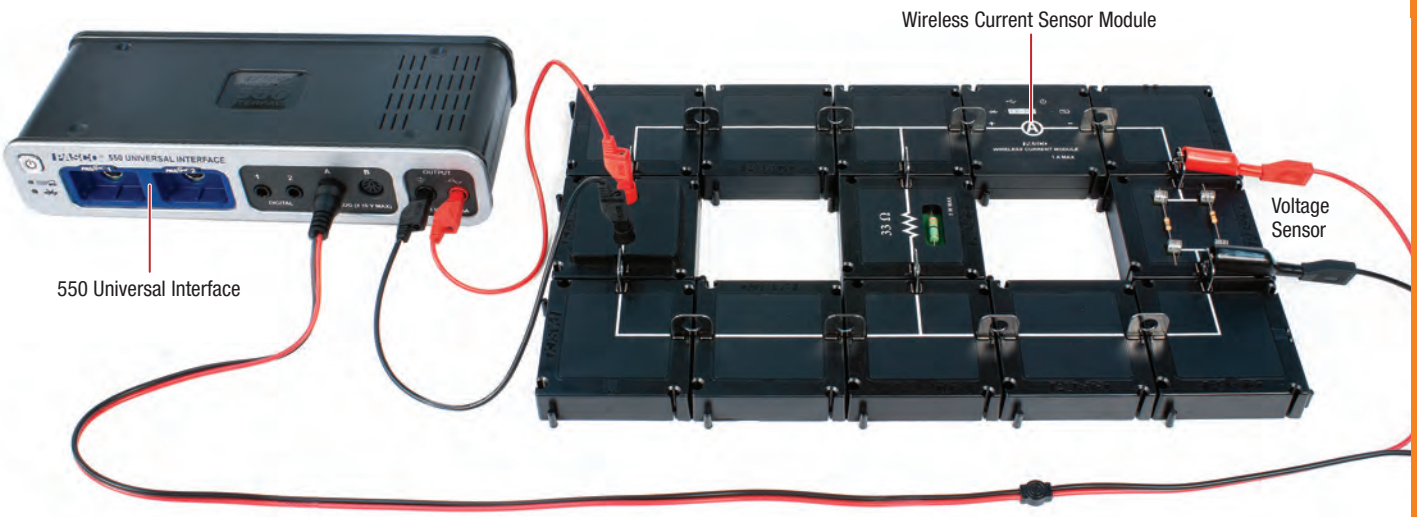
Electromagnetism

Heat, Waves, Sound, and Light Includes:

- Sound Sensor
- Calorimeter Cup with Lid (2)
- Tuning Fork Set
- Resonance Air Column
- Mini Speaker
- Basic Optics System
- Precision Diffraction Slits
- Adjustable Focal Length Lens
- Red Diode Laser
- Polarization Analyzer
- Linear Translator
- PASPORT Absolute Pressure Sensor
- PASPORT Quad Temperature Sensor
- PASPORT High Sensitivity Light Sensor
- Red Banana Plug Cord (5 Pack)
- Radiation Cans
- Ideal Gas Law Apparatus

Electromagnetism Includes:

- Modular Circuits Set
- Modular Circuits Expansion Pack
- Charge Sensor
- Wireless Current Sensor Module
- Charge Producers and Proof Plane
- Faraday Ice Pail
- Conductive Spheres
- Electrostatics Voltage Source
- Field Mapper Kit
- Voltage Sensor (2)



In this parallel resistor experiment, the 550 Universal Interface is used as a DC power supply to measure both the output voltage and the voltage across the resistors. The Wireless Current Sensor Module is used in-line in the circuit to measure the current in each loop.

550 Universal Physics System Experiment Manual

UI-5831

This complete manual is included with the 550 Universal Physics System (UI-5830). Each experiment consists of student instructions in a Word® document that the instructor can modify as they like, a PASCO Capstone setup file ready for data collection, a Capstone file with sample data, and all the lab equipment required for the experiment. All of this content is provided on a flash drive.

Experiments:

1. Introduction to Measurement
2. Uncertainty and Error Analysis
3. Graph Matching
4. Instantaneous and Average Velocity and Speed
5. Motion with Constant Acceleration
6. Equations of Motion for Constant Acceleration
7. Acceleration Due to Gravity
8. Freefall of a Picket Fence
9. Acceleration on an Inclined Track
10. Projectile Range vs. Launch Angle
11. Newton's First Law
12. Newton's Second Law
13. Force & Acceleration
14. Inertia and Newton's Second Law
15. Newton's Third Law
16. External Force and Newton's Laws
17. Atwood's Machine
18. Friction and Newton's Laws
19. Centripetal, Tangential, and Angular Acceleration
20. Conservation of Energy on an Inclined Track
21. Hooke's Law
22. Conservation of Energy for a Simple Pendulum
23. Work-Energy Theorem: Compare W to ΔE
24. Conservation of Momentum
25. Impulse and Change in Momentum
26. Ballistic Pendulum
27. Newton's Second Law for Rotation
28. Rotational Inertia
29. Rotational Kinetic Energy
30. Conservation of Angular Momentum
31. Oscillations of Cart and Springs
32. Physical Pendulum
33. Period of a Large Amplitude Pendulum
34. Archimedes' Principle - Buoyant Force
35. Transfer of Heat by Radiation
36. Specific Heat
37. Boyle's Law: P and V of a Gas at Constant T
38. Resonant Modes of Sound in a Tube
39. Speed of Sound in Air
40. Superposition of Sound Waves
41. Interference of Sound Waves
42. Object and Image Distances for a Thin Lens
43. Reflection
44 Refraction
45. Dispersion
46. Focal Length of a Concave Mirror
47. Optical Instruments: Telescope and Microscope
48. Variation of Light Intensity
49. Light Intensity versus Distance
50. Polarization: Verify Malus' Law
51. Brewster's Angle
52. Diffraction of Light
53. Electrostatic Charges
54. Electric Field Mapping
55. Ohm's Law
56. Series and Parallel Circuits
57. Kirchhoff's Laws
58. RC Circuit
59. General Properties of Diodes
60. Magnetic Field Mapping
61. Induction – Magnet Through a Coil

Order Information

Universal 550 Physics Experiment Bundle.....UI-5830
Universal 550 Physics Experiment Manual UI-5831
(included in UI-5830)

Physics Lab Station: Mechanics Starter

ME-5300

The Physics Lab Station: Mechanics Starter bundle is a lab-ready solution for performing several key experiments in mechanics. It includes a sensor-loaded Smart Cart, a durable PAStrack, and a variety of accessories that support student studies of core topics such as velocity, conservation of energy, and Newton's Second Law.

Real-Time Sensor Measurements

Students can use the Smart Cart's built-in sensors to make real-time measurements of position, velocity, acceleration, force, and rotation, displaying them as the lab unfolds for more meaningful learning. They can also collect and compare data from multiple trials, easily apply lines of fit, and perform statistical analysis using PASCO software.

Ready-Made Mechanics Labs

This kit is complemented by a collection of ready-made experiments that can be downloaded for free from the Experiment Library. Each lab comes ready-to-use with editable student handouts, teacher answer keys, and helpful teaching tips.

Perform These Experiments:

- Average Speed and Velocity
- Graphing Motion
- Speed and Velocity Graphs
- Conservation of Energy
- Work and Kinetic Energy
- Newton's Second Law
- Coefficients of Friction
- Momentum and Impulse
- Periodic Motion: Mass and Spring

Includes:

• Smart Cart (Red)	ME-1240	1
• Smart Cart Rod Stand Adapter	ME-1244	1
• Cart Mass (Set of 2)	ME-6757A	2
• PAStrack	ME-6960	1
• Aluminum Meter Stick		1
• Dynamics Track End Stop (Pair)	ME-8971	1
• Small "A" Base	ME-8976	1
• Stainless Steel Rod, 60 cm Threaded	ME-8977	1
• Mass and Hanger Set	ME-8979	1
• IDS Spring Kit	ME-8999	1
• Super Pulley Kit	ME-9433	1
• Angle Indicator	ME-9495A	1
• Multi-Clamp	ME-9507	1
• Friction Block	ME-9807	1
• Track Rod Clamp	ME-9836	1
• Bumper Accessory Set	ME-9884	1

Order Information

Physics Lab Station: Mechanics Starter..... ME-5300

Physics Lab Station: Mechanics Extension

ME-5301

NEW PRODUCT!

The Physics Lab Station: Mechanics Extension bundle expands your physics toolbox, allowing students to explore topics such as statics, rotation, projectile motion, and periodic motion. It includes an additional Smart Cart for studying collisions, a Mini Launcher for firing projectiles, and a Wireless Smart Gate for timing events accurately. A variety of accessories are also included.

Real-Time Sensor Measurements

Students can use the Wireless Smart Gate and patented Smart Cart to monitor key measurements in real time, displaying them as the lab unfolds for more meaningful learning. Use the Smart Cart's built-in sensors to measure motion on or off the track, or time events with precision using the dual-beam Wireless Smart Gate. Students can also collect and compare data from multiple trials, easily apply lines of fit, and perform statistical analysis using PASCO software.

Ready-Made Mechanics Labs

This kit is complemented by a collection of ready-made experiments that can be downloaded for free from the Experiment Library. Each lab comes ready-to-use with editable student handouts, teacher answer keys, and helpful teaching tips.

Perform These Experiments:

- Conservation of Momentum
- Momentum and Explosions
- Simple Pendulum
- Atwood's Machine
- Two Dimensional Motion: Projectiles
- Exploring Torque
- Exploring a Rotating System
- Momentum and Impulse
- Exploring Physical Pendulums

Includes:

• Smart Cart (Blue)	ME-1241	1
• Photogate Mounting Bracket	ME-6821A	1
• Mini Launcher	ME-6825B	1
• Pivot	ME-7034	1
• Meter Stick Torque Mass Hanger Set	ME-7035	1
• Photogate Pendulum Set	ME-8752	1
• Pendulum Clamp	ME-9506	1
• Photogate Wireless Smart Gate	PS-3225	1

Requires Physics Lab Station: Mechanics Starter (ME-5300) on page 98.

Order Information

Physics Lab Station: Mechanics Extension ME-5301
Required:
Physics Lab Station: Mechanics Starter ME-5300

Physics Lab Station: Fluids

ME-2040

The Physics Lab Station: Fluids bundle enables students to perform several essential experiments in fluids. It includes a Wireless Pressure Sensor for making measurements of pressure in liquids and gases. A Density Set and Overflow Can are also included for measuring buoyant forces in fluids.

Real-Time Sensor Measurements

Students can use the Wireless Pressure Sensor to make real-time measurements of pressure in liquids or gases, displaying them as the lab unfolds for more meaningful learning. They can also collect and compare data from multiple trials, easily apply statistics, and export their data using PASCO software.

Ready-Made Fluids Labs

This kit is complemented by a collection of ready-made experiments that can be downloaded for free from the Experiment Library. Each lab comes ready-to-use with editable student handouts, teacher answer keys, and helpful teaching tips.

Perform These Experiments:

- Boyle's Law
- Hydrostatic Pressure
- Buoyant Force

Includes:

• Wireless Pressure Sensor	PS-3203	1
• Density Set	ME-8569A	1
• Overflow Can	SE-8568A	1

Requires Physics Lab Station: Mechanics Starter (ME-5300) on page 98.

Order Information

Physics Lab Station: Fluids..... ME-2040
Required:
Physics Lab Station: Mechanics Starter..... ME-5300

Physics Lab Station: Electricity and Magnetism

EM-3557

NEW PRODUCT!

This lab-ready equipment set supports experiments in electricity and magnetism across all levels of physics. It includes Wireless Voltage, Current, and Magnetic Field Sensors, an Essential Physics Modular Circuits Kit, and an Electronic Components Kit.

Textbook Circuits for the Real World

The Essential Physics Modular Circuits Kit brings 2D circuitry to the real world, allowing students to study and measure circuits using components that look like textbook models. Each square piece displays both the physical component (resistor, capacitor, etc.) and the schematic to help bridge the gap between circuit diagrams and functioning circuits.

Real-Time Measurements

Students can use the Wireless Voltage and Current Sensors to make measurements anywhere in their circuit. Voltage and current readings are displayed in real time, allowing students to quickly compare and contrast different circuit configurations. They can also use PASCO software to collect and compare data, apply lines of fit, and perform statistical analysis.

Ready-Made Electricity & Magnetism Labs

This kit is complemented by a collection of ready-made experiments that can be downloaded for free from the Experiment Library. Each lab comes ready-to-use with editable student handouts, teacher answer keys, and helpful teaching tips.

Perform These Experiments:

- Ohm's Law
- DC Circuits
- Capacitors and RC Circuits
- Magnetic Field of a Permanent Magnet
- Electromagnetic Induction
- Magnetic Field in a Coil
- Planck's Constant

Includes:

• Essential Physics Modular Circuits Kit	EM-3536	1
• Wireless Current Sensor Module*	EM-3534	1
• Wireless Voltage Sensor*	PS-3211	1
• Wireless Magnetic Field Sensor	PS-3221	1
• Electronic Components Kit	EM-8818	1

* Included with EM-3536

Order Information

Physics Lab Station: Electricity and Magnetism..... EM-3557

Physics Lab Station: Optics

OS-8910

NEW PRODUCT!

The Physics Lab Station: Optics bundle is a lab-ready solution for performing a wide range of optics experiments – from introductory investigations of lenses to advanced experiments in Snell's Law. It includes a Basic Optics Ray Table, a Light Source, Concave and Convex Mirrors, and various lenses and accessories. The included equipment mounts easily to a PASCO Dynamics Track or a 1.2m Optics Track (sold separately) for hassle-free alignment.

Ready-Made Optics Labs

This kit is complemented by a collection of ready-made experiments that can be downloaded for free from the Experiment Library. Each lab comes ready-to-use with editable student handouts, teacher answer keys, and helpful teaching tips.

Includes:

• Concave/Convex Mirror	OS-8457	1
• Basic Optics Viewing Screen	OS-8460	1
• Basic Optics Ray Table	OS-8465	1
• Basic Optics Light Source	OS-8470	1
• Dynamics Track Optics Carriages (Set of 4)	OS-8472A	1
• Basic Optics Geometric Lens Set	OS-8456	1
• Accessory Lens Set	OS-8519	1

Requires either:
Physics Lab Station: Mechanics Starter (ME-5300) on page 98
or Optics Track (OS-8508) on page 286.

Perform These Experiments:

- Spherical Mirror Reflection
- Snell's Law
- Focal Length of a Converging Lens
- Virtual Images
- Telescope and Microscope
- Shadows

Order Information

Physics Lab Station: Optics	OS-8910
Required:	
Physics Lab Station: Mechanics Starter	ME-5300
OR	
1.2. m Optics Track	OS-8508

Physics Lab Station: Waves and Sound

WA-9515

NEW PRODUCT!

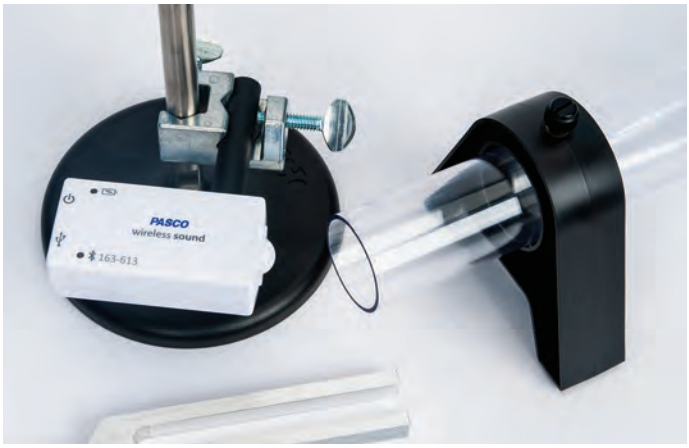
The Physics Lab Station: Waves & Sound bundle is a lab-ready solution for performing a variety of experiments in waves and sound. It includes a 2-in-1 Wireless Sound Sensor, a complete Tuning Fork Technical Set, a high-quality Resonance Air Column, and a Double-Length Slinky.

Real-Time Sensor Measurements

The Wireless Sound Sensor gives students unparalleled insight into the physics of sound and waves. Students can use the sensor to measure the frequency of a sound wave, and then visualize the waveform using PASCO software. Students can use the Double-Length Slinky to create a waveform with a partner, then use PASCO software to easily measure sound waves for further analysis.

Ready-Made Sound and Wave Labs

This kit is complemented by a collection of ready-made experiments that can be downloaded for free from the Experiment Library. Each lab comes ready-to-use with editable student handouts, teacher answer keys, and helpful teaching tips.



Perform These Experiments:

- Resonance and Standing Waves
- Properties of Sound Waves
- Measuring the Speed of Sound
- Decoding DTMF Tones

Includes:

• Wireless Sound Sensor	PS-3227	1
• Tuning Fork Technical Set	SE-7728	1
• Resonance Air Column	WA-9606	1
• Double-Length Slinky	SE-8760	1

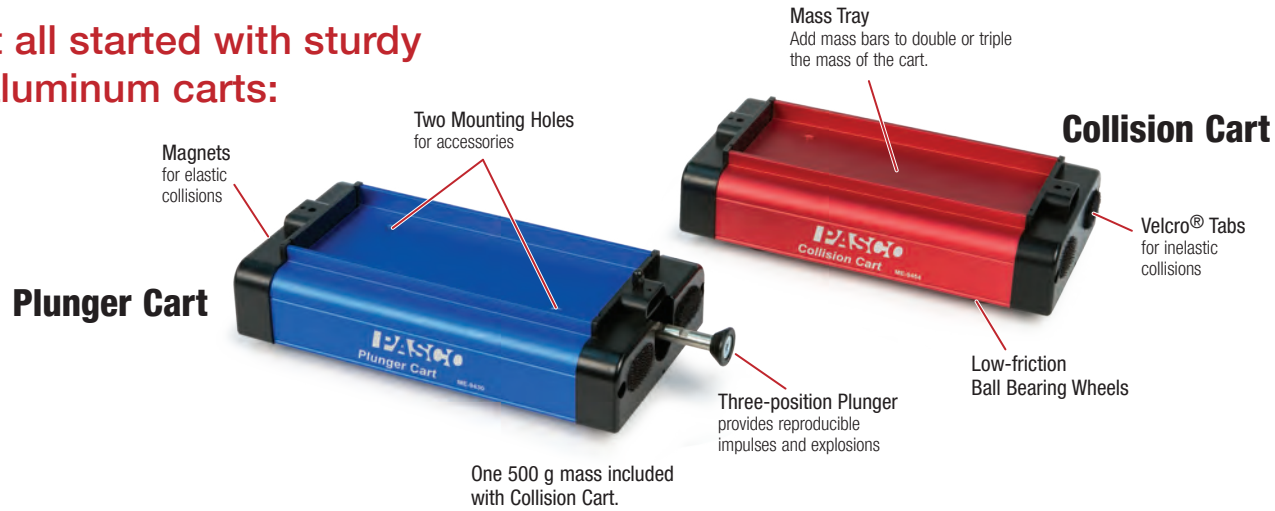
Order Information

Physics Lab Station: Waves and Sound WA-9515

The Best Dynamics Systems in the World

PASCO introduced the first dynamics system in 1992... and we have been refining it ever since.

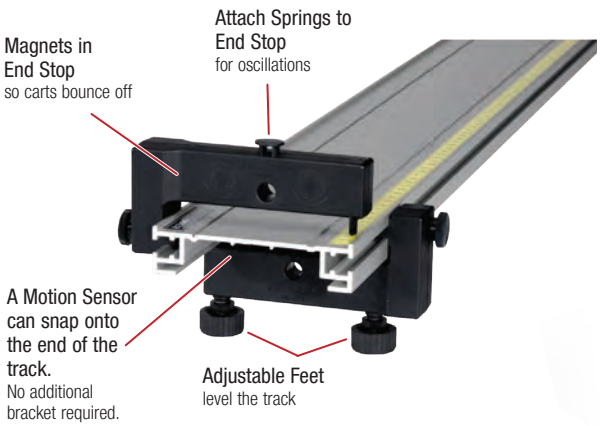
It all started with sturdy aluminum carts:



So little friction they will roll off the table if you set them down on their wheels, and so sturdy they will survive the fall!

Spring-loaded, retractable wheels prevent damage and keep your students from skating on them.

Soon, we added an aluminum dynamics track to align collisions:

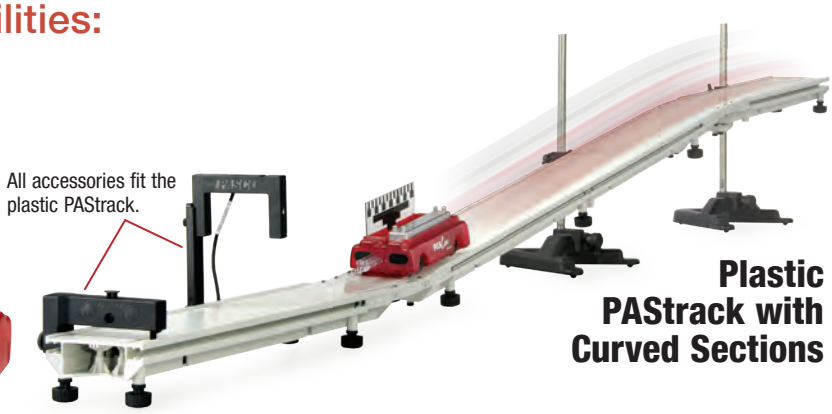


New technologies led to new innovations...

Plastic brought new possibilities:

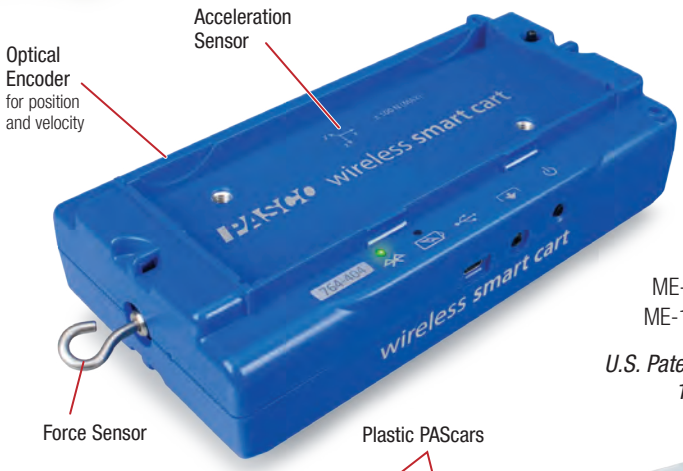
- Durable lightweight PAScars
- Curved track for Conservation of Energy

Plastic PAScars



Plastic PAStrack with Curved Sections

Then in 2016, PASCO introduced the Smart Cart, the first fully instrumented dynamics cart.



Smart Cart

ME-1240 (red)
ME-1241 (blue)

U.S. Patent Number 10,481,173

Snap together individual sections to make a track as long as you want with PAStrack.

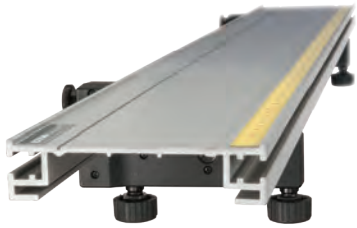
Now, these three types of carts are compatible with both types of tracks, and there are many accessories to complete your lab.

See the next two pages to configure your dynamics system.

How to choose the Dynamics System that's best for you:

1 Select the type of track you want.

Do you want metal or plastic tracks?



Metal Track Advantages

- Available in 1.2 m or 2.2 m lengths
- Straight and rigid
- Supports induced magnetic drag because it's conductive
- Feet can be placed at any position
- High-contrast scale

Plastic Track Advantages

- Add tracks to extend the length
- Lightweight
- Supports curved track for hills
- Built-in feet
- Storage: 1-meter track disassembles into two 50-cm parts
- Less expensive

2 Select the type of carts you want.

Do you want metal, plastic or Smart Carts?

Metal Cart Advantages

- Red and blue for distinguishing in collisions
- More inertia
- Sturdy body
- User-replaceable wheels

Plastic Cart Advantages

- Red and blue for distinguishing in collisions
- Least expensive
- Two string tie positions
- Plunger has a long throw

Smart Cart Advantages

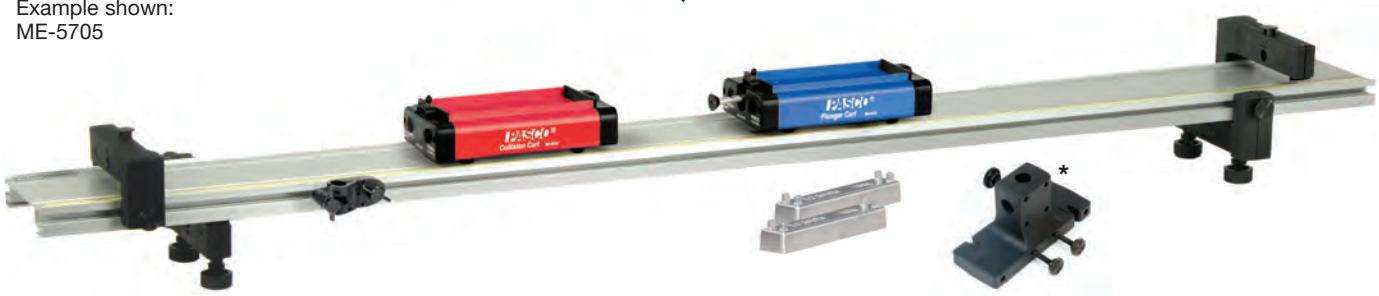
- Red and blue for distinguishing in collisions
- Completely instrumented with all the sensors you need for dynamics
- Two string tie positions
- Bluetooth 4.0 wireless: No interface required

For more info, see the Dynamics Cart & Track System Configuration page at pasco.com/dynamics

3 Which system is best for you?

Basic System – Just Carts and Track

Example shown:
ME-5705



OR

Standard System – Basic System and Accessory Pack

Example shown:
ME-5715

Basic System Includes

- Track
- 2 Carts
- 2 Feet
- 2 Endstops
- Rod Clamp
- 2 Mass Bars (4 with metal carts)
- Smart Cart Rod Stand Adapter*

Choose your Track and Carts	Plastic Track 1 m	Metal Track 1.2 m	Metal Track 2.2 m
Plastic Carts	ME-5701	ME-5702	ME-5703
Metal Carts		ME-5705	ME-5706
Smart Carts	ME-5707A	ME-5708A	ME-5709A

Standard System Includes

- Track
- 2 Carts
- 2 Feet
- 2 Endstops
- Rod Clamp
- 2 Mass Bars (4 with metal carts)
- Spring Set
- Clamp-on Super Pulley
- Friction Block
- Angle Indicator
- Smart Cart Rod Stand Adapter*

Choose your Track and Carts	Plastic Track 1 m	Metal Track 1.2 m	Metal Track 2.2 m
Plastic Carts	ME-5711	ME-5712	ME-5713
Metal Carts		ME-5715	ME-5716
Smart Carts	ME-5717A	ME-5718A	ME-5719A

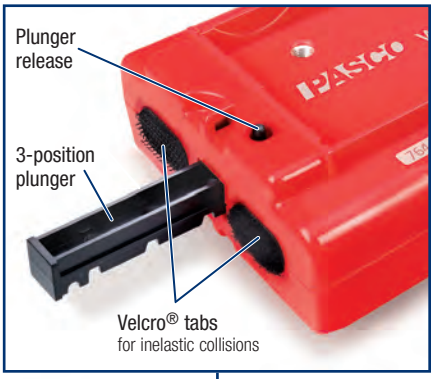
*Smart Cart Rod Stand Adapter is only included in Smart Cart Dynamics Systems (ME-5707A, ME-5708A, ME-5709A, ME-5717A, ME-5718A, and ME-5719A)

Wireless Smart Cart

ME-1240 (red) ME-1241 (blue)

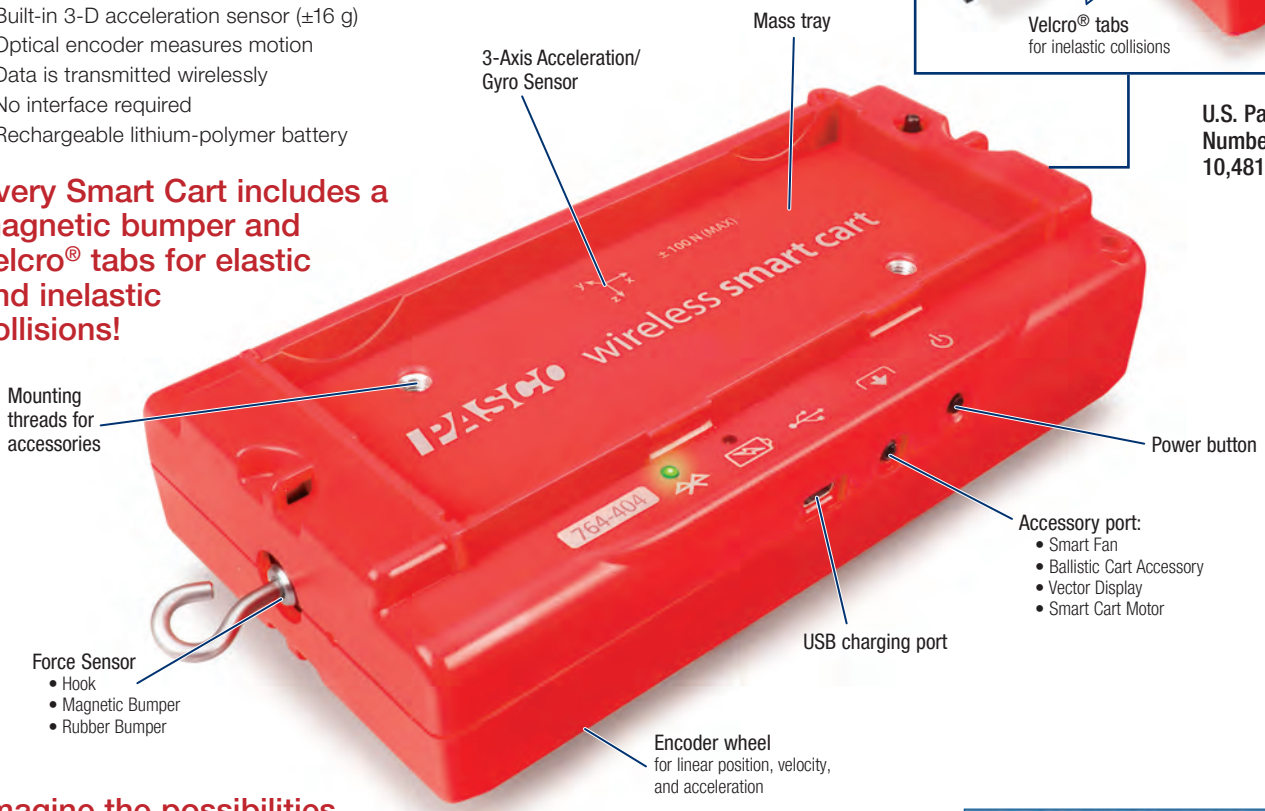
The patented Smart Cart is the ultimate tool for studying kinematics, dynamics, Newton's Laws, and more. It is based on a durable ABS body with nearly frictionless wheels, just like our high quality PAScars. Now, we've added built-in sensors that measure force, position, velocity, and acceleration. The versatile Smart Cart can collect measurements on or off a track and transmit the data wirelessly over Bluetooth. In essence, it is a wireless dynamics cart that combines all the necessary sensors, without requiring any additional hardware.

- Built-in force sensor (±100 N)
- Built-in 3-D acceleration sensor (±16 g)
- Optical encoder measures motion
- Data is transmitted wirelessly
- No interface required
- Rechargeable lithium-polymer battery



U.S. Patent Number 10,481,173

Every Smart Cart includes a magnetic bumper and Velcro® tabs for elastic and inelastic collisions!



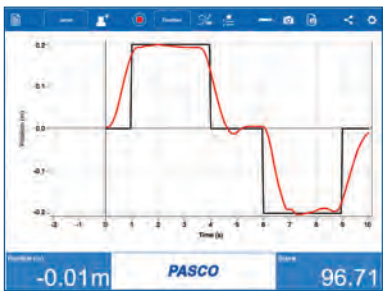
Imagine the possibilities…

1. Measure cart velocity on a curved track where Motion Sensors cannot work because there is no straight line of sight.

2. Directly measure the tension in the string connected to the Smart Cart.

Hang a mass over a pulley, hold the cart in place, and then let go. When the cart is stationary, the tension is equal to the hanging weight. When the cart accelerates, the tension is less than the hanging weight.

3. Match Position and Velocity vs. Time graphs with FREE MatchGraph! Software. Visit pasco.com/downloads



4. Measure oscillations of a cart and spring.

Measure the position, velocity, and acceleration of the cart, and the force of the spring.

5. Go trackless!

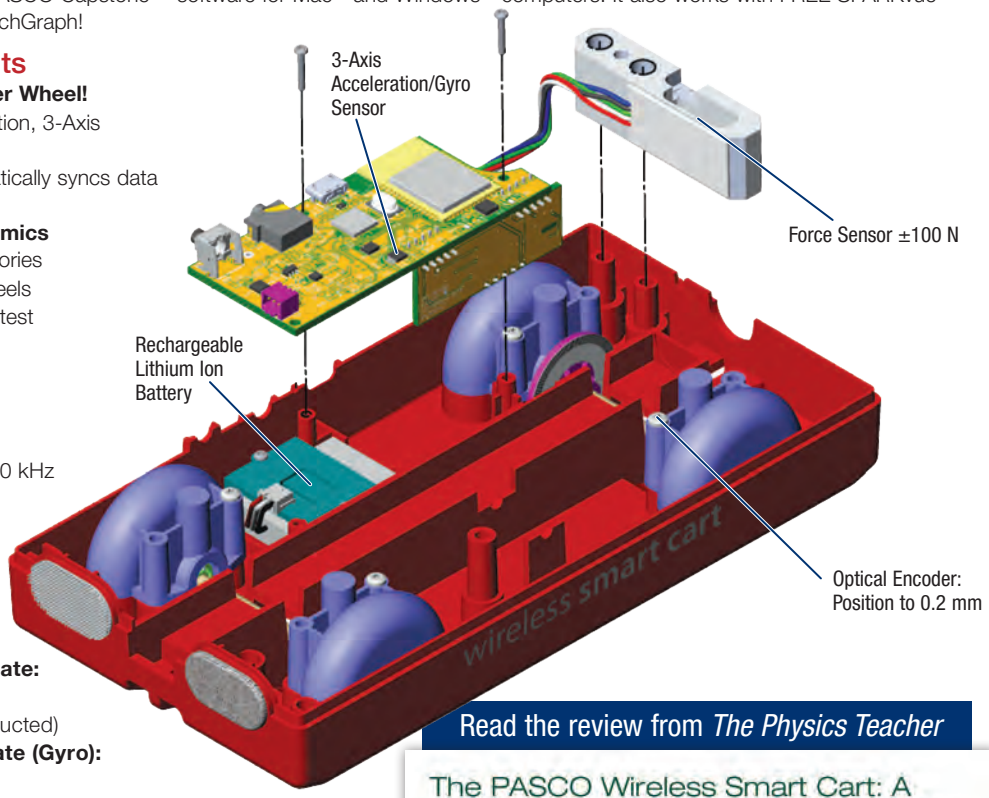
Measure velocity as the cart travels across the floor or table without a track.

Four built-in sensors, one low price, zero additional equipment

- Wirelessly measure position, velocity, acceleration (3-axis and resultant), rotation and force, either individually or simultaneously.
- Use on a tabletop or a standard physics dynamics track.
- Wirelessly connect the Smart Cart to your laptop or tablet, and the built-in sensors will measure and transmit data.
- The Smart Cart is compatible with PASCO Capstone™ software for Mac® and Windows® computers. It also works with FREE SPARKvue® software for mobile devices and MatchGraph!

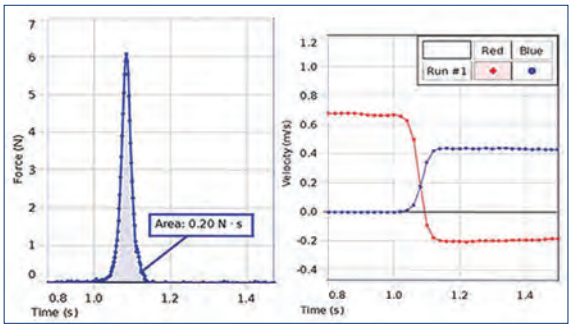
It's what's inside that counts

- **Enclosed High-resolution Encoder Wheel!**
- **4 Embedded Sensors:** Force, Position, 3-Axis Acceleration, 3-Axis Gyroscope
- **Special Sync Technology:** Automatically syncs data from two Smart Carts to within 2 ms
- **Compatible with All PASCO Dynamics Systems:** Tracks, carts, and accessories
- **Ultra-low Friction:** Ball bearing wheels
- **Rugged Design:** Survives the drop test



Specifications:

Force Range: ±100 N
Force Resolution: 0.1 N
Force Accuracy: ±1.0%
Force Maximum Sampling Rate: 2.0 kHz
Position Resolution: ±0.2 mm
Max Velocity: ±3.0 m/s
Velocity Max Sample Rate: 500 Hz
Acceleration Range: ±16 g
Acceleration Max Sample Rate: 500 samples/second
Max Rotational Speed Sampling Rate: 500 samples/second
Max Wireless Range: 30 m (unobstructed)
Maximum Measurable Rotation Rate (Gyro): ±245 deg/second
Mass Without Accessories: 245 g
Patent No.: 10,481,173
Magnetic Bumper Mass: 23.6 g



Smart Carts can be used to investigate impulse and collisions, as well as velocity and acceleration, motion graphs, Newton's Laws, conservation of momentum, conservation of energy, centripetal force, and much more!

Read the review from *The Physics Teacher*


The PASCO Wireless Smart Cart: A Game Changer in the Undergraduate Physics Laboratory

Asif Shakur and Rainor Connor, Salisbury University, Salisbury, MD

With the introduction of the Wireless Smart Cart by PASCO scientific in April 2016, we expect a paradigm shift in undergraduate physics laboratory instruction. We have evaluated the feasibility of using the smart cart by carrying out experiments that are usually performed using traditional PASCO equipment. The simplicity, convenience, and cost-saving achieved by replacing a plethora of traditional laboratory sensors, wires, and equipment clutter with the smart cart are reported here.

Inelastic collision

We performed a simple inelastic collision experiment to ascertain the feasibility of using the wireless smart cart in an undergraduate laboratory setting. Two similar smart carts (red and blue) were placed on a 1-m PASCO aluminum track. The free PASCO app SPARKvue was installed on an iPhone. The app paired up with the blue cart via Bluetooth and recognized the unique identification sticker on the cart. We gave the blue cart a gentle push in the direction of the stationary red cart. The two carts collided and stuck together on the Velcro pads. The two carts moved together with a slower speed. Note that we only needed one iPhone to pair up with only one cart (blue) in order to draw meaningful conclusions. The velocity and time data (in addition to position, acceleration, and a raft of other data) were wirelessly transmitted by the smart cart to the iPhone as a CSV file (comma separated values). The data were tabulated in an Excel file, and a graph of velocity vs. time is depicted in Fig. 2.

Fig. 1. The PASCO Wireless Smart Cart.

Go to **pasco.com/smartcart**

6. Use two Smart Carts for collisions.

Each cart measures its own velocity and force. Will students correctly predict the forces recorded by each cart for these parameters?

- Use equal masses and unequal masses.
- Use the same spring bumpers on the Smart Cart force sensors and then change the spring on one Smart Cart to a weaker spring.

The magnetic bumper for the force sensor is included with the Smart Cart.

Includes:

- Hook
- Rubber bumper
- Magnetic bumper
- USB cable for charging

Order Information

Smart Cart (Red)	ME-1240	
Smart Cart (Blue)	ME-1241	
Recommended:		
Smart Cart Charging Garage	ME-1243	p. 111
PAScar Cart Mass (set of 2)	ME-6757A	p. 121

Smart Fan Accessory

ME-1242

- Provides a constant force
- Hands-off operation
- Sense and control
- Manual mode for non-Smart Carts

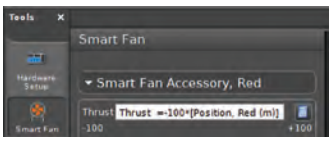
What makes this fan so smart?

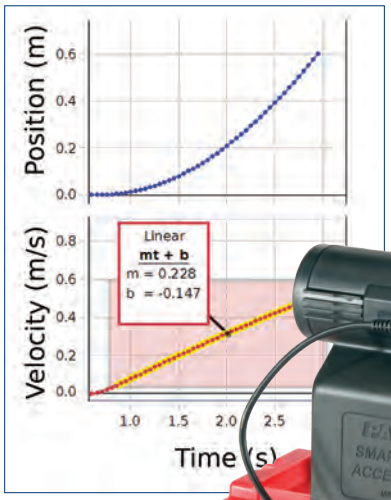
If you use this fan on a regular cart, you can turn it on and select one of three speeds by pushing the button on the side. But plugging it into a Smart Cart gives this Smart Fan Accessory added capabilities:

- **Hands-off Operation:** You can turn the Smart Fan on and off wirelessly from your computing device.
- **Adjust the Thrust:** Move the slider in the software and watch the fan respond.
- **Reverse the Spin of the Fan:** Input a negative thrust to make the fan blow in the opposite direction.
- **Set Start and Stop Conditions:** Choose to start the fan when a measurement (such as Position) reaches a certain value. Make the fan stop after a certain time so the cart coasts during part of the experiment.
- **Sense and Control:** Program the Smart Fan thrust to respond to a calculation based on sensor measurements, for example:

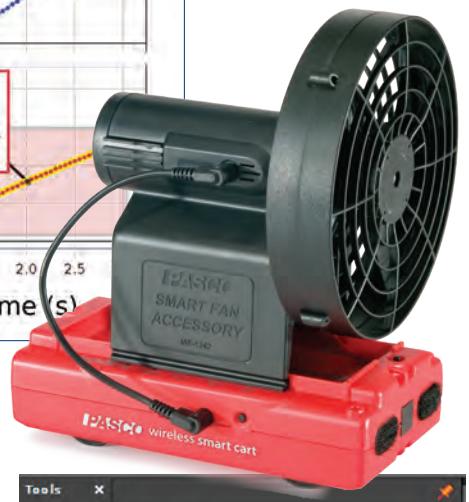
Thrust = -100*[Position]

- This will cause the fan to blow harder as the cart moves down the track, causing the cart to reverse. Eventually the fan will reverse when the Position becomes negative, accelerating the cart in the positive direction.

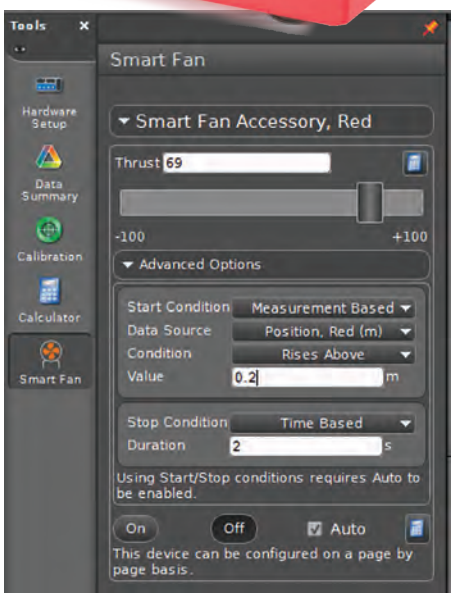




Sample data capture of position and velocity over time.



The Smart Fan Accessory becomes smart when plugged into a Smart Cart.



This is the control panel for the Smart Fan in PASCO Capstone software.

Specifications:

Push-button for on/off: 3 speed settings

Maximum thrust: 0.2 N

Uses 4 AA batteries (alkaline or rechargeable)

Lithium battery performance: On medium speed, fan slows after 5.2 hrs and stops after 5.6 hrs.

Alkaline battery performance: On medium speed, fan slows after 1 hr and stops after 8.9 hrs.

Patent No.: 10,482,789

Fits all PASCO dynamics carts

Smart Cart required for extended Smart features

Make your fan rotatable:

3D print your own rotating base for the Smart Fan Accessory at pasco.com/diy

Includes:

- Smart Fan Accessory
- Smart Cart Cable (19 cm)
- AA Alkaline Batteries (4)

Order Information

Smart Fan Accessory	ME-1242
Requires:	
Smart Cart or Dynamics Cart	pp. 108, 115
PASCO Capstone Software	pp. 84-87
Suggested:	
Battery Charger and 8 AA Batteries	SE-3570

Smart Cart Vector Display

ME-1246

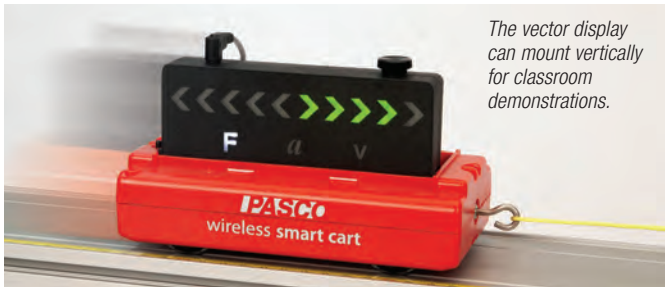
Help your students visualize acceleration, force, and velocity in real time!

The Smart Cart Vector Display adds visual vectors to your Smart Cart for Force, Acceleration, or Velocity. Connect it to the Smart Cart's accessory port to visualize vectors in real time! Arrows light up proportional to the sensor reading showing either positive or negative direction and magnitude.

The vector display can sit flat in a Smart Cart.

Features

- Select between force, acceleration, or velocity vectors and watch them in real time.
- Students can visualize constant acceleration as a cart rolls up and then down an incline.
- Great for the student lab station or for a physics lecture demonstration!
- Selectable ranges



The vector display can mount vertically for classroom demonstrations.

Order Information

Smart Cart Vector Display ME-1246

Smart Cart Charging Garage

ME-1243

Charge up to five Smart Carts at once. Provides storage for the carts and accessory bumpers. Includes power adapter.

Order Information

Smart Cart Charging Garage ME-1243

Fan Sail

ME-1248

This sail fits into a Smart Cart or Super Fan Cart (ME-6977). When the fan blows into the sail, the cart remains stationary, demonstrating Newton's third law. When the concave side of the sail faces the fan, the air rebounds off the sail and moves the cart.

Order Information

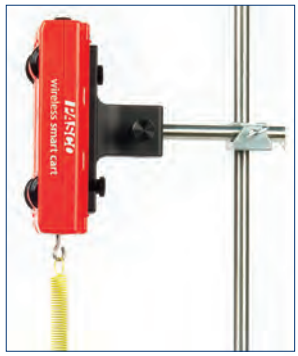
Fan Sail ME-1248

Smart Cart Rod Stand Adapter

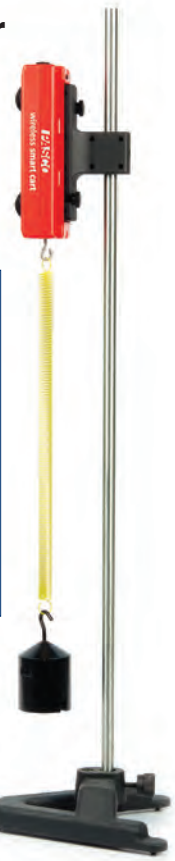
ME-1244

This accessory allows the Smart Cart to be suspended from a rod stand. Use the Smart Cart's force sensor to measure the force of an oscillating spring and mass.

The Smart Cart can be mounted directly to a vertical rod or to a horizontal cross-rod.



Screw storage



Order Information

Smart Cart Rod Stand Adapter ME-1244

Smart Ballistic Cart Accessory

ME-1245

- Updated to take advantage of Smart Cart capabilities
- Demonstrates the independence of vertical and horizontal motion
- Works with all PASCO carts
- Shoots over 50 cm high

The Smart Ballistic Cart Accessory mounts to any PASCO dynamics cart for a classic demonstration on the independence of X and Y motion. A projectile fired from the accessory while a cart is in motion will be caught farther down the track. When mounted to a PASCO aluminum cart, or PAScar, the projectile is launched using a push button timer delay. When connected to a PASCO Smart Cart, the accessory takes on new features, allowing it to launch the projectile based on measurements made by the Smart Cart in either SPARKvue or PASCO Capstone software.

How It Works:

The Smart Ballistic Cart Accessory can be mounted to any PASCO dynamics cart using the captured mounting screws. Use the X-Y adjustments on the top deck of the accessory (red thumb screws) to adjust the aim of the launcher. Next, insert one of the yellow projectiles into the launcher and press down. The launcher is now set to fire!

With the accessory attached to any PASCO dynamics cart, press the timer button to initiate a one-second delay prior to the projectile being launched. After the button is pressed, give your dynamics cart a push. The projectile will fire upwards and be caught farther down the track.

When used with a PASCO Smart Cart, the accessory cable connects to the accessory port on the Smart Cart. You can use either PASCO Capstone or SPARKvue to launch the ball by pressing a button in the software. You can also set a particular distance or time at which the ball will launch using PASCO Capstone. Additional applications can be explored through Blockly coding, available in both PASCO Capstone and SPARKvue software. With Blockly, you can set the launch condition to be based on a Smart Cart measurement of position, velocity, or acceleration. Simply start recording data, give the Smart Cart a push, and the projectile will fire when the measurement condition is met. If the cart is moving at a constant velocity, the ball will fall back into the catcher on the cart!

Includes:

- Smart Ballistic Cart Accessory
- Plastic Balls (2)
- USB Charging Cable
- Smart Cart Accessory Cable

Features

- Compatible with all PASCO dynamics carts.
- Push button timer delay launches the projectile after the cart is pushed.
- Release mechanism does not affect cart motion or ball flight path.
- The barrel has X and Y adjustments, so perfect vertical projections can be produced every time.
- Fires a colored nylon ball 0.5 meters or higher for impressive demonstrations.
- Connects to the Smart Cart for measurement-based launching conditions.
- USB rechargeable Li-Ion battery.

Order Information

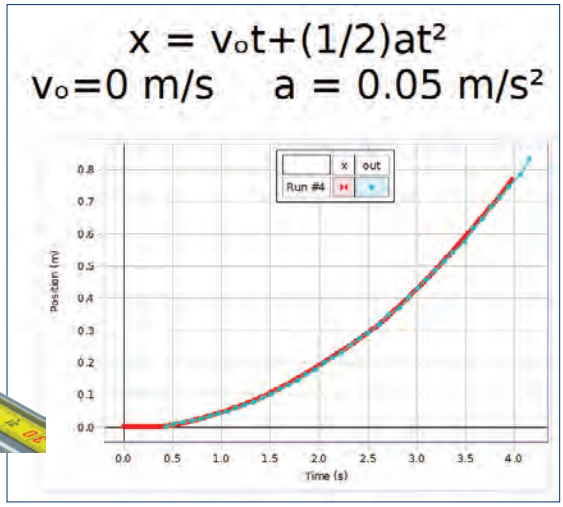
Smart Ballistic Cart Accessory ME-1245
Requires:
Smart Cart or any other PASCO Cart
Recommended:
Aluminum Dynamics Track with Leveling Feet

Smart Cart Motor

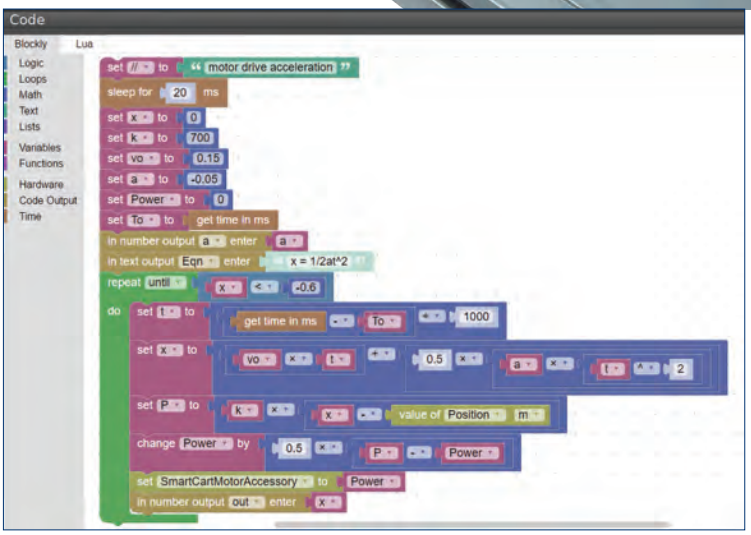
ME-1247

The Smart Cart Motor is a motor-driven wheel that attaches to the Smart Cart to make it go at a constant velocity, forwards or backwards. In PASCO Capstone or SPARKvue, you can control the motor remotely through its wired connection to the Smart Cart by setting the power on a scale of -100 to +100%.

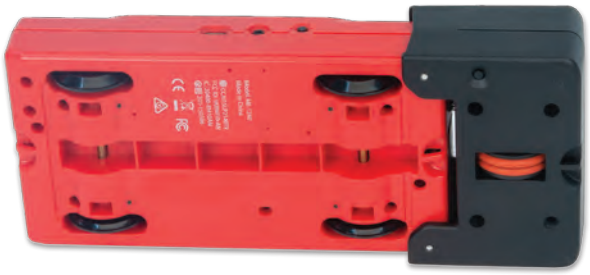
A brass mass is added to the slot on top of the Motor to increase the traction.



Program the Smart Cart to follow an equation of motion and graph its real-time motion alongside the theoretical equation of motion.



Program with Blockly in Capstone or SPARKvue to make the Smart Cart with Motor follow an equation of motion.



This view of the underside of a Smart Cart with Motor shows the red motor-driven wheel, which can be used on or off a track.

Includes:

- Smart Cart Motor
- Smart Cart Connector Cable
- USB Charging Cable

Order Information

Smart Cart Motor	ME-1247	
Required:		
Smart Cart (Red)	ME-1240	pp. 108-109
OR		
Smart Cart (Blue)	ME-1241	pp. 108-109
Recommended:		
1.2 m Aluminum Dynamics Track	ME-9493	p. 115

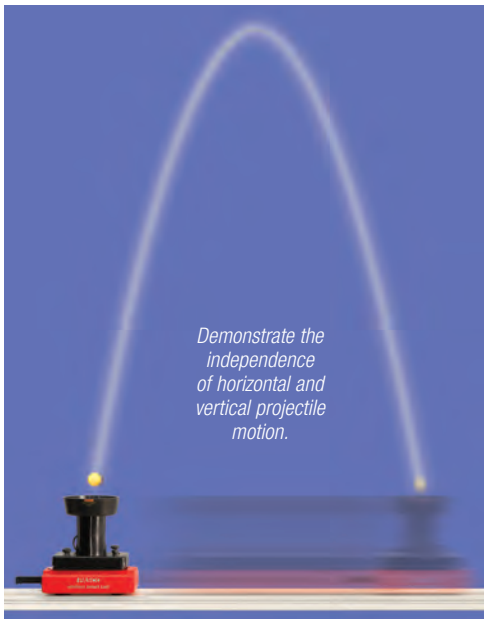
Smart Cart Demonstration Kit

ME-1272 (with red cart) ME-1273 (with blue cart)

The Smart Cart Demonstration Kit comes with either a red or blue Smart Cart and all the accessories you need to perform amazing physics demonstrations in kinematics and dynamics.

Demonstrate:

- Differences between Velocity and Acceleration
- Independence of Horizontal and Vertical Projectile Motion
- Newton's First Law
- Newton's Second Law
- Newton's Third Law
- Impulse and Force
- Force and Acceleration in Collisions
- Centripetal Acceleration
- Compare Velocity, Acceleration, and Force in Simple Harmonic Motion
- Buoyant Force and Archimedes' Principle



Demonstrate the independence of horizontal and vertical projectile motion.

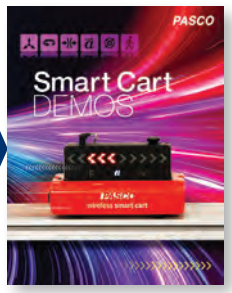
Blowing a fan into the sail to demonstrate Newton's Third Law.

Smart Cart Vector Display shows the force applied to the cart by the string.

Includes:

- Red Smart Cart (included in ME-1272) OR — ME-1240
- Blue Smart Cart (included in ME-1273) — ME-1241
- Smart Fan Accessory — ME-1242
- Smart Cart Rod Stand Adapter — ME-1244
- Smart Ballistic Cart Accessory — ME-1245
- Smart Cart Vector Display — ME-1246
- PAScar Cart Mass (set of 2) — ME-6757A
- Fan Cart Sail
- Storage Tray
- Smart Cart Demonstration Manual

Demo Manual Included!



Order Information

Red Smart Cart Demonstration Kit ME-1272
Blue Smart Cart Demonstration Kit..... ME-1273

PASCO Dynamics Carts

PAScar

ME-6933 (red) ME-6934 (blue)

Each 250 gram polycarbonate plastic cart includes a spring plunger, magnets and Velcro tabs for collision studies. The PAScars come in red and blue and are compatible with all PASCO Dynamics Tracks and accessories.

Polycarbonate Body
Total mass: 250 g

Order Information

PAScar Red	ME-6933	
PAScar Blue	ME-6934	
PAScar (Set of 2)	ME-6950	
Replacement Supplies:		
Cart Replacement Axles (4 pack)	ME-6957	p. 122
PAScar Cart Mass (set of 2)	ME-6757A	p. 121

PAStrack

ME-6960

Includes:

- Two piece track
- Connector clips (2)
- Leveling feet (6)

Order Information

PAStrack	ME-6960

Curved PAStrack

ME-6841

Create hills, valleys and inclines. Molded PAStrack system has straight and curved sections that just snap together. Connect multiple sets to make a track as long as you want.

Includes:

- Concave-up Curved Piece
- Concave-down Curved Piece
- PAStrack Connector Clips (2)

Order Information

Curved PAStrack	ME-6841

Classic Aluminum Carts

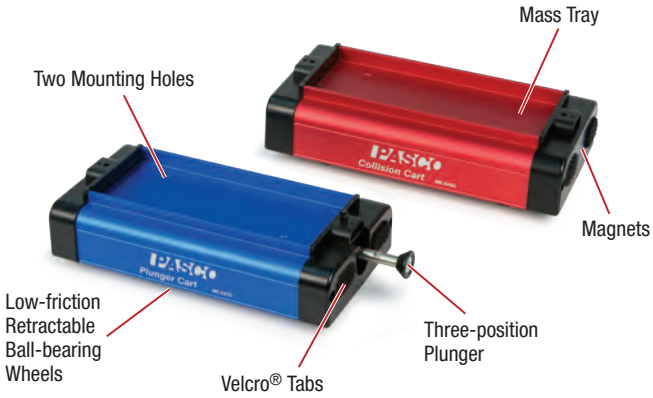
Plunger Cart

ME-9430 (blue)

Collision Cart

ME-9454 (red)

These are the standard carts in thousands of physics labs around the world. With an aluminum body and high-impact ABS plastic end caps, they make dynamics experiments quick to set up and very quantitative. The Classic Carts are compatible with all PASCO Dynamics Tracks and accessories. The plunger cart has a spring loaded plunger for launching.



Order Information

Plunger Cart	ME-9430	
Collision Cart	ME-9454	
Replacement Supplies:		
Cart Replacement Axles (4 pack)	ME-6957	p. 122
PAScar Cart Mass (set of 2)	ME-6757A	p. 121

Aluminum Starter Tracks

Have 1.2 m length tracks and want to change to 2.2 m?

These aluminum tracks are available in 1.2 m and 2.2 m lengths.

Order Information

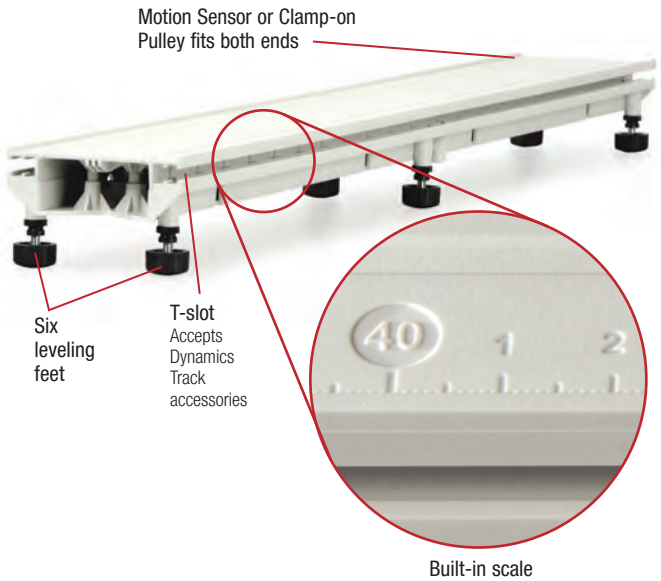
1.2 m Aluminum Dynamics Track	ME-9493
2.2 m Aluminum Dynamics Track	ME-9779

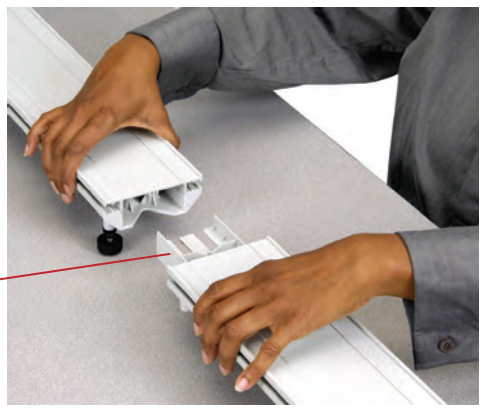
PAStrack

ME-6960

- 1 m length dynamics track
- Two-piece molded construction
- Accepts dynamics track accessories

This track's two-piece construction makes storage easy! Use the snap-on connector clip to hold sections straight and rigid. Use the second clip (included) to connect multiple tracks! The track ends are designed to accept the Motion Sensor and Clamp-on Pulley, and the side T-slots accept Dynamic Track accessories, such as photogate brackets and end stops. The track includes six built-in leveling feet.





Includes:

- Two piece track
- Connector clips (2)
- Leveling feet (6)

Order Information

PAStrack	ME-6960

PAStrack Inclined Plane Accessory

ME-6965

The Inclined Plane Accessory includes the hinge with angle scale and the rubber cord for the rubber bumper. A PAStrack is required to make a complete inclined plane.

Includes:

- Inclined Plane Accessory
- Rubber Cord, 1.5 mm square, 30 m

Order Information

PAStrack Inclined Plane Accessory	ME-6965
Required:	
PAStrack	ME-6960

PAStrack Inclined Plane

ME-6967

The PAStrack Inclined Plane includes the Inclined Plane Accessory (ME-6965) and the PAStrack (ME-6960).

Includes:

- PAStrack Inclined Plane Accessory ME-6965
- PAStrack ME-6960

Order Information

PAStrack Inclined Plane	ME-6967

Curved PAStrack

ME-6841

- Attaches to Straight PAStrack
- Put two curved pieces together
- One concave up and one concave down

Create hills, valleys and inclines. The molded PAStrack system has straight and curved sections that just snap together. Connect multiple sets to make a track as long as you want.

Includes:

- Concave-up Curved Piece
- Concave-down Curved Piece
- PAStrack Connector Clips (2)

Order Information

Curved PAStrack.....ME-6841

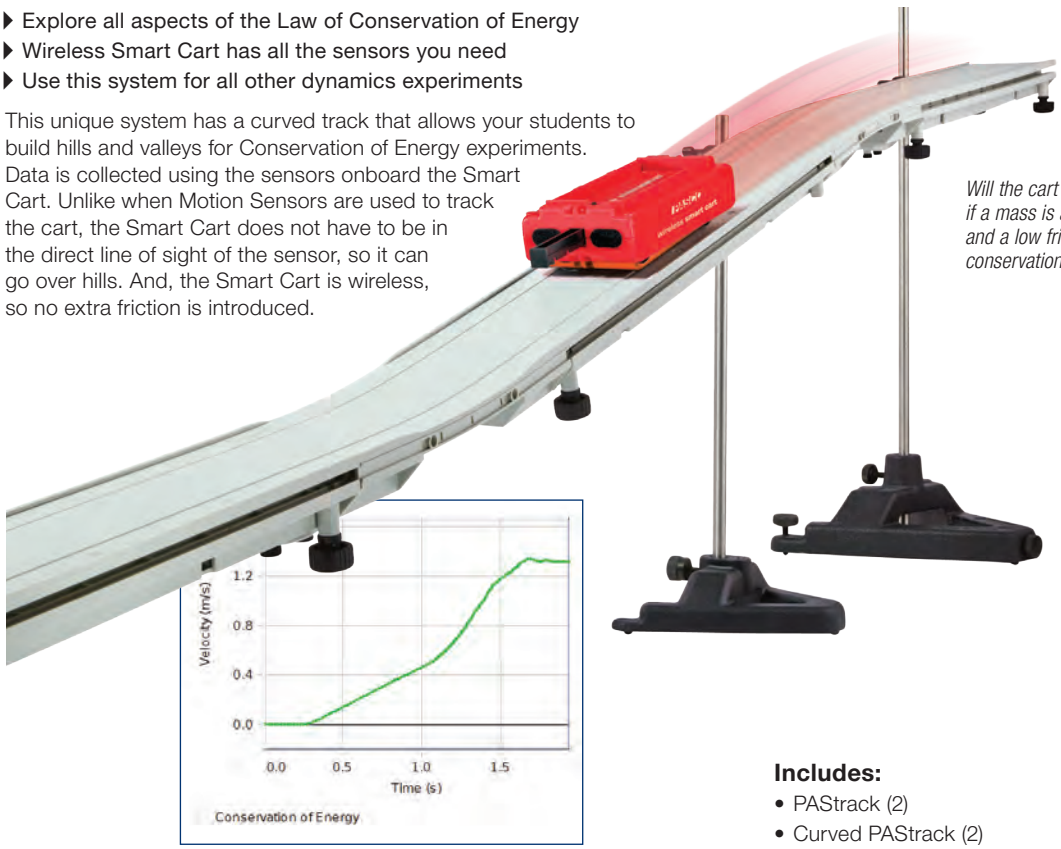
Conservation of Energy Experiments

Smart Cart Curved Track System

ME-5700B

- Explore all aspects of the Law of Conservation of Energy
- Wireless Smart Cart has all the sensors you need
- Use this system for all other dynamics experiments

This unique system has a curved track that allows your students to build hills and valleys for Conservation of Energy experiments. Data is collected using the sensors onboard the Smart Cart. Unlike when Motion Sensors are used to track the cart, the Smart Cart does not have to be in the direct line of sight of the sensor, so it can go over hills. And, the Smart Cart is wireless, so no extra friction is introduced.



Will the cart be going any faster at the bottom if a mass is added? With the Curved PAStrack and a low friction cart, students can investigate conservation of energy to find out for themselves!

Smart Cart Rod Stand Adapter

The curved and straight track pieces can be combined to form a step, so the cart starts out on a nearly level upper step, travels down the step, and ends on a level straight section. This makes measuring the change in height very easy.

During the experiments, the mass of the cart is varied to see what effect, if any, it has on the results.

Another configuration forms a potential well so the cart oscillates back and forth.

This versatile system can also be used for regular dynamics experiments such as impulse and Newton's Second Law.

Experiments can be downloaded at pasco.com

Includes:

• PAStrack (2)	ME-6960
• Curved PAStrack (2)	ME-6841
• Track Rod Clamps (4)	ME-9836
• Dynamics Track End Stop (Two 2 Packs)	ME-8971
• Stainless Steel Rod, 60 cm (threaded) (2)	ME-8977
• Round Base with Rod (2)	ME-8270
• Small "A" Base (2)	ME-8976
• PAScar Cart Mass (set of 2)	ME-6757A
• Smart Cart (Red)	ME-1240

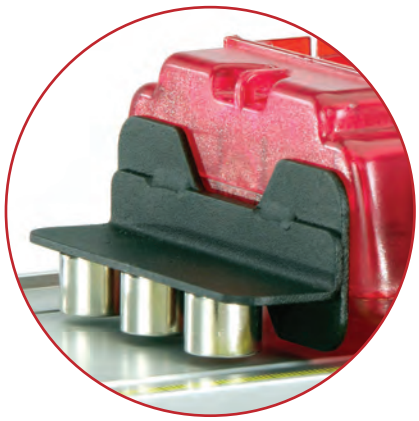
Order Information

Smart Cart Curved Track System.....ME-5700B
Required:
PASCO Capstone Software.....pp. 84-87
Bluetooth 4.0 compatible computer

Dynamics Cart Magnetic Damping

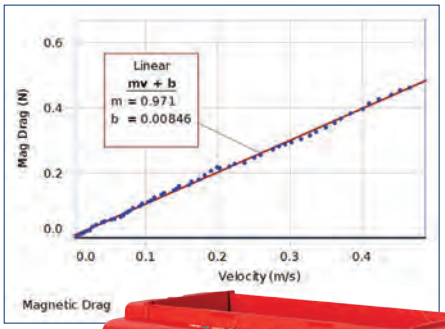
ME-6828

- Damping Accessory connects to cart magnets
- Magnets cause eddy currents in aluminum tracks
- Magnetic drag is proportional to cart speed
- Slide magnets up/down to adjust amount of drag



Magnetic Damping using the Wireless Smart Cart

Measure the magnetic drag force directly with the Smart Cart's on-board force sensor. The Smart Cart also has an encoder that keeps track of its velocity. This plot of Force vs. Velocity shows the induced magnetic drag is proportional to the velocity.



Includes:

- Bracket
- Magnets
- Keeper

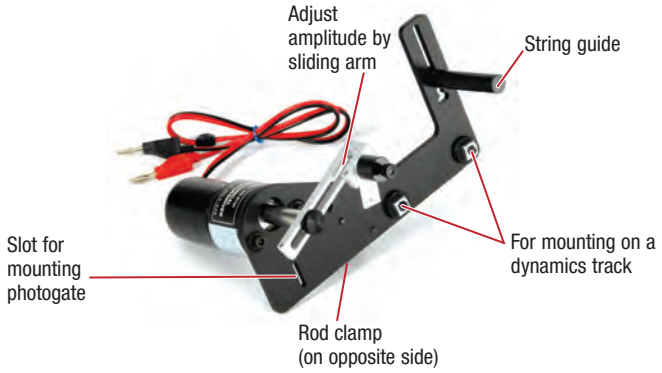
Order Information

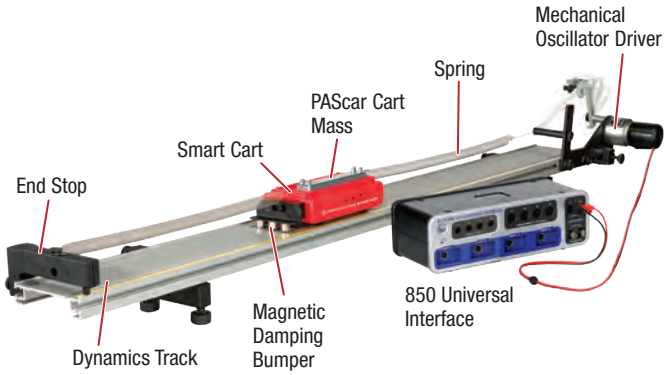
Dynamics Cart Magnetic Damping	ME-6828	
Shown in use with:		
Basic Smart Cart Metal Track 1.2 m System	ME-5708A	p. 107
IDS Spring Kit	ME-8999	p. 121

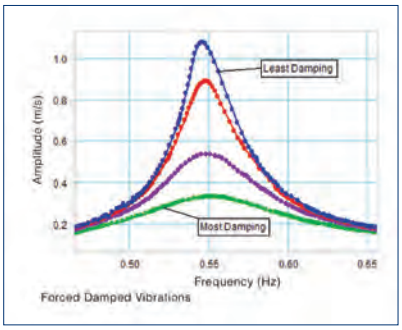
Mechanical Oscillator/Driver

ME-8750

The Mechanical Oscillator/Driver delivers repeatable, low-frequency, high-force sinusoidal motion for harmonic motion experiments. Shown with the Smart Cart Standard Dynamics System (ME-5718), it also works with other Dynamics Systems having a metal track.







The velocity amplitude is plotted as a function of driving frequency. The four resonance curves show the effect of varying the strength of the magnetic damping.

Specifications:

Sinusoidal Drive: 12 VDC motor
(Frequency: 0.3-3 Hz, Current: 0-0.3 A).

Adjustable Amplitude: Up to 12 cm.

Mounts to Dynamics Track or Rod

Photogate Mounting Holes

Order Information

Mechanical Oscillator/Driver	ME-8750	
Shown in use with:		
Standard Smart Cart Metal Track 1.2 m System	ME-5718A	p. 107
Dynamics Cart Magnetic Damping	ME-6828	
850 Universal Interface	UI-5000	p. 26

Friction Block

ME-9807

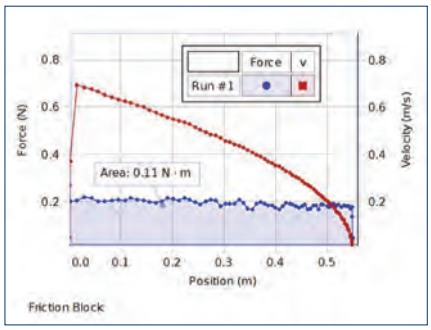
- Two types of material
- Vary surface area by using it flat or up on its side
- Hook for attaching a string to pull it
- Slot for a picket fence or flag for photogate timing

The wooden Friction Block has felt on two sides, so the frictional coefficients for felt or wood can be measured. It also fits into the dynamics cart tray so the cart can run on its wheels, or it can be turned upside down to run on the Friction Block without changing the mass.

Specifications:

Dimensions: 13 cm x 5 cm x 1.7 cm

Approximate Mass: 110 g



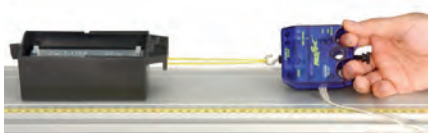
The sliding friction block does work on the moving Smart Cart and stops it quickly. The graph above shows the cart velocity and applied friction stopping force vs. the distance travelled by the cart and block. The area under the Force vs. Distance curve gives the work done, and the loss of kinetic energy can be calculated from the velocity.

Order Information

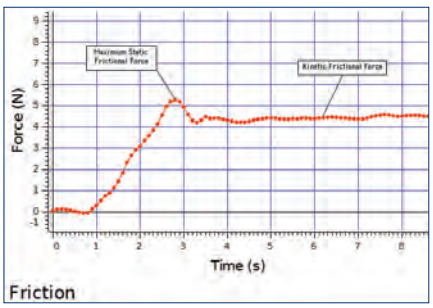
Friction Block..... ME-9807
Shown in use with:
Dynamics Track System..... See pages 106-107
Dynamics Track End Stop
(2 Pack)..... ME-8971 p. 121

Discover Friction Accessory

ME-8574



PASCO's Discover Friction Accessory is unlike any other friction set. The trays are designed to work effectively with PASCO carts and sensors. Using the four trays, students can discover concepts such as coefficient of friction, static friction, kinetic friction and the sliding friction equations. The two trays with identical plastic surfaces can be hooked together to explore the relationship between surface area and sliding frictional forces.



The peak of the graph represents the maximum static frictional force. Once the friction tray begins to move, the kinetic frictional force is evident on the graph.

Features

- **Compatible:** Can be used with PASCO carts, masses and Force Sensors
- **Versatile:** Allow students to discover key friction concepts
- **Easy Storage:** Friction trays are stackable, both for adjusting the pulling height and storage

Includes:

- Friction Tray - Felt
- Friction Tray - Cork
- Friction Tray - Plastic (2)

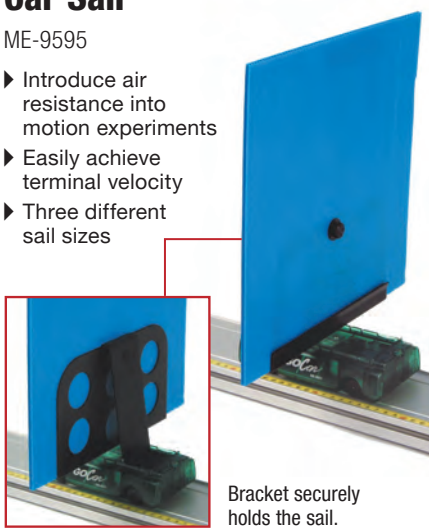
Order Information

Discover Friction
Accessory..... ME-8574
Recommended:
Cart Mass (Set of 2)..... ME-6757A
PAScar (Red)..... ME-6933
PAScar (Blue)..... ME-6934
Force Sensor ..... See pages 32, 42
Dynamics System..... See pages 106-107

Car Sail

ME-9595

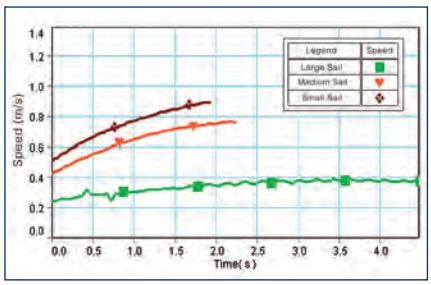
- Introduce air resistance into motion experiments
- Easily achieve terminal velocity
- Three different sail sizes



Bracket securely holds the sail.

The Car Sail allows students to study the effects of air resistance on PASCO carts. Simply attach the bracket to the mass tray of the cart and attach any of the three included sails. Using the various sails, the relationship between surface area and terminal velocity can be determined.

Terminal velocity is related to both the surface area and the mass of an object in motion. Students should compare the motion of the cart without a sail to its motion with the sails. As the surface area of the sail increases, the cart will more closely approach a terminal velocity.



Comparison of cart velocity as it moves down the track with various sails attached.

Includes:

- Sail Bracket
- Screws for Cart and Sail Mounting
- Sails: 3600 cm^2, 1800 cm^2, and 900 cm^2

Order Information

Car Sail..... ME-9595

Super Fan Cart

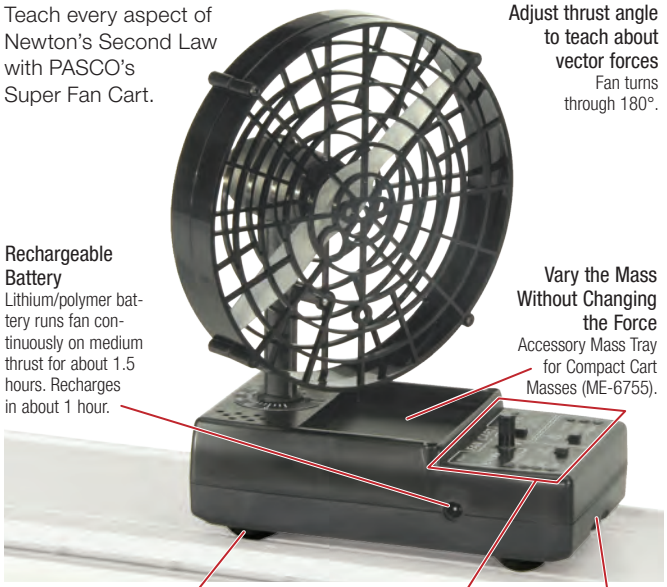
ME-6977

- Constant force
- Rechargeable
- Programmable

$$\vec{F}_{Net} = m\vec{a}$$

Teach every aspect of Newton's Second Law with PASCO's Super Fan Cart.

Adjust thrust angle to teach about vector forces
Fan turns through 180°.



Rechargeable Battery
Lithium/polymer battery runs fan continuously on medium thrust for about 1.5 hours. Recharges in about 1 hour.

Vary the Mass Without Changing the Force
Accessory Mass Tray for Compact Cart Masses (ME-6755).

Retractable Wheels
with low friction ball bearings

Adjustable Fan Speed
Apply different forces using three standard settings or the continuously variable setting. Regulated power supply gives constant thrust even as the battery discharges.

String Attachment
Connect two fan carts together to add or subtract forces.

The Net Force Is Zero
Removable sail can be used two ways: When positioned as shown, the sail cancels the forward air flow and there is no thrust. If the sail is reversed, its curved shape reflects the air backwards, causing the cart to move.

Pulse Duration
Program the fan to be pulsed on for specific time to demonstrate acceleration only occurs when a force is applied. Includes time delay and auto-repeat option.

Specifications:

Fan Cart Mass: Approximately 0.3 kg
Sail Mass: Approximately 0.1 kg
Regulated Power Supply: Lithium-polymer battery (7.2 volts, 1.25 amp-hour)
Run-time: Runs approximately 1.5 hr on medium thrust
Recharge Time: One hour
Thrust Settings: Approximately 0.04 N on Low, 0.15 N on Medium, and 0.22 N on High
Thrust, Variable: Approximately 0.01 N to 0.23 N

Includes:

• Fan Cart • Sail • Charger

Order Information

Super Fan Cart	ME-6977	
Recommended:		
PAStrack	ME-6960	p. 116
Compact Cart Mass	ME-6755	p. 121
Replacement Part:		
Fan Sail	ME-1248	p. 111

Hooke's Law, Spring Potential Energy, and Work-Kinetic Energy Theorem, all in one cart launcher

Spring Cart Launcher

ME-6843*

- Affordable cart launcher
- Hooke's Law
- Spring potential energy

See EX-5504A Hooke's Law and Energy Stored in a Spring on p. 334

The Spring Cart Launcher provides an economical way to launch carts in a repeatable fashion. It can be used for Hooke's Law, collisions, and for Conservation of Energy. It fits into the bed of a Dynamics Cart or PAScar. To launch the cart, the plunger is pulled through the hole in the new endstop, compressing the spring, and then released. To add repeatability, a second endstop can be used with the supplied pin to hold the plunger at a specified compression position. Three different strength springs are provided with the Spring Cart Launcher. Use with or without probeware.

NOTE: The Spring Cart Launcher is not compatible with the Smart Cart.

Includes:

- Spring Cart Launcher
- Trigger Pin
- Three Different Strength Springs

Order Information

Spring Cart Launcher	ME-6843	
Required:		
Dynamics Track System	See pages 106-107	
Shown in use with:		
Dynamics Track End Stop (2 Pack)	ME-8971	p. 121
Cart Launcher Springs (Three different strength springs, two each)	ME-6847	
Compact Cart Mass	ME-6755	p. 121

Constant Speed Buggy

SE-8028A

Turn on the Constant Speed Buggy and watch it go. When it reaches a wall, it flips over and changes directions. This low-cost solution features flashing lights and a sporty appearance. Requires two "C" batteries that are not included. Actual product may vary from picture.

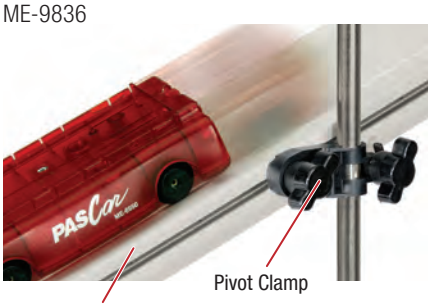
⚠ WARNING
CHOKING HAZARD
Small parts. Not for children under 3 years.

Order Information

Constant Speed Buggy	SE-8028A

Track Rod Clamp

ME-9836



Shown with PAStrack

Track Rod Clamp fastens to the T-slot of a Dynamics Track and accepts 1/2" rod.

Order Information

Track Rod Clamp ME-9836

Dynamics Track Feet (Pair)

ME-8972

A pair of adjustable feet for the classic aluminum tracks included in PASCO Dynamics Systems.

Order Information

Dynamics Track Feet (Pair)..... ME-8972

Dynamics Track End Stop (2 Pack)

ME-8971

A replacement supply for tracks included in PASCO Dynamics Systems.

Order Information

Dynamics Track End Stop (2 Pack) ME-8971

Angle Indicator

ME-9495A

The Angle Indicator fastens to the T-slot of a dynamics track. Hanging plumb-bob indicates angle to 1/2°.

Order Information

Angle Indicator..... ME-9495A
Recommended:
Launcher Plumb Bobs (12-pack)..... ME-9868A

PAScar Cart Mass (Set of 2)

ME-6757A

These 250-gram masses fit in any Dynamics Cart (including the Smart Cart) or the Discover Friction Accessory.

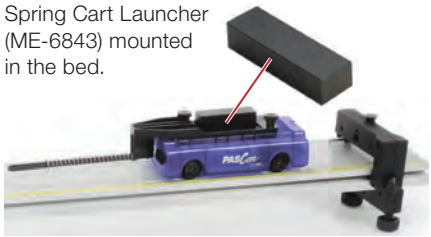
Order Information

PAScar Cart Mass (set of 2).....ME-6757A

Compact Cart Mass

ME-6755

This 250-g mass allows students to change the mass of the Classic Cart or PAScar when a force sensor is mounted in the bed of the cart. It also fits on a cart that has a Spring Cart Launcher (ME-6843) mounted in the bed.



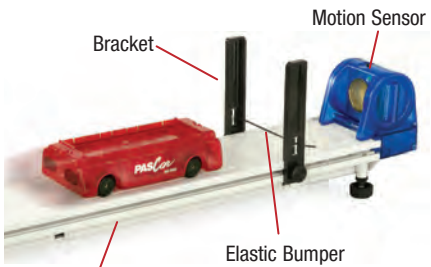
Order Information

Compact Cart Mass ME-6755

Elastic Bumper

ME-8998

The Elastic Bumper protects the Motion Sensor from the carts, but doesn't interfere with the ultrasonic pulse.



Shown with PAStrack

Includes:

- Two pairs of brackets
- 10 meters of elastic material

Order Information

Elastic Bumper ME-8998

Super Pulley with Clamp

ME-9448B

Shown with PAStrack

The Super Pulley, with its integral clamp, makes setup and alignment easy. The pulley height is fully adjustable, so you can keep the force parallel to the track on an inclined plane.

Includes:

- Super Pulley
- Super Pulley Clamp
- Mounting Screws (2)

Order Information

Super Pulley with Clamp ME-9448B

IDS Spring Kit

ME-8999

Includes 12 springs (1.6 cm diameter) with approximate spring constants of:

3.4 N/m (3 short and 3 long springs)
6.8 N/m (3 short and 3 long springs)

Order Information

IDS Spring Kit ME-8999

Harmonic Springs (8 Pack)

ME-9803B

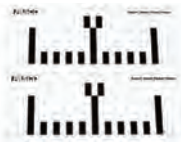
Includes eight identical springs: 8 cm long, 3.4 N/M spring constant.

Order Information

Harmonic Springs 8 Pack..... ME-9803B

Photogate Brackets (2 Pack)

ME-9806



ME-8933

ME-9804

Order Information

Photogate Brackets (2 Pack)– IDS ME-9806
Picket Fences (Smart Timer) ME-8933
Cart Picket Fences (2 Pack) – IDS ME-9804

Cart Replacement Axles* (4 Pack)

ME-6957

***Not suitable for Smart Carts**

Although the ball bearings are designed for many years of use, the bearings may become damaged from dirt and other contaminants. The wheels and axles of the PAScar can be easily replaced by removing the lower section of the car and placing the new wheels in the chassis. A perfect tune-up for a PAScar or GOcar! The wheels of the Classic Carts can also be replaced with the same set of wheels. Contact PASCO's technical support for further assistance.

Order Information

Cart Replacement Axles (4 pack) ME-6957

Braided Physics String

SE-8050

This braided Dacron® string is tough, resists stretching, and won't unravel. Withstands up to 133 Newtons of force (equivalent to 13.6 kg). Each roll provides 320 meters of string.

Order Information

Braided Physics String SE-8050

Spares Kit - IDS

ME-9823

The Spares Kit contains many of the small parts that can get lost after classroom use. All parts are organized in a convenient case for easy storage.

Includes:

- Cart Bumper Magnets (2)
- Velcro® Hoop and Loop Bumpers (4)
- Dynamics Track Feet Screws (4)
- 1/4"-20 x 9/16" Tee Thumb Screws (4)
- 1/4"-20 x 9/16" Round Thumb Screws (6)
- 1/4"-20 x 3/8" Round Thumb Screws (6)
- 1/4"-20 x 7/32" Square Nuts (20)
- 1/4"-20 Nylon Thumb Nuts (6)
- 6-32 x 3/8" Nylon Thumb Screw (6)
- M5 x 0.8 x 20 mm Nylon Thumb Screw (4)
- 1/4"-20 x 3/8" Set Screws (4)
- Bumper Squares (8)
- Round Rubber Bumpers (4)

Order Information

Spares Kit - IDS ME-9823

Rubber Cord for IDS System (30m Spool)

ME-8986

This rubber cord is used with PASCO's Elastic Bumper, and also fits the Air Track Bumper Set with Holder.

Order Information

Rubber Cord for IDS System (30m Spool) ME-8986

Use your Rotary Motion Sensor to track cart motion.

Dynamics Track Mount

CI-6692

The Dynamics Track Mount (CI-6692) is used to mount the Rotary Motion Sensor to the Dynamics Track, allowing it to act as a high resolution, bi-directional Smart Pulley.

Includes:

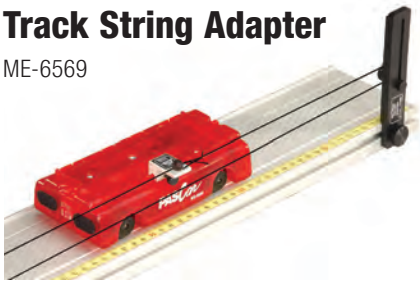
- Bracket

Order Information

Dynamics Track Mount.....CI-6692

Track String Adapter

ME-6569



When the Track String Adapter is used in conjunction with the Dynamics Track Mount (CI-6692), the Track String Adapter allows a Rotary Motion Sensor to continuously monitor the Dynamics Cart's position. A loop of string wraps around the Rotary Motion Sensor pulley and the ball-bearing pulley, and then it attaches to the cart via a special clip (included).

Includes:

- Bracket with Pulley
- Cart String Clip
- Thread

Order Information

Track String Adapter ME-6569

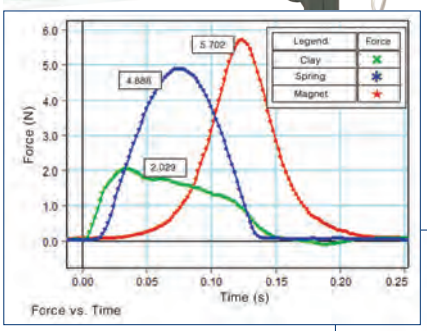
Force Sensor Track Bracket

ME-6622

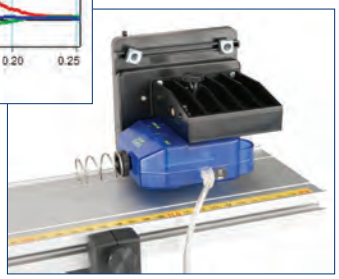
The Force Bracket with bumpers mounts the PASCO Force Sensor directly to a dynamics track. It includes 5 collision attachments for the Force Sensor and conveniently stores each attachment on the bracket itself.

Using any of these attachments, the bracket serves as an excellent support or target for collision studies using the Force Sensor.

Use it with the Wireless Force Acceleration Sensor (PS-3202) to study cart collisions.



Force vs. Time data for clay, spring, and magnet attachments.



Includes:

- Spring Bumpers (different spring constants) (2)
- Magnetic Bumper
- Rubber Bumper
- Clay Cup for Inelastic Collisions (clay included)
- #0 Phillips Head Screwdriver (to attach to Force Sensor)

Order Information

Force Sensor Track Bracket ME-6622

Bumper Accessory Set

ME-9884

This set of bumpers can be used with any PASCO Force Sensor to perform both elastic and inelastic collisions. The standard hook for each Force Sensor can be easily removed and replaced with any of these bumpers. Use a spring and a cup for elastic collisions. Combine two cups with clay to explore inelastic collisions.

Includes:

- Stiff Spring
- Light Spring
- Empty Cup (2)
- Modeling Clay

Order Information

Bumper Accessory Set ME-9884

Magnetic Bumper Set

ME-9885A

This set of magnetic bumpers can be used with any PASCO Force Sensor or Smart Cart to perform elastic collisions without any contact. The bumpers screw directly into the beam of the sensor. They can also be used with the Force Bracket.

Includes:

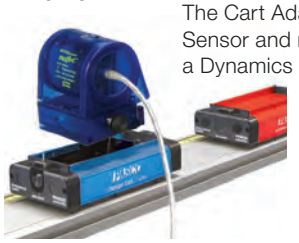
- Magnetic Bumper (2)

Order Information

Magnetic Bumper Set ME-9885A

Cart Adapter Accessory

ME-6743



The Cart Adapter Accessory allows the Motion Sensor and many other sensors to be mounted to a Dynamics Cart or a PAScar.

Mounting a Motion Sensor on a cart is ideal for the study of relative motion. The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Includes:

- Two M5 thumb screws to attach to cart
- 1/4"-20 screw at center

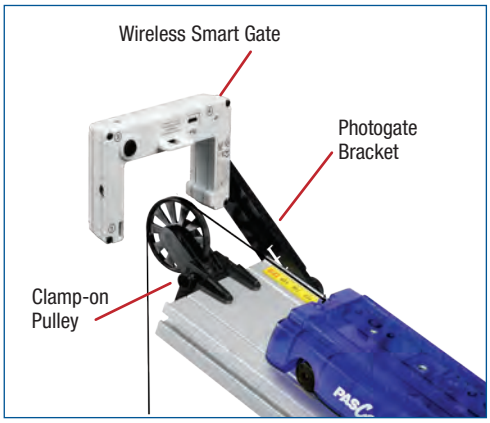
Order Information

Cart Adapter Accessory ME-6743

Smart Gate

PS-2180

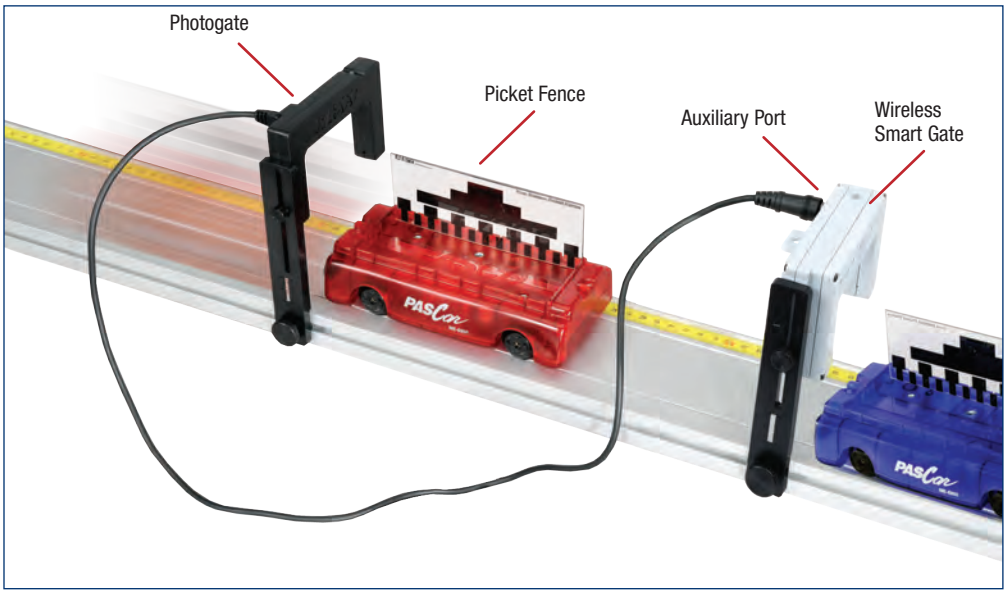
The Smart Gate connects directly to any PASPORT interface, and has an auxiliary port to daisy chain to an additional Photogate. It can be used with cart picket fences, Clamp-On Super Pulley, and flexible Photogate Tape.



Wireless Smart Gate

PS-3225

The Wireless Smart Gate has all the features of the Smart Gate (PS-2180), but it connects to your computing device via Bluetooth® or USB; it does not require an interface.



Smart Pulley

Use the Smart Gate and Photogate Bracket with the Clamp-on Super Pulley to create a "smart pulley."

Double Infrared Beams

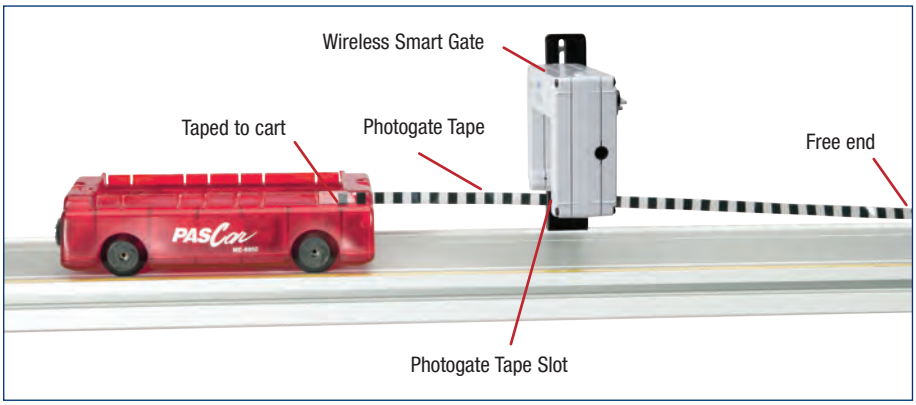
With the Smart Gate's double beam, the velocity of a cart can accurately be determined using the front edge of a single flag.

Auxiliary Port

Here, a second photogate is connected to the Wireless Smart Gate Auxiliary Port.

Photogate Tape Slot

The Smart Gate has a special slot through which the Photogate Tape can be threaded. This creates an excellent way of continuously measuring the speed of the cart as it accelerates down the inclined track.



PS-2180 Includes:

- Smart Gate
- PASPORT Cable
- Interface Cord

PS-3225 Includes:

- Wireless Smart Gate
- USB Charge Cable

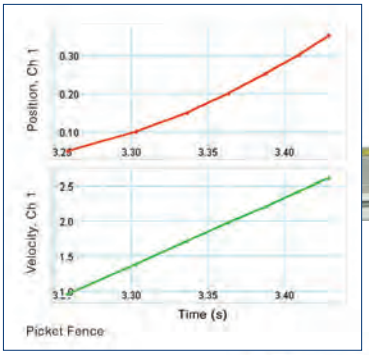
Order Information

Smart Gate	PS-2180	p. 38
Wireless Smart Gate	PS-3225	p. 64
Recommended:		
Photogate Head	ME-9498A	p. 39
Photogate Tape, High Resolution (30 m)	ME-6666	p. 39
Photogate Brackets (2 Pack) – IDS	ME-9806	p. 122
Cart Picket Fences (2 Pack) – IDS	ME-9804	p. 125
Super Pulley with Clamp	ME-9448B	p. 121

Photogates and Fences Dynamics System

ME-9471A

When used with a computer for data recording, display, and analysis, the photogate/pulley timing system provides a wide range of time, speed, and velocity measurements. The Photogates mount to the dynamics track using the provided brackets. The Picket Fences provided mount directly to the Dynamics Carts.



Position and velocity graphs are obtained using a Picket Fence and Photogate.

Includes:

- Photogate Heads (2)
- Photogate Brackets (2)
- Picket Fences (2)
- Super Pulley with attachment screw (attaches Super Pulley to Photogate)
- Pulley Mounting Rod

Order Information

Photogates and Fences Dynamics System	ME-9471A	
Individual Components:		
Photogate Head	ME-9498A	p. 39
Photogate Brackets (2 Pack) – IDS	ME-9806	
Cart Picket Fences (2 Pack) – IDS	ME-9804	
Super Pulley	ME-9450A	p. 151
Pulley Mounting Rod	SA-9242	p. 151
Required for use with PASPORT interfaces:		
PASPORT Digital Adapter	PS-2159	p. 60

Wireless Smart Gate Dynamics System

NEW PRODUCT!

PS-3703

The Wireless Smart Gate Dynamics System provides a wide variety of time, speed, and velocity measurements. Mount the Photogates to a Dynamics Track using the included brackets. Use the Picket Fences to track Dynamics Carts.

Includes:

- Wireless Smart Gate: PS-3225
- Photogate Head: ME-9498A
- Photogate Brackets: ME-9806
- Picket Fences: ME-9804

Order Information

Wireless Smart Gate Dynamics System	PS-3703	

Photogate Brackets (2 Pack) – IDS

ME-9806

- Attaches Photogates to PASCO Dynamics Tracks
- Easily Adjust Photogate Height

The Photogate Bracket allows the Photogate Head to be attached directly to PASCO dynamics tracks. This eliminates the need for separate photogate stands and allows the photogate height to be easily adjusted relative to the track. Includes two Photogate Brackets.

(Photogates not included.)

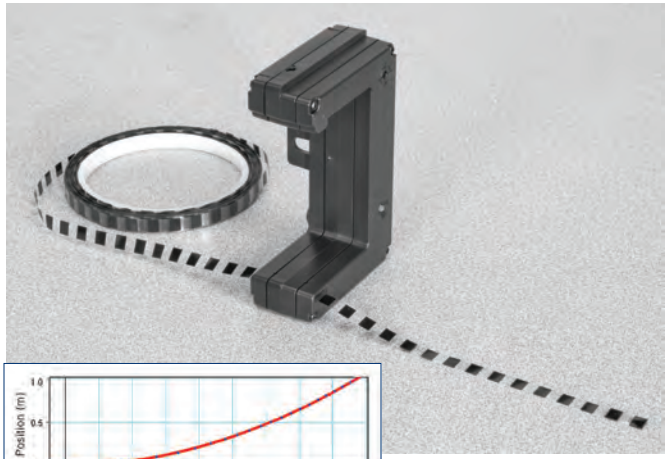
Order Information

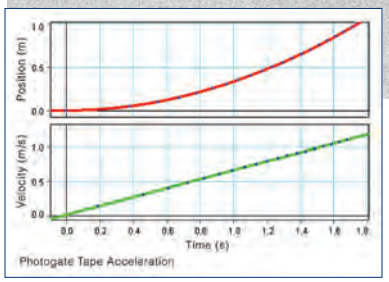
Photogate Brackets (2 Pack) – IDS	ME-9806	

Photogate Tape, High Resolution (30 m)

ME-6666

Cut this flexible Mylar Picket Fence Tape to any length and slide it into a Smart Gate to more accurately measure the motion of a cart.





Photogate tape can be used as a picket fence "string" to continuously measure the motion of the cart.

Slide the Photogate Tape through the slot to measure position, velocity, and acceleration. The band spacing on the tape is 1 cm from edge to edge.

Order Information

Photogate Tape, High Resolution (30 m)	ME-6666	
Required:		
Smart Gate	PS-2180	p. 38
Wireless Smart Gate	PS-3225	p. 64

The Most Versatile Stand-Alone Timer Available

Smart Timer

ME-8930

- Portable timer for photogates and smart pulleys
- Measures time, speed and acceleration
- Counter for G-M Tubes
- Crystal-controlled 0.01% accuracy

The ME-8930 Smart Timer works with all PASCO timing devices:

- Accessory Photogate
- Photogate/Pulley System
- Time-of-Flight Accessory
- Freefall Adapter
- Laser Switch
- G-M Tube

Measure Time:

- One Gate: Returns time from leading edge to leading edge
- Fence: Returns 10 time values
- Two Gates: Returns time between two gates
- Pendulum: Measures pendulum period
- Stopwatch: Returns time between pressing Start/Stop button

Measure Speed:

- One Gate: Single object speed using picket fence
- Collision: Initial and final speeds for one or two carts
- Pulley: Angular speed

Measure Acceleration:

- One Gate: Direct measurement of acceleration using picket fence
- Linear Pulley: Acceleration of string
- Angular Pulley
- Two Gates: Object's average acceleration between two photogates

Measure Counts:

- Three timing intervals
- Manual mode counts until Stop is pressed
- Up to 5,000 counts/second
- Up to 9,999,999 total counts

2-line, 16-character Alphanumeric LCD

- Top Line: Measurement Description; Bottom Line: Numerical Values

It's as easy as 1-2-3.

1. Measurement
Press this button to select the quantity to be measured: "Time," "Speed," "Accel," "Count" or "Test" will appear on the display.

2. Mode
Press this button to select the type of experimental setup. Each mode is shown in words on the display.

3. Start/Stop
Press Start. The Smart Timer "beeps," and waits for an event to occur. After the event, the Smart Timer displays a result.

Features:

- **Works with Two Photogates**
- **More Than Just a Timer:** Measures speed and acceleration as well as time.
- **Quick Setup:** Turn on the switch, plug in the photogates, and it's ready to use.
- **Portability or Plug-in:** The battery-operated (four "AA"s) Smart Timer can be used outside the classroom away from power outlets. It can also be operated on the 9 VAC adapter (included).
- **Calculation Lock-out Switch:** A switch inside the battery compartment disables the speed and acceleration modes. Timing modes are unaffected, and students are required to do their own calculations.

Specifications:

Resolution: 100 µs
Accuracy: 0.01% of full range of the measured time
Display: 2-line, 16-character, alphanumeric LCD
Inputs: Two 1/4" stereo phone jacks on side panel— TTL compatible
Power Requirements: Four "AA" batteries (not included) or AC adapter (9 VDC, 500 mA) included

Typical Experiments

- Acceleration Due to Gravity*
- Newton's Second Law*
- Conservation of Momentum in Collisions*
- Rotational Inertia of a Disk & Ring*
- Acceleration Down an Incline
- Simple Harmonic Oscillator
- Oscillations on an Incline
- Springs in Series and Parallel
- Projectile Motion Using Photogates
- Time-of-Flight and Initial Velocity
- Determining the Acceleration Due to Gravity
- Counting Radiation with the G-M Tube

*Experiments require accessories listed on pages 33 and 37.

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

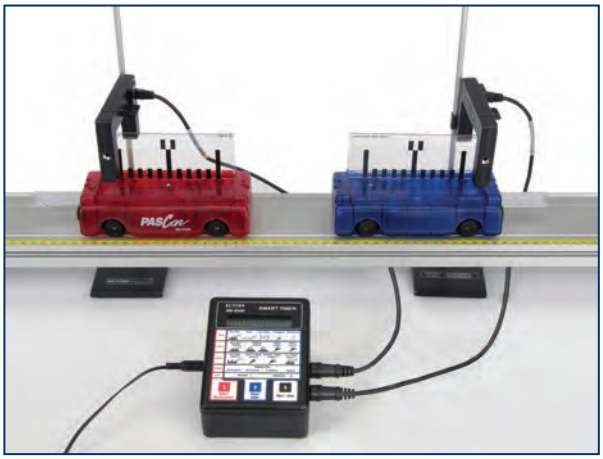
Two Photogate Ports

Durable Positive-click Buttons

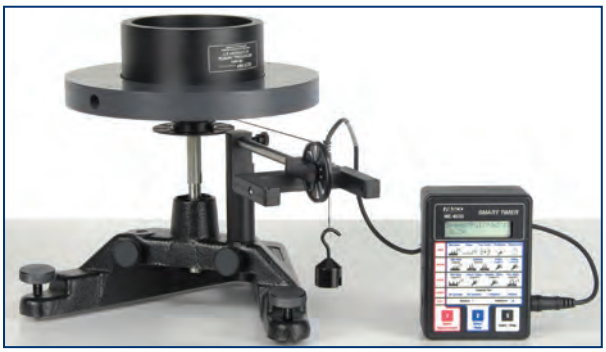
The microprocessor-based PASCO Smart Timer is the most versatile way to make time, speed, acceleration, and count measurements.

Speed of projectile—In Time: *Two Gates mode; determine the speed of a ball fired by a Projectile Launcher through two photogates.*

Speed of object through one gate—In Time: *One Gate mode; timing begins when the photogate beam is first blocked and continues until the beam is blocked again. Use the fence supplied with the Smart Timer.*



Speed before and after collision—In Speed: *Collision mode; use two carts and two photogates with a single Smart Timer to measure initial and final speeds of both carts.*



Rotary motion—In Acceleration: *Linear Pulley mode; the Smart Timer measures the acceleration of the string over the Smart Pulley.*

Includes:

- Smart Timer
- Picket Fences (2)
- 9 VAC Adapter
- Lab Manual

Order Information

Smart Timer	ME-8930	
Recommended:		
Accessory Photogate	ME-9204B	p. 33
Picket Fences (Smart Timer)	ME-8933	
Freefall Adapter	ME-9207B	
Photogate & Pulley System	ME-6838A	p. 33
Time-of-Flight Accessory	ME-6810A	p. 33
Phone Jack Extender Cable	PI-8117	p. 33

Smart Timer Photogate System

ME-8932

The PASCO Smart Timer is among the most versatile and affordable measurement tools available to physics educators. This system includes a PASCO Smart Timer and two Photogates for measuring time, speed, acceleration, and count.

Includes:

- Accessory Photogate (2) ME-9204B
- Super Pulley ME-9450A
- Smart Timer ME-8930
- Picket Fences (Smart Timer) ME-8933
- 9 VAC Adapter and Lab Manual (not shown)

Order Information

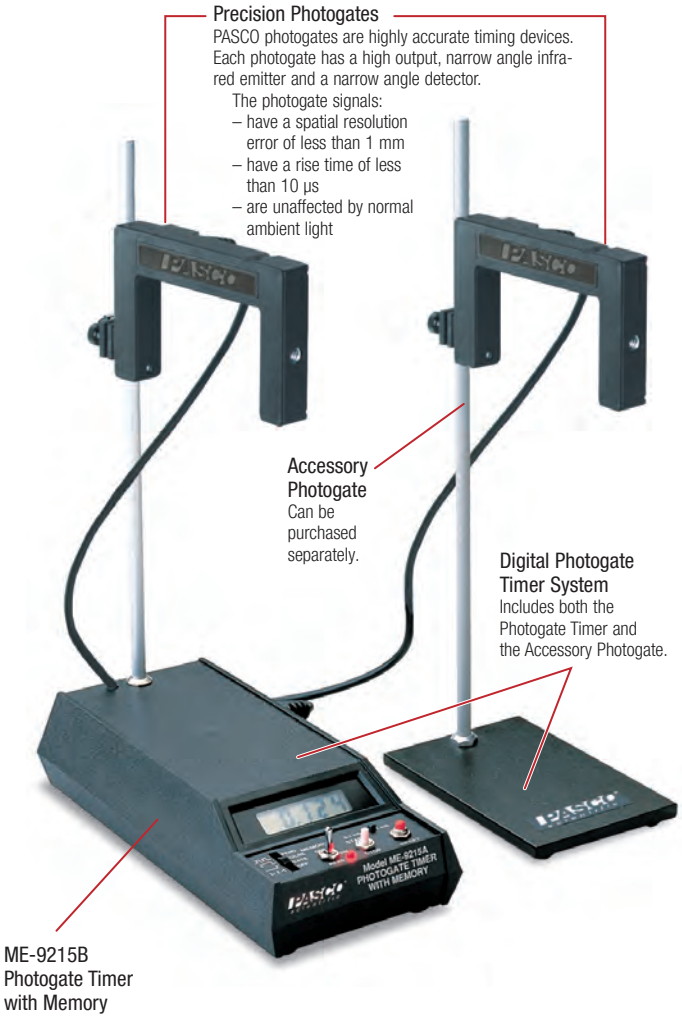
Smart Timer Photogate System..... ME-8932

Digital Photogate Timer System

ME-9403A

- High accuracy and resolution
- Four timing modes: gate, pulse, pendulum, and manual stopwatch
- Built-in memory
- Two Photogates for measuring time between gates

PASCO Photogates and Digital Timers are used in thousands of physics labs throughout the world because they are rugged and simple to operate.



Specifications:

Modes: Gate, pulse, pendulum, manual stopwatch
Resolution: 0.1 ms (max time 19.9999 s)
Accuracy: 0.05% of full range of the measured time ±1 digit
Display: 5-1/2 digit, 10 mm high LCD
Memory: Preserves displayed time while new time is measured
Photogate: 6.5 cm wide; fully adjustable swivel mount; LED trigger indicator; fall time <10 ns; spacial resolution <1 mm
Inputs: Accessory Photogates, or TTL-compatible signals; one photogate jack and a 9-V AC adapter jack (or four "C" size batteries) on back panel

Compatible with these PASCO products:

- Time-of-Flight Accessory
- Freefall Timer
- Laser Switch

Features:

- Timer serves as the base
- 0.1 ms resolution and 0.01% accuracy
- Memory Function allows two measurements to be made in rapid succession, such as pre-collision and post-collision velocities
- Two Photogates for measuring elapsed time between gate interferences
- Simply turn it on and begin collecting measurements
- Powered by 4 C batteries (not included) or the 9V AC adapter (included)
- Manual includes ten ready-to-use experiments

Order Information

Digital Photogate Timer System	ME-9403A
Photogate Timer	ME-9215B
Accessory Photogate	ME-9204B

Tape Timer

ME-9283

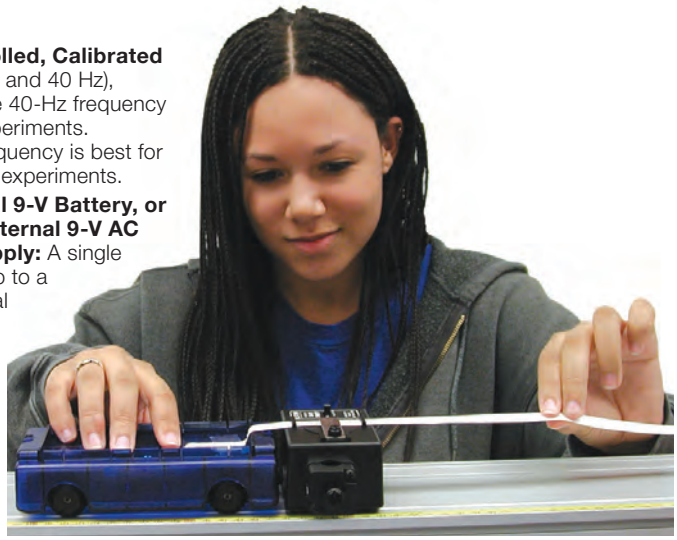
- Crystal-controlled
- Two frequencies (10 Hz and 40 Hz)
- Easy-to-read dots

Provides students with a visual demonstration of speed and acceleration. A moving object pulls a paper tape through the timer. The timer prints dots on the tape at equal time intervals. The result is a series of dots on the paper tape, representing the position of the object as a function of time.

From the dots on the tape, the distance traveled can be measured, and the average speed for each time interval can be calculated. Plotting position versus time enables students to determine the average speed. Plotting the average speed for each time interval versus time enables acceleration to be determined.

The paper tape can be attached to air track carts, dynamics carts, falling masses or other objects.

Features:



- **Two Crystal-controlled, Calibrated Frequencies:** (10 Hz and 40 Hz), accurate to 0.1%. The 40-Hz frequency is ideal for freefall experiments. The slower 10-Hz frequency is best for most dynamics track experiments.
- **Includes an Internal 9-V Battery, or Use an Optional External 9-V AC Adapter/Power Supply:** A single battery can last for up to a year's worth of normal experiments.
- **Low Mass, Small-pin Printing Head:** Driven by short millisecond pulses, produces sharp, round dots without smearing.
- **Plain Paper:** Print on 12.5 mm (1/2 inch) wide, plain paper supplied in 150-meter (500 feet) rolls.
- **Carbon Paper Discs:** Used for printing. The adjustable disc holder allows the printing point to be adjusted, giving a long life to the discs.
- **Rod Clamp:** Allows the Tape Timer to be mounted on a standard lab stand rod so that the paper path is either parallel or perpendicular to the rod. Rod sizes between 13 mm (1/2 inch) and 9 mm (3/8 inch) are accommodated.

Includes:

- Roll of paper
- Carbon paper discs
- Battery
- Manual (not shown)

Order Information

Tape Timer..... ME-9283

Recommended:

Tape Timer Supplies..... ME-9284

Includes five rolls of paper (150 m each) and 10 carbon discs.

PASCO Stopwatch

ME-1234

- No alarm or clock
- Memory for stored event times
- Uses one AA battery
- Durable buttons

Are you tired of annoying stopwatch alarms going off all day? Are your students stuck in the clock mode and can't get their stopwatch back into the timing mode? Does your stopwatch stop working after changing that little watch battery? The PASCO Stopwatch solves all these problems.

This stopwatch was designed specifically for science timing. The modes of operation are intuitive and complete instructions are included. The buttons are built to last and it uses a single long-lasting AA battery, which is less expensive than a watch battery (and easier to install).

The PASCO Stopwatch fits comfortably in your hand.

The EVENT/RECALL button allows you to view the last time, in case students forget to write down their data. The EVENT/RECALL button is also used to store and recall up to nine event times. For example, record a series of events, such as times at which sandbags were dropped along the gym floor.

Specifications:

LED Display: Visible indoors and outdoors

Two Display Modes: MM:SS.SS (01:25.34) or Decimal Sec (85.34 s)

Precision: 0.01 sec up to 59:59.99 (MM:SS.SS) or 3599.99 s Then 1 sec to 99:59:59 (HH:MM:SS) or 359999 s

Max Number of Event Times: Nine

Auto-off: After one hour idle

Can be used with a lanyard (not included)

Includes: One AA battery and instruction sheet

Order Information

PASCO Stopwatch.....ME-1234

PASCO Stopwatch, 10-pack.....ME-1235

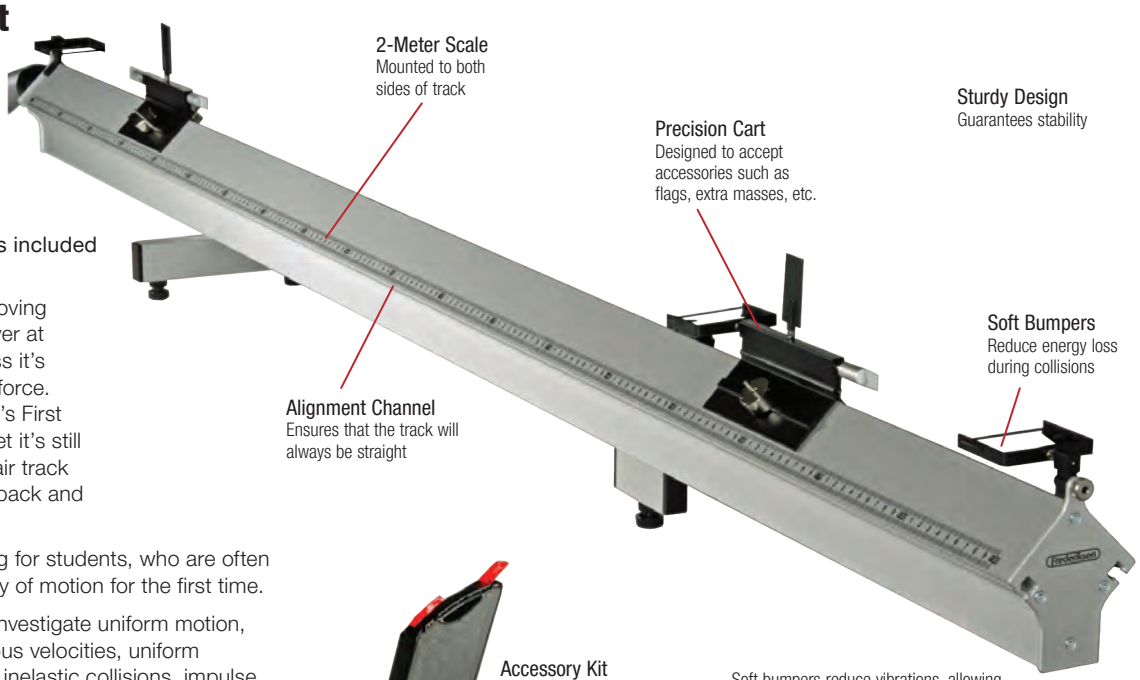
2.0 m Air Track

SF-9214

Variable Output Air Supply

SF-9216

- Nearly frictionless linear motion
- Two meters long
- Complete accessories included



It's simple physics—a moving object will continue forever at a constant velocity unless it's acted on by an external force. To the physicist, Newton's First Law is second nature. Yet it's still fascinating to watch an air track glider moving endlessly back and forth on an air track.

It's even more fascinating for students, who are often seeing this simple display of motion for the first time.

Add a timing system to investigate uniform motion, average and instantaneous velocities, uniform acceleration, elastic and inelastic collisions, impulse and change in momentum, conservation of momentum, conservation of energy, and more. The data is precise and unambiguous and frictional forces are negligible.

Accessory Kit

Soft bumpers reduce vibrations, allowing elastic collisions that really are elastic.

Compared to other air tracks, the PASCO Air Track is:

- **Longer:** The full 2-meter length provides more room for experimenting (yet it still fits on a standard lab table).
- **Straighter:** Guaranteed straight to within 0.04 mm over its entire 2-meter length. If your air track should ever become misaligned, return it to us and we will realign it for free.
- **Tougher:** The track is a large square aluminum extrusion with 3 mm thick walls that are further strengthened by a supporting U-channel. This construction preserves straightness and allows for accurate realignment.
- **Quieter:** When using PASCO's Air Supply (SF-9216 Sold Separately) this system is exceptionally quiet (allows the air to be adjusted), and the variable flow provides the perfect amount of air for each experiment. (Too little air causes friction; too much air causes energy loss due to glider "flutter.")
- **Versatile:** The PASCO Air Track comes with a large set of accessories.
- **Precision Cart:** Designed to easily accept accessories such as flags, extra masses, etc.
- **2-Meter Scale:** Mounted to both sides of track.
- **Soft Bumpers:** Reduce energy loss during collisions.
- **Alignment Channel:** Ensures that the track will always be straight.

Specifications:

Length: 2 m (working distance 1.9 m)
Base: Three-point with bilateral leveling screws
Millimeter Scales: 2 meters long on each side

Includes:

- Gliders (2): 13 cm long; 170 g; with rubber-band bumpers
- Glider Flags (2): 25 mm
- Glider Masses (4): 50 g
- Glider Bumper (3)
- Inelastic Collision Kit: Needle with wax-filled receptacle
- Constant Acceleration Kit: Ball-bearing pulley, glider hook, mass hanger (2 g) and five acceleration masses: two 1 g; one 2 g; one 5 g; one 10 g
- Storage Case

Order Information

2.0 m Air Track	SF-9214	
Required:		
Variable Output Air Supply	SF-9216	p. 131
Recommended:		
Replacement Parts		see opposite page

Air Track Accessory Kit

SF-9295

A set of accessories comes with every PASCO Air Track. All that's needed is a timing system. The pieces of the set may be ordered separately.

Order Information

Air Track Accessory Kit..... SF-9295
Recommended:
Glider Kit..... SF-9224
Air Supply Hose for
Air Track (2m) SF-9298

Variable Output Air Supply

SF-9216

The PASCO Air Supply is exceptionally quiet. Its variable output lets students match the air flow to the experiment. A 2-meter hose is included. By adding the T-Adapter and Hose (SF-9217), the Air Supply can operate two PASCO Air Tracks at the same time.

Note: This Air Supply produces 36 cfm at 0.122 psi for use with the Precision Air Track SF-9214. If used with another track, the total area of the air flow holes must be greater than 2.6 cm^2, or the supply may overheat.

Order Information

Variable Output Air Supply.....SF-9216

Rubber Cord for IDS System (30m Spool)

ME-8986

This rubber cord is used with PASCO's Elastic Bumper, and also fits the Air Track Bumper Set With Holder.

Order Information

Rubber Cord for IDS System
(30m Spool)..... ME-8986

Air Track Accessories and Replacement Parts

The Air Track includes accessories for standard air track experiments, from simple acceleration to elastic and inelastic collisions. To add more advanced experiments, a variety of additional accessories are available.

Included in the SF-9295 Kit

(Each item may be ordered separately. The number in parentheses indicates how many of each item is included in the Accessory Kit.)

Mass/Hanger Set (1)
SF-6300

Bumper Set with Holder (3)
SF-6301

Bumper Set Air Track (3)
SF-6302

Inelastic Collision Needle (1)
SF-6303

Wax Receptacle (1)
SF-6304

Glider Hook (1)
SF-6305

Glider Mass (4)
SF-6307

Ball Bearing Pulley (1)
SF-6308

Photogate Flags (25 mm) (2)
SF-6311

Not Included in the SF-9295 Kit

(Must be ordered separately.)

Glider
SF-6306

Fixed End Stop
SF-6313

Adjustable End Stop
SF-6309

Glider Kit
(see photo below)
SF-9224

Air Supply Hose (2m)
SF-9298

Additional Glider Kit
SF-9224

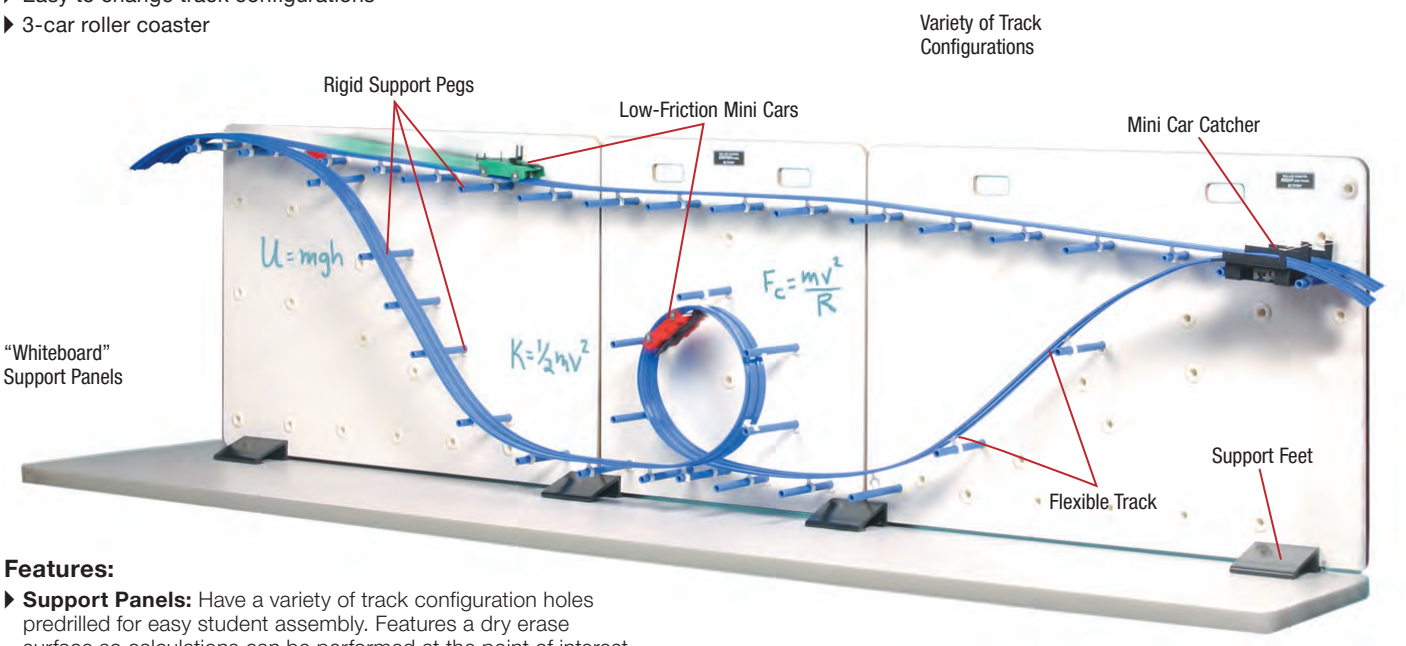
Includes:

- Glider
- 50 g Masses (2)
- Bumper with Holder
- Bumper Blade

Roller Coaster Complete System

ME-9812

- Quantitative studies of Energy Conservation
- Easy to change track configurations
- 3-car roller coaster



Features:

- **Support Panels:** Have a variety of track configuration holes predrilled for easy student assembly. Features a dry erase surface so calculations can be performed at the point of interest on the track.
- **Mini Cars:** Have low-friction ball bearings and ABS construction to withstand repeated impacts. One red, one yellow and one green Mini Car included. Each car includes a slot for a supplied photogate flag, cup/mass holder and cup. The body of the car extends just far enough below the wheels to protect them should the car leave the track.
  - The Roller Coaster's Mini Cars are low friction, yet rugged; mass can be added to the cars on top or in the ballast position.
  - Bumpers mount on Mini Cars to allow rubber band or clay collisions. Also used to couple Mini Cars into a train.
- **Ballast Mass:** Can be added to the mass tray of a Mini Car or hidden under a Mini Car to increase the energy without changing the car's appearance.
- **Flexible track:** Guides carts on their path, yet is flexible enough to form loops and hills, or can be rolled out flat on a table. Easily attaches to the support pegs using the twist-on track clips. Long pegs allow two tracks side-by-side for comparison.
- **Probeware Compatible:** Threaded support pegs and Mini Car photogate flags allow photogates to be used at many positions around the track to measure velocity and acceleration.

Applications:

- **Conservation of Energy:** Release the Mini Car and measure its velocity and height at several points along the track. Use these values to calculate total energy of the Mini Car. Frictional losses are less than 5%.
- **Constant Acceleration:** Several straight inclined sections can be used to measure and demonstrate constantly accelerated motion.
- **Projectile Motion/Conservation of Energy:** Use the initial height of the Mini Car to determine its speed as it flies off the end of the track. Using this speed and height above the ground when it leaves the track, predict where the Mini Car will land.
- **Multi-car Train:** Mini Cars can be coupled to form a train and the velocity of each car can be measured with a photogate and a Smart Timer. The velocities are not the same.
- **Brachistochrone:** A Mini Car traveling between two points along a brachistochrone path takes less time compared to the straight line path.

Includes:

- Support panel (3 sections)
- Support feet (4)
- Flexible track (9.1 meters)
- Mini Cars (3)
- Support pegs for track (43)
- Photogate support pegs (4)
- Track clips (50)
- Mini Car catcher (2)
- Mini Car starter bracket (2)
- Mini Car collision accessory (3)
- Mini Car photogate flags (3)
- Water cup (3)
- Mini Car ballast mass (3)
- Photogate brackets (4)
- Track couplers (2)

Order Information

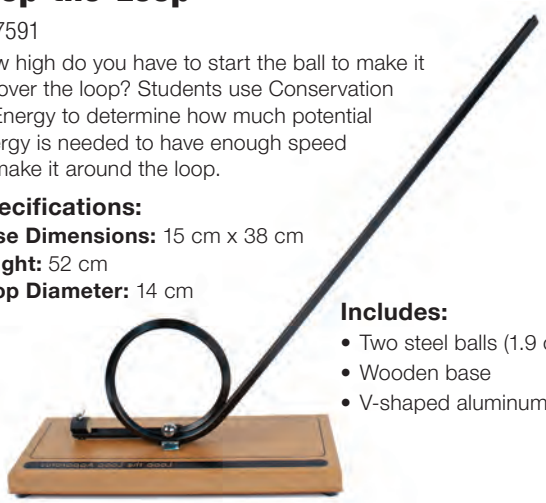
Roller Coaster Complete System	ME-9812	
Recommended: Photogate Head	ME-9498A	p. 39
Photogate Brackets (2 Pack) – IDS	ME-9806	p. 125
Spares Kit – Roller Coaster	ME-9815	
Mini Cars (Set of 3)	ME-9813	
Roller Coaster Track	ME-9814	
Smart Timer	ME-8930	p. 126

Loop-the-Loop

SE-7591

How high do you have to start the ball to make it go over the loop? Students use Conservation of Energy to determine how much potential energy is needed to have enough speed to make it around the loop.

Specifications:
Base Dimensions: 15 cm x 38 cm
Height: 52 cm
Loop Diameter: 14 cm



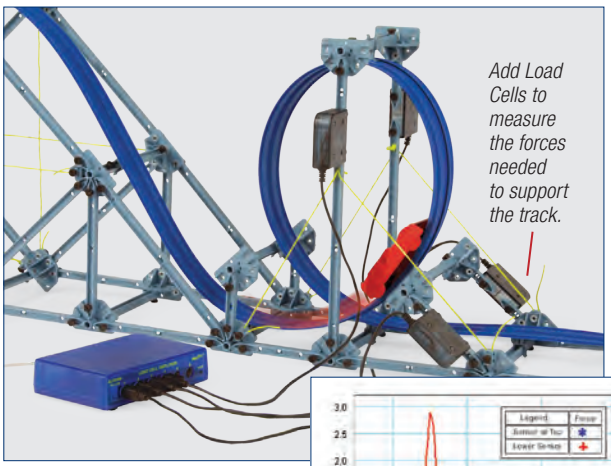
Includes:
- Two steel balls (1.9 cm dia.)
- Wooden base
- V-shaped aluminum track

Order Information

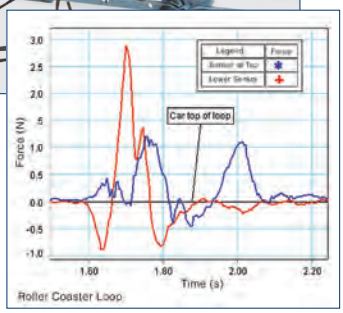
Loop-the-Loop SE-7591

Design your own roller coaster with PASCO's Structures System.

PASCO's Structures System allows students to design and build their own roller coaster for detailed studies of conservation of energy and centripetal force. The flexible track is perfect for building hills, valleys and even a loop! Car with low-friction, ball-bearing wheels minimizes energy losses. Measure the speed of the car using photogates or a Motion Sensor.



Add Load Cells to measure the forces needed to support the track.



Graph shows support forces exerted on the track as the car goes up and over the loop.

Add a loop to your roller coaster

Investigate the effect of changing the size and shape.

Order Information

Large Structures Set	ME-7003	p. 160-161
Shown in use with:		
Load Cell and Amplifier Set	PS-2199	p. 44
Accessory Photogate	ME-9204B	p. 33

Amusement Park Physics Kit

ME-9426A

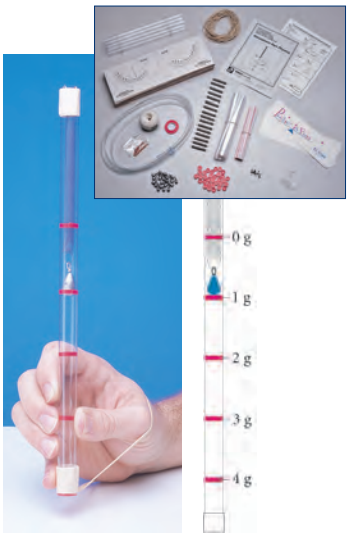
- Extend your lab into the "real world"
- Complete kit for 15 students
- Developed in conjunction with AAPT*

They might lose their notes. They might even lose their nerve. But in one day at an amusement park, students will also gain a real "gut-level" appreciation for Newton's Laws. Using this kit, students don't observe a dynamics cart. They are the dynamics cart. This is the only kit that is:

- Approved by the safety officers of major amusement parks across the USA.
- Student-tested in amusement parks by hundreds of schools.
- Teacher-tested in hundreds of Amusement Park Physics Workshops.
- Made with a metal coil spring for the Vertical Accelerometer (far more accurate than the commonly used rubber band).

Students experience the thrill of scientific investigation.

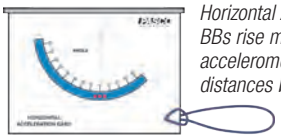
Photo courtesy of Paramount's Great America.



Vertical Accelerometer: The stretch of the spring measures the vertical acceleration in "g's."

Includes:
- Brass Hanging Weights (19)
- Springs* k = 3 N/m (16)
- Plastic Tubing (2.5 m)
- Plastic Tubes, 30 cm long (16)
- Plastic Tube End Caps (32)
- Bumper Stickers (16)
- Horizontal Accelerometer
- Cards (16)
- Push Pins (5)
- No. 3 Paper Clips (17)
- Cotton String
- Metal Balls (60)
- Straws (16)
- Wire Ties
- Vinyl Tape
- Rubber Bands #117 (32)
- Rubber Bands #19 (6)
- Plastic Storage Bags (16)
- Instruction Manual

**Additional accelerometer springs may be purchased separately. See order information below.*



Horizontal Accelerometer: The angle to which the BBs rise measures the horizontal acceleration. This accelerometer doubles as a sextant to measure distances by triangulation.

Order Information

Amusement Park Physics Kit (15 Pack) ME-9426A
Recommended:
Accelerometer Springs (16 Pack) ME-8734
Scissors, pliers, masking tape, clear plastic tape

Hovercraft

ME-9838

- Students experience Newton's Laws
- Durable nylon skirt
- Rubber bumper
- Optional cordless air supply

Our Hovercraft follows the classic design, with a rugged nylon skirt attached around a 1.2 m wood platform. Students can easily ride on the Hovercraft to experience firsthand the kinematics of frictionless motion.

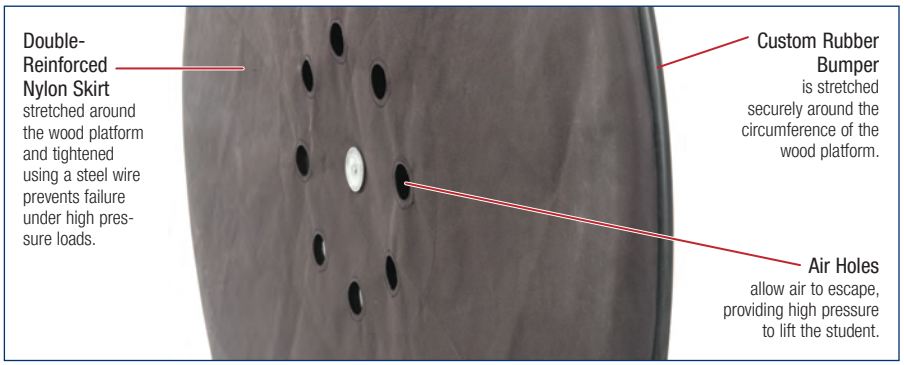
Air source not included.

How It Works

The nylon skirt is stretched around the wood platform and tightened using a steel wire. The center of the skirt is attached to the bottom of the wood platform. A custom rubber bumper is placed around the circumference of the wood platform. The bumper helps secure the skirt and also provides a soft cushion around the edge of the Hovercraft. A high-volume air source is used to force air through the platform and into the skirt. After sitting on the platform, the air source is turned on and the skirt inflates. Small holes in the skirt allow the air to escape, while providing the higher pressure needed to lift the rider. A built-in level helps students center their weight on the Hovercraft.

A Cordless Air Source (SE-8806) is orderable separately (below). In addition, most leaf blowers provide enough air flow to support the Hovercraft.

The PASCO Hovercraft is capable of supporting up to 300 lbs and comes completely assembled.



Includes:

- Wood platform (1.2 m diameter, 1.9 cm thick)
- Nylon skirt with mounting hardware
- Rubber bumper
- Liquid level
- Connection hose for air source

Order Information

Hovercraft	ME-9838
Recommended:	
Cordless Air Source	SE-8806

Hover Puck

SE-7335B

- Hovers on a cushion of air
- Ideal for inertia activities

The Hover Puck glides on a self-generated cushion of air across any smooth surface, including low-pile carpet. The rubber bumper provides protection for the puck and other objects during collisions. Each puck includes four "AA" batteries.

Specifications:
Diameter: 18.5 cm
Height: 6.0 cm

(Appearance may vary)

Includes:

- Hover Puck
- Four "AA" Batteries

Order Information

Hover Puck	SE-7335B	
Recommended:		
PASPORT		
Motion Sensor	PS-2103A	p. 40
Motion Sensor II	CI-6742A	p. 32
Wireless Motion Sensor	PS-3219	p. 63

Cordless Air Source

SE-8806

Includes:

- Rechargeable Battery
- Charging Adapter

Order Information

Cordless Air Source	SE-8806

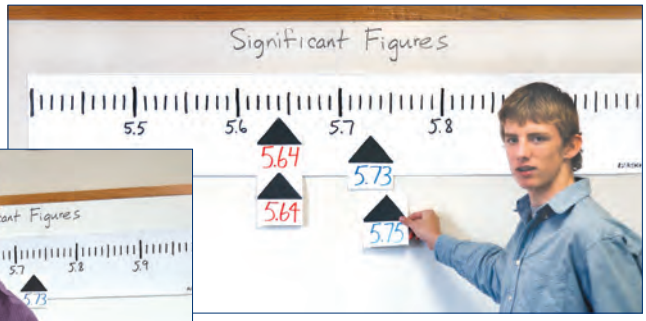
Significant Figures Set

ME-9850

- Connects measurements to Significant Figures
- Includes materials for one student group
- Detailed activity manual

The series of activities included in the Significant Figures Set emphasize the connection between measurements and significant figures. Students work through a number of situations in which they experience the concepts of accuracy and precision. Through these activities, students learn the importance of the measuring tool and its role in the uncertainty of measurements. For each activity, student groups are asked to place their measurements and/or calculations along a demonstration number line. The groups can then share their results with the entire class during discussions and presentations.

The Number Line and Data Pointers are laminated for use with dry erase markers.



The Ball Drop activity gives students experience with accuracy and precision.

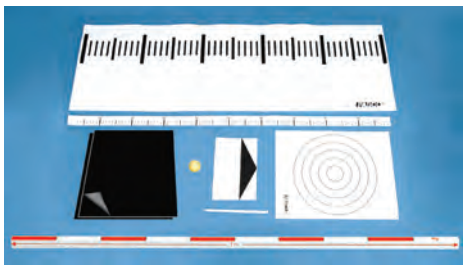
The Four-Scale Meter Stick is an important part of the Significant Figures Kit as it includes four scales of varying precision.

Perform These Experiments:

- **Ball Drop:** Students toss small balls on a bulls-eye to discover the relationship between technique and measurements. In addition, the concepts of accuracy and precision are explored.
- **"Forced Error" Measurements:** Students use a meter stick that has inaccurate markings to take measurements to reinforce that precise measurements are not always accurate.
- **Mass/Length Measurements:** Students use a balance or Four-Scale Meter Stick with imprecise scales to limit the certainty in their measurements.
- **Area/Volume/Density Calculations:** Students use a variety of measuring devices to calculate the area, volume, and density of various objects.

Includes:

- Yellow Nylon Ball
- Paper Bullseye (2)
- Carbon Paper (100 Sheets)
- Four Scale Meter Stick
- Number Line
- Data Pointer
- Meter Stick Label
- Balance Label



Order Information

Significant Figures Set..... ME-9850

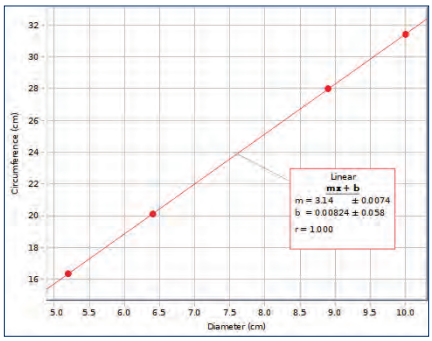
Discover Pi Set (10 pack)

ME-6819A

- Students discover the meaning of Pi
- Pi circles stack together for easy storage

The student reads the circumference directly from the transparent tape wrapped around the pi circle.

The Discover Pi Set allows students to derive the meaning of pi directly from their measurements. This activity transforms pi from a constant with unknown origin to a fundamental characteristic of all circular objects.



The slope of the circumference vs. diameter graph is equal to π.

Includes:

- Each pack includes 4 Pi Circles: 5.2, 6.4, 8.9, 10.0 cm diameter
- Transparent Measuring Tape

Order Information

Discover Pi Set (10 pack)..... ME-6819A

Discover Freefall System

ME-9889

- Determine g
- Investigate air resistance dependence on mass, volume, cross-sectional area

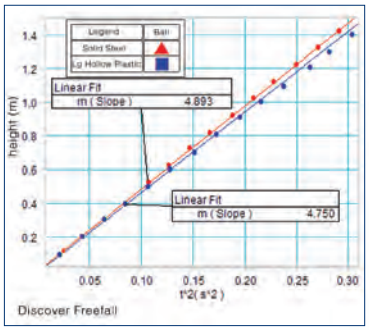
PASCO's Discover Freefall System can be used to drop almost any small object by attaching a small steel washer with a small adhesive pad (both are included in the system). Using an electric switch, timing is started automatically, just as the object is dropped. And the Time-of-Flight Pad stops timing when the object strikes it.

Students can investigate the effect of air resistance on acceleration. In addition, students can drop objects of the same size but different mass to study how object mass affects terminal velocity during freefall. The drop box has a magnetic mount for attaching to metal frames in ceilings.

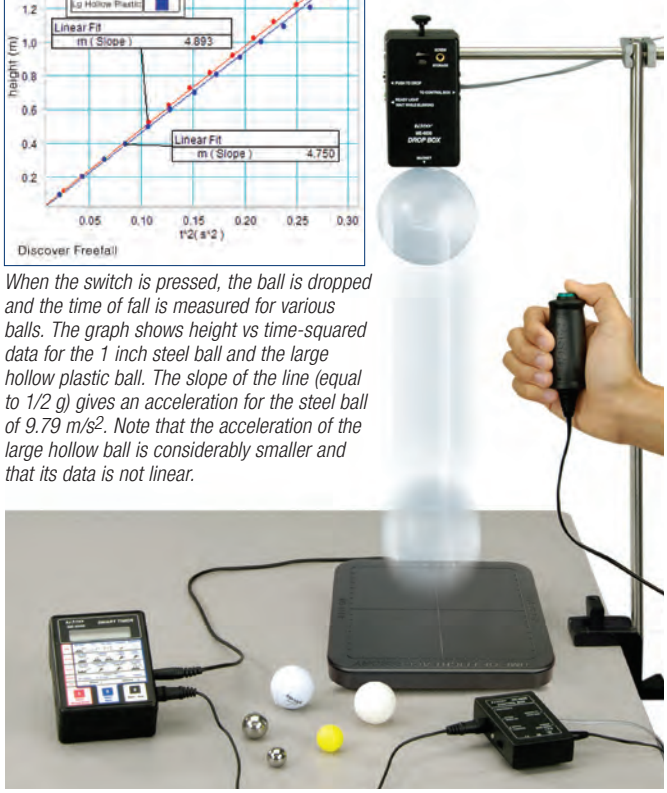
This system can also accept the Target Accessory, ME-6853, to perform the shoot-the-target demonstration. See page 141.

Includes:

- Drop box
- Control cable
- Control box
- AC adapter
- Time-of-Flight receptor pad
- Timer Switch
- Release washers (10)
- Release labels for attaching washers to object (50)
- Small nylon ball
- Large plastic ball
- Golf ball
- Hollow golf ball
- 1" steel ball
- 5/8" steel ball

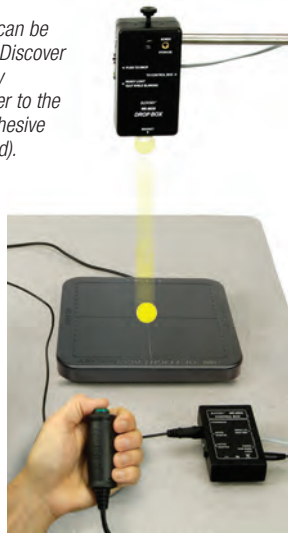


When the switch is pressed, the ball is dropped and the time of fall is measured for various balls. The graph shows height vs time-squared data for the 1 inch steel ball and the large hollow plastic ball. The slope of the line (equal to 1/2 g) gives an acceleration for the steel ball of 9.79 m/s^2. Note that the acceleration of the large hollow ball is considerably smaller and that its data is not linear.



Shown in use with rods and clamps sold on pages 196-199. The Drop Box also has built-in magnets to fasten directly to the ceiling.

Any small object can be dropped with the Discover Freefall System by attaching a washer to the object with an adhesive pad (both included).



The Discover Freefall System also works with the 850, PASPORT, or any ScienceWorkshop Interface. Shown here using a Digital Adapter.

Order Information

Discover Freefall System	ME-9889	
Required:		
Smart Timer	ME-8930	p. 126
or 850/550 Interface		pp. 26-29
Recommended:		
Freefall Balls Accessory	ME-9890	p. 203
Rods and Clamps		pp. 196-199

Freefall Adapter

ME-9207B

How it Works:

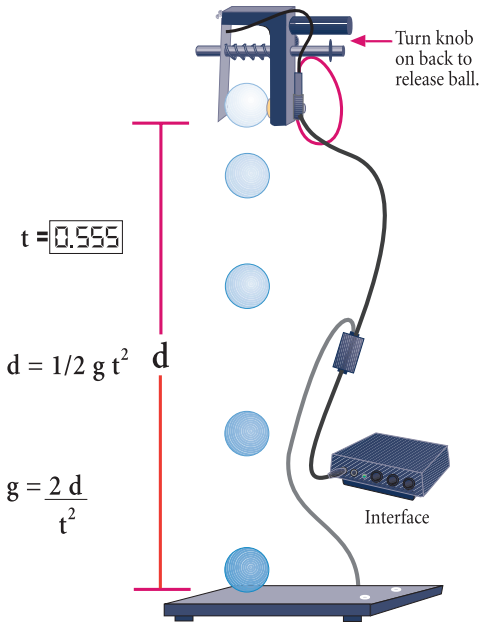
A steel ball is clamped into a spring-loaded release mechanism. At the instant the ball is released, the electronic timer automatically starts. The timer stops when the ball hits the receptor pad. With the accurate, high resolution timing and automatic start and stop, the resulting measurements of "g" are precise and repeatable.

Designed for use with any of the following:

- 850 Universal Interface (UI-5000)
- 550 Universal Interface (UI-5001)
- Smart Timer (ME-8930)
- Photogate Timer (ME-9215B)
- AirLink (PS-3200) with Digital Adapter (PS-2159)

Maximum distance of fall is 2 m.

Freefall Timer Adapter shown in use with the Smart Timer. The Smart Timer records the elapsed time from when the ball is dropped until the ball hits the receptor pad.



Includes:

- Ball release mechanism with stereo phone plug and receptor pad
- Four steel balls (1.9 cm, 1.6 cm diameter)

Order Information

Freefall Adapter	ME-9207B	
Required:		
Large Table Clamp	ME-9472	p. 199
Multi-Clamp	ME-9507	p. 198
90 cm Stainless Steel Rod	ME-8738	p. 196
Photogate Timer	ME-9215B	p. 128
Smart Timer	ME-8930	p. 126
or 850/550 Interface		pp. 26-29

Projectile Launcher

ME-6800

- Accurate
- Durable
- High Repeatability

Add optional Smart Gate to measure launch velocity.

Launcher Spares Kit

ME-6802

Contains spare equipment for the PASCO Projectile Launcher.

Includes:

- Loading Rod (10)
- 2-D Collision Accessory (2)
- Plastic Balls (10)
- Sights (5)
- Angle Indicator (1)
- Plumb Bobs (12)
- Thumbscrew to attach launcher to base (10)

Order Information

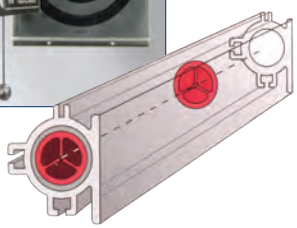
Launcher Spares Kit	ME-6802

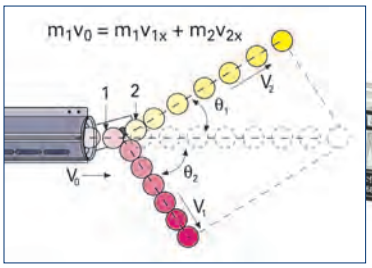
Unique Sights

Shoot-the-Target

The "gun" is aimed directly at the target. Although the target "drops" the moment the projectile is fired, the ball still hits the target since the ball falls with the same acceleration.

Two bore sights simplify aiming the launcher.





*The 2-D Collision Accessory (included with all PASCO launchers) allows the study of **Conservation of Momentum** in two dimensions. Use the points of impact with the floor of each of the two balls to determine relative velocities and angles.*

Specifications:

Ranges: 1.2, 3, 5 m
Launch Angles: 0 to +90°
Launcher Length: 21 cm

Features:

- **Variable Launch Speed:** For short range or longer range experiments.
- **Fixed Firing Height at Any Launch Angle:** Firing height of ball is same for any launch angle.
- **Unique Piston Design:** Minimizes projectile spin to ensure repeatability of impact position.

Includes:

- Projectile Launcher
- Launcher Base
- Projectile Balls (2)
- Loading Rod
- Safety Glasses
- 2-D Collision Accessory
- Manual

Order Information

Projectile Launcher	ME-6800	
Shown in use with:		
Shoot-the-Target	ME-6853	p. 141
Photogate Mounting Bracket	ME-6821A	p. 143
Smart Gate	PS-2180	p. 38
Recommended:		
Time-of-Flight Accessory	ME-6810A	p. 143
Large C Clamp (6 Pack)	SE-7285	p. 143
Plumb Bobs (10 Pack)	SE-8728	p. 143

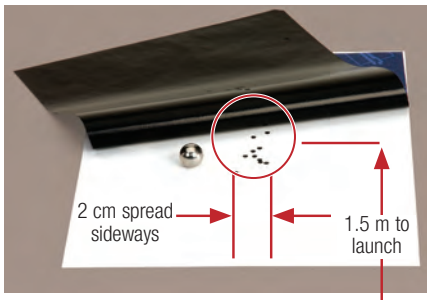
Mini Launcher

ME-6825B

- Ideal for tabletop projectile experiments
- Fires at downward angles
- Low cost

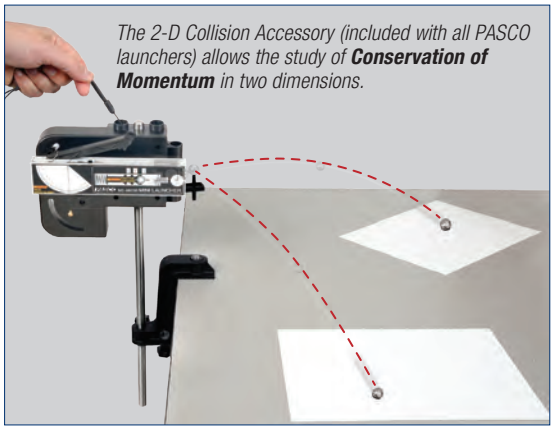
Bracket features include:

- Magnetic ball storage
- New plunger storage
- Labeled shooting positions



Typical pattern for Mini Launcher –
Ball was launched 10 times off 1 m high table at 30° angle. All 10 shots landed within 5 cm diameter circle.

2-D Collision



*The 2-D Collision Accessory (included with all PASCO launchers) allows the study of **Conservation of Momentum** in two dimensions.*

Unique stand design allows ball to be launched from tabletop height. The ball lands on the table at the same height from which it was launched.

Magnetic Piston holds ball in place for launching at downward angles.

Specifications:
Range: 0.5, 1, 2 m
Launch Angle: 0 to +90° and 0 to -45°
Launcher Length: 18 cm

Includes:

- Launcher Base
- Loading Rod
- 2-D Collision Accessory
- Steel Ball Projectile, 16 mm (2)
- Safety Glasses
- Manual
- Mini Launcher

Order Information

Mini Launcher	ME-6825B	
Recommended:		
Photogate Mounting Bracket	ME-6821A	p. 143
Smart Gate	PS-2180	p. 38
Time-of-Flight Accessory	ME-6810A	p. 143
Large C Clamp (6 Pack)	SE-7285	p. 143
45 cm Stainless Steel Rod	ME-8736	p. 196
Plumb Bobs (10 Pack)	SE-8728	p. 143
Carbon Paper (100 Sheets)	SE-8693	p. 143
30 Meter Measuring Tape	SE-8712A	p. 202

Mini Launcher Spares Kit

ME-6824

Includes several spare parts for Mini Launcher.

Includes:

- Loading Rod (10)
- 2-D Collision Accessory (2)
- Steel Balls (10)
- Angle Indicator
- Plumb Bobs (12)
- Thumbscrew to attach launcher to base (10)

Order Information

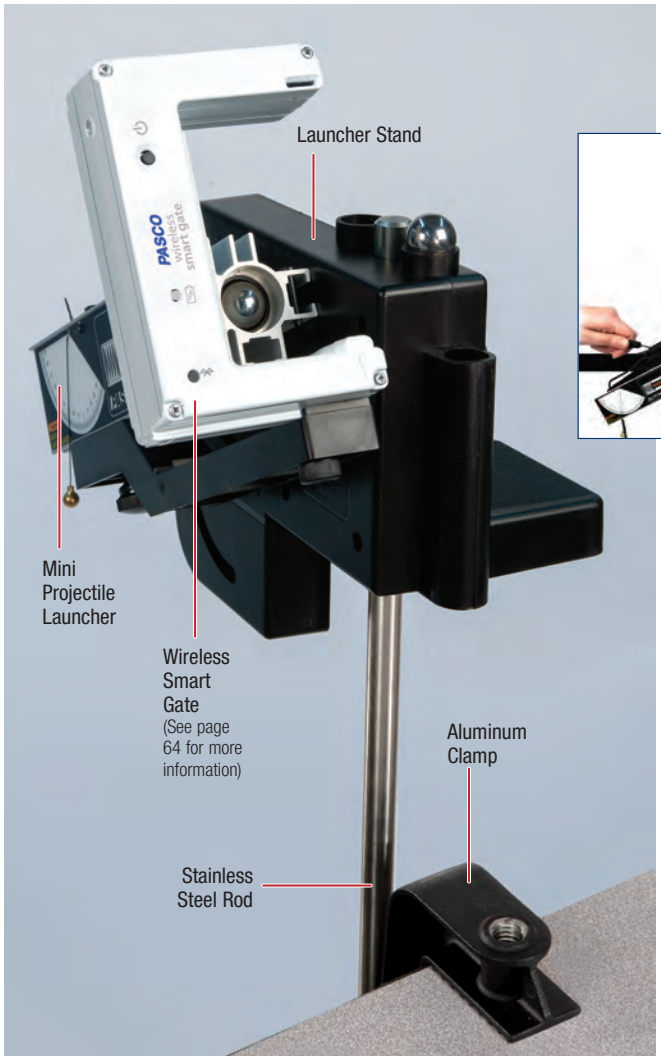
Mini Launcher Spares Kit	ME-6824

Projectile Launcher Wireless Smart Gate System

ME-6796

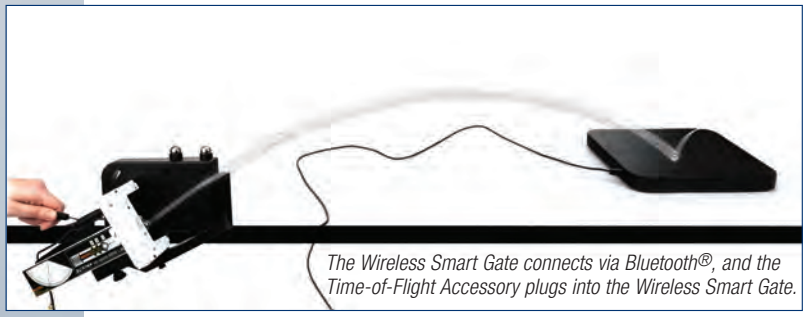
- Vary height
- Vary launch speed
- Vary angle
- Measure accurately with Smart Gate

Study projectile motion through live data collection and analysis with this complete system. The Mini Launcher and Wireless Smart Gate make the setup simple: Just clamp the launcher to the table and slide the Wireless Smart Gate on. The Wireless Smart Gate's dual photogate beams accurately capture initial velocity data, without requiring any additional equipment. Includes necessary equipment.



Specifications:
Range: 0.5, 1, 2 m
Launch Angle: 0 to +90° and 0 to -45°
Launcher Length: 18 cm

Add the Time-of-Flight Accessory!


The Wireless Smart Gate connects via Bluetooth®, and the Time-of-Flight Accessory plugs into the Wireless Smart Gate.

Includes:
- Wireless Smart Gate with Mounting Bracket
- Mini Launcher with Mounting Stand
- Steel Balls (2) with Loading Rod
- 2-D Collision Accessory
- Aluminum Table Clamp
- 45 cm Stainless Steel Rod

Order Information

Projectile Launcher Wireless Smart Gate System ME-6796

Shoot-the-Target

ME-6853

- Demonstrate independence of x- and y-motion
- For use with all launchers

The PASCO Shoot-the-Target Accessory, in combination with a Projectile Launcher, demonstrates that acceleration is constant for all objects in freefall, regardless of initial velocity. A target is initially suspended near the ceiling, and a Projectile Launcher is aimed directly at it. As soon as the projectile is shot from the launcher, the target is released. The projectile hits the target as it falls, proving that both objects accelerate downward at the same rate.

Before it falls, the target is attached to the drop box by a permanent magnet so it can hang indefinitely, even when the drop box is not powered. A photogate detects the projectile as it leaves the launcher and triggers the drop box. The drop box releases the target by driving a current through a coil that cancels the field of the permanent magnet.

The "gun" is aimed directly at the target. Although the target "drops" the moment the projectile is fired, the ball still hits the target. Both the ball and the target fall with the same acceleration.

Includes:

- Drop Box & Control Box
- Control Cable
- Target ME-6852
- Photogate Head & Bracket
- AC Adapter (9 VDC, 500 mA)

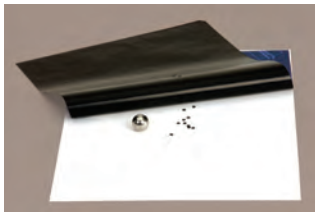
Order Information

Shoot-the-Target	ME-6853	
Recommended:		
Projectile Launcher	ME-6800	p. 138
Mini Launcher	ME-6825B	p. 139

Carbon Paper (100 Sheets)

SE-8693

Carbon paper is ideal for marking the position of an object as it strikes the floor or other surface.



Order Information

Carbon Paper (100 Sheets)	SE-8693

Time-of-Flight Accessory

ME-6810A

- For use with all PASCO launchers

Includes:

- Time-of-Flight Accessory
- Instruction Manual
- Experiment Guide

Order Information

Time-of-Flight Accessory	ME-6810A

Drop Shoot Accessory

ME-9859

- Simultaneously drops one ball and launches a second ball horizontally
- Proves the independence of x- and y-motion
- Mounts on PASCO projectile launchers (short- and long-range)

The Drop-Shoot Accessory is an easy-to-use tool that helps students better understand the independence between the horizontal and vertical motion of a projectile. Connect the accessory to either the short or long range projectile launchers, hang one ball from the magnet and fire away. The fired ball strikes the hanging ball, causing one ball to shoot horizontally at the same instant the other ball falls straight down. Both balls hit the ground at the same time, regardless of the fired projectile's muzzle velocity, provided the Projectile Launcher is level. This device also provides an interesting demonstration of Conservation of Momentum in collisions.

When the (included) hollow steel ball is used, the two balls are both fired horizontally at two different speeds. A Photogate and Time-of-Flight Accessory can also be used to directly measure time of flight.

When the solid ball hits the hanging solid ball, the hanging ball shoots out horizontally, while the ball shot out of the launcher drops straight down.

Either the solid steel ball or hollow steel ball is hung by a magnet.

Includes:
- Drop-Shoot Bracket
- 2.5 cm Steel Balls (2)
- 2.5 cm Hollow Steel Ball
- Mounting Hardware
- Loading Rod

Order Information

Drop Shoot Accessory	ME-9859	
Required:		
Projectile Launcher	ME-6800	p. 138

Ball Ramp

SE-7596

- Use for Projectile Motion
- Use for 2-D Collisions

This apparatus consists of a curved track with a base at one end. On the base is a support to hold a ball at the proper height for a center-to-center collision with a second ball rolling down the track. The track is level so collision occurs only in the horizontal plane, simplifying calculations.

Includes:
- 25 cm one-piece track
- 3 balls (12 mm diameter): 2 steel, 1 glass
- Plumb bob

Order Information

Ball Ramp	SE-7596

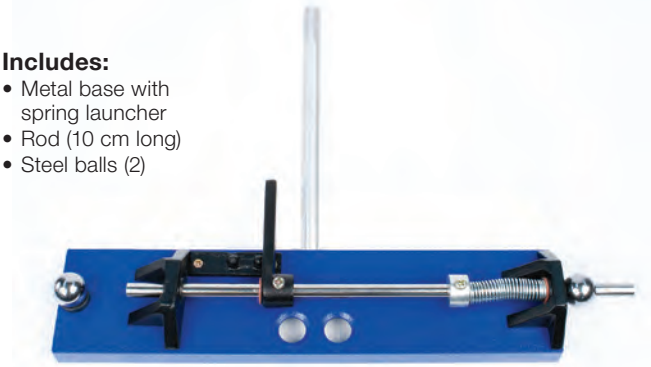
Drop-Shoot Demo

SE-7592

- Demonstrates the independence of horizontal and vertical components of projectile motion

Releasing the spring causes one ball to drop directly down while the other is projected horizontally. Listen and you'll hear that both hit the floor at the same time! The Drop-Shoot Demo is 25 cm long.

Includes:
- Metal base with spring launcher
- Rod (10 cm long)
- Steel balls (2)



Order Information

Drop-Shoot Demo	SE-7592

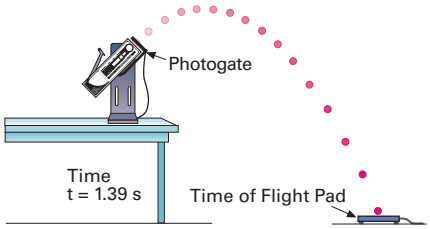
Time-of-Flight Accessory

ME-6810A

▶ For use with all PASCO launchers

The Time-of-Flight Accessory is designed primarily for freefall or projectile experiments. When an object hits the plate, a signal is sent to the interface.

Note: When used with the Projectile Launcher, a photogate is used to start the timer and the 20' extension cable is recommended.



Includes:
- Time-of-Flight Accessory
- Instruction Manual
- Experiment Guide

Order Information

Time-of-Flight Accessory ME-6810A

Photogate Mounting Bracket

ME-6821A

Mount one or two photogates on any Projectile Launcher. Compatible with the Photogate Heads below.

Order Information

Photogate Mounting Bracket	ME-6821A	
Photogate Head	ME-9498A	p. 39
Accessory Photogate	ME-9204B	p. 33
Smart Gate	PS-2180	p. 38
Wireless Smart Gate	PS-3225	p. 64

Small Steel Balls (10 Pack)

ME-9872

These 1.6 cm diameter steel balls are used with the Mini Launcher (ME-6825).

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Order Information

Small Steel Balls (10 Pack) ME-9872

Steel Balls (4 Pack)

ME-9864

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Purchase this 4 pack of 2.5 cm diameter balls for use with PASCO Short or Long-Range Projectile Launchers (ME-6800 or ME-6801).

Order Information

Steel Balls (4 Pack) ME-9864

Plastic Balls (10 Pack)

ME-6822

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

These extra brightly colored balls are designed for the Projectile Launcher. Diameter is 2.5 cm (1 in.).

Order Information

Plastic Balls (10 Pack)..... ME-6822

Spherical Mass Set

ME-8968

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

This set includes four balls with a diameter of 2.5 cm each, but features various masses, including a hollow steel ball, solid steel ball, plastic ball and aluminum ball.

Order Information

Spherical Mass Set ME-8968

Launcher Sights

ME-9865

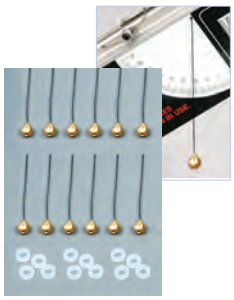
Purchase this 5 pack of aiming sights as a replacement for the Short-Range or Long-Range Projectile Launchers.

Order Information

Launcher Sights.....ME-9865

Launcher Plumb Bobs (12 Pack)

ME-9868A



This kit includes 12 brass plumb bobs and 12 washers to replace lost or broken parts from any of PASCO's projectile launchers.

Order Information

Launcher Plumb Bobs (12 Pack) ME-9868A

Large C Clamp (6 Pack)

SE-7285

These rugged clamps are perfect for attaching a variety of objects to a table. Size 10 cm (4 inch).

Order Information

Large C Clamp (6 Pack) SE-7285

Plumb Bobs (10 Pack)

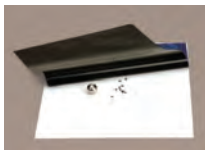
SE-8728

Order Information

Plumb Bobs (10 Pack).....SE-8728

Carbon Paper (100 Sheets)

SE-8693



Carbon paper is ideal for marking the position of an object as it strikes the floor or other surface.

Order Information

Carbon Paper (100 Sheets) SE-8693

Ballistic Pendulum

ME-6830

- Extremely accurate: ±2.5% of predicted values
- Both elastic and inelastic experiments
- Projectile launcher experiments
- Now includes ME-6800 bracket!

This classic physics experiment combines the laws of Conservation of Momentum and Conservation of Energy to determine the muzzle velocity of the projectile. Only simple mass and distance measurements are required to make this determination.

How It Works

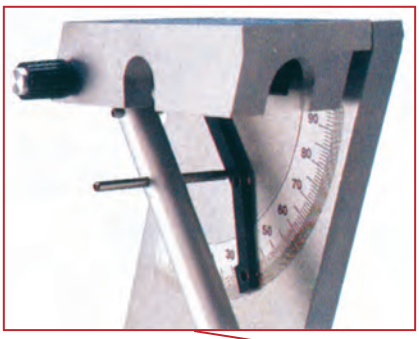
A projectile is fired into a pendulum, causing it to rise.

Using the projectile mass, the pendulum mass, and the rise in pendulum height, students can calculate the gravitational potential energy of the system.

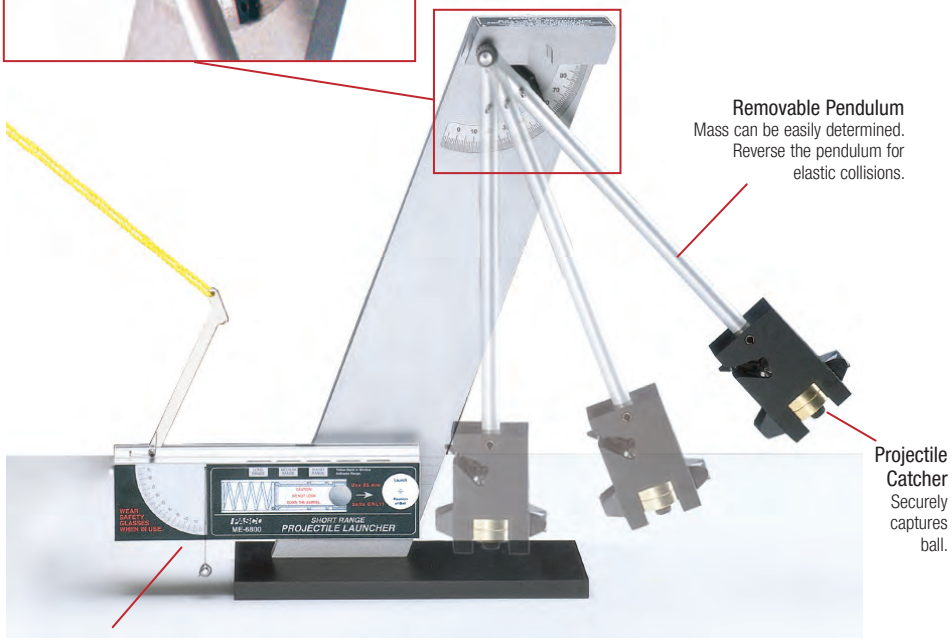
Since the potential energy is equal to the pendulum's kinetic energy at the lowest point, students can calculate the speed of the pendulum at impact.

Applying the Law of Conservation of Momentum, the projectile's speed is easily calculated.

An additional mounting bracket is included to perform the full range of projectile launcher experiments.



Unique Angle Measurement Design
Easily measures pendulum angle to 0.5°. Low friction gives repeatable results.



Removable Pendulum
Mass can be easily determined. Reverse the pendulum for elastic collisions.

Projectile Catcher
Securely captures ball.

Projectile Launcher
Durable with three repeatable launch settings.

Add Masses
Two 50 g masses (included) can be added to change the pendulum mass and rotational inertia.

Already own a PASCO Projectile Launcher?

The base and pendulum assembly can be purchased separately.

See Ballistic Pendulum (No Launcher) in the order block for more information.

Features:

- **Repeatable:** The three velocity settings on the Projectile Launcher produce consistent velocities.
- **Accurate:** The 0-80° angle measurement scale resolves to 0.5°, leading to experimental results within 2.5% of predicted values.
- **Removable Pendulum:** Remove the pendulum to determine its mass and center of mass, let it swing freely for rotational inertia calculations, or mount it backwards for elastic collision experiments.
- **Ball and Pendulum Masses:** This set includes two, 50 g pendulum masses, as well as two steel and two plastic balls.
- **Projectile Launcher:** Mount the Projectile Launcher on the other side of the base to give students access to its accessories.
- **Unique Angle Measurement:** The PASCO Ballistic Pendulum pushes a low friction, low mass pointer to the highest point. It remains there, permitting an accurate measurement.

Includes:

- Ballistic Pendulum (without launcher)
- Projectile Launcher
- Projectile Launcher Base
- 2.5 cm Plastic Balls (2)
- 2.5 cm Steel Balls (2)
- Masses (2)
- 2-D Collision Accessory
- Safety Glasses (2)
- Operations and Experiment Manual

Order Information

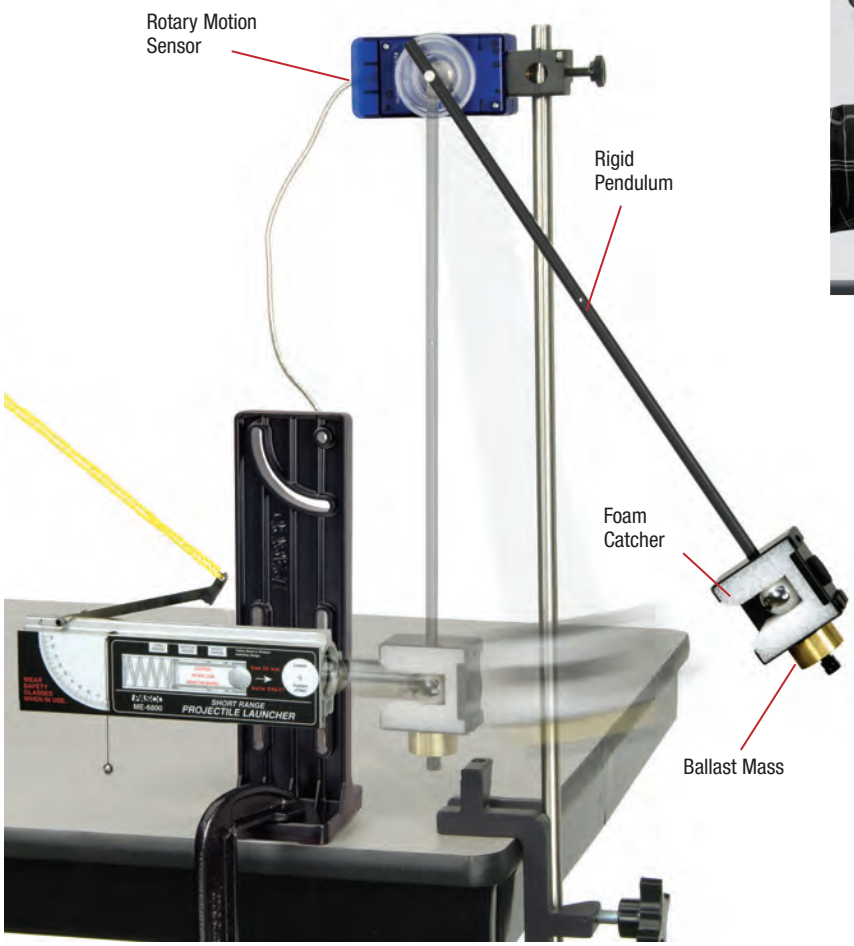
Ballistic Pendulum	ME-6830	
Ballistic Pendulum (without launcher)	ME-6831	
Recommended:		
Spherical Mass Set	ME-8968	p. 143
Shoot-the-Target	ME-6853	p. 141
Time-of-Flight Accessory	ME-6810A	p. 141
Large C Clamp (6 Pack)	SE-7285	p. 143

Ballistic Pendulum Accessory

ME-9892

- Accessory to the Rotary Motion Sensor
- Designed for use with Projectile Launcher (ME-6800) on page 138.
- Low cost

This Ballistic Pendulum Accessory uses a Rotary Motion Sensor to measure the speed of the catcher immediately after the collision, as well as the maximum height to which the pendulum swings. The Rotary Motion Sensor can also be used to measure the rotational inertia of the pendulum for a detailed study of the collision using conservation of angular momentum.

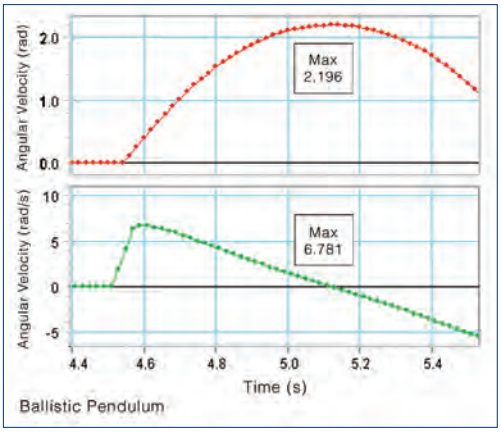


Mini Ballistic Pendulum Accessory

ME-6829

- Designed for use with the Mini Launcher (ME-6825B) on page 139.

Turn your PASCO Launcher into a Ballistic Pendulum using the Rotary Motion Sensor. Combine this accessory with the Mini Launcher and a Rotary Motion Sensor to study ballistic pendulums, momentum and energy.



Rotary Motion Sensor (required for use) allows measurement of the catcher's instantaneous velocity immediately after collision, as well as the total angle of rotation of the pendulum arm.

Both accessories include:

- Pendulum Arm with Catcher
- Ballast Mass
- Steel Ball

Order Information

Ballistic Pendulum Accessory	ME-9892	
Recommended:		
Projectile Launcher	ME-6800	p. 138
PASPORT Rotary Motion Sensor	PS-2120A	p. 41

Order Information

Mini Ballistic Pendulum Accessory	ME-6829	
Recommended:		
Mini Launcher	ME-6825B	p. 139
PASPORT Rotary Motion Sensor	PS-2120A	p. 41

Pulley Demonstration System

SE-8685

- Demonstrate the mechanical advantage of single or combination pulleys
- Complete stand-alone pulley apparatus
- Simple setup

Features:

- **Stable Base:** Easily attach two threaded 81 cm rods to the sturdy base. An eye-hook and capstan are included to demonstrate an entire pulley system.
- **Comprehensive:** Contains everything needed to effectively display the usefulness of pulleys, including slotted masses and mass hangers.
- **Several Pulley Types:** Reveal the benefits of single pulleys, tandem pulleys, quadruple pulleys and even the 4-step pulley. Combine several of them for an efficient pulley system.

Set up a double pulley and a single pulley, each with a 200 g mass. Simultaneously pull the string of each from the same vertical height down to the base. Observe that the mass of the single pulley moves twice as high as the double pulley with twice the force.

Includes:

- 20 cm x 81 cm base with eye-hook and capstan
- Threaded 81 cm rods (2)
- Clamps (2)
- Horizontal rod
- Hook collars (8)
- 90° clamp
- Single pulleys (2)
- Triple-tandem pulleys (2)
- Quadruple pulleys (2)
- Four-step pulley
- Slotted masses (13)
- Mass hangers (6)

Order Information

Pulley Demonstration System SE-8685

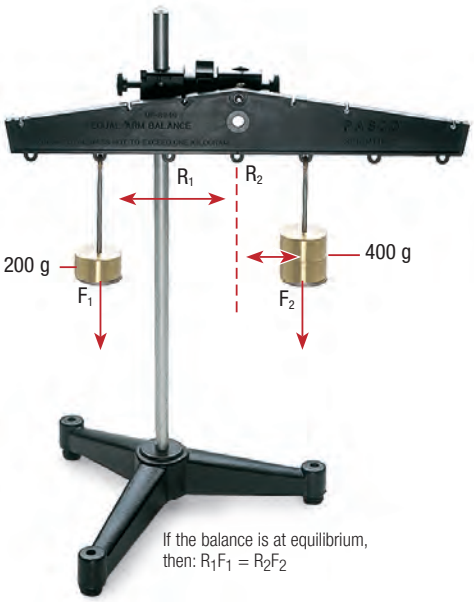
Equal Arm Balance

ME-8949

Developed for Workshop Physics® activities

WORKSHOP PHYSICS
Activity-Based Learning

The Equal Arm Balance was specially designed to simplify the study of torques. This balance has a ball-bearing pivot.



With 200 g and 400 g masses placed as shown above, the balance remains in equilibrium.

Specifications:

Total length: 34 cm
Maximum weight exerted on balance arm:: 1 kg or 10 N

Includes:

- Balance Arm with Ball-Bearing Pivot

Order Information

Equal Arm Balance..... ME-8949
Required:
Mass and Hanger Set..... ME-8979 p. 207

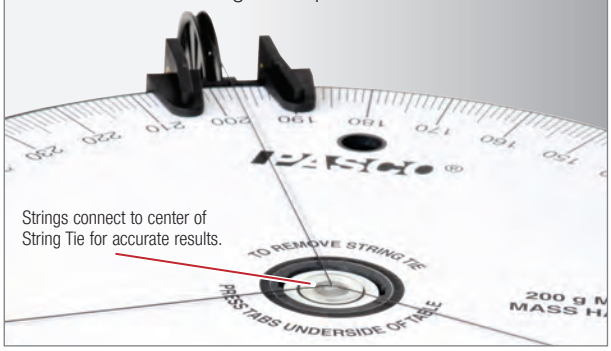
Super Pulley Force Table

ME-9447B

- High accuracy
- Easy, compact storage
- Inexpensive!

String Tie

String Tie is captured to make setup of hanging masses easy, but it freely floats over bulls-eye pattern to clearly show even small changes in equilibrium.



Adjustable height

The swivel feature of the pulleys can virtually eliminate parallax for more precise angle measurements.

Built-in Scale
Measure angles quickly and accurately.

Compact, Easy Storage

Mass and Hanger
(sold separately)

Change the mass by 1/2 gram or an angle by 1/2 degree and see an immediate change in the equilibrium.

Improved leg storage

The screw-in legs snap under the table for easy storage.

Improved stacking

Stacked tables are keyed together to eliminate slipping. Now you can store all your Force Tables in one convenient stack!

Includes:

- 25 cm diameter table with detachable legs
- Adjustable Super Pulleys with clamps (3)
- Spool of thread

Mass and Hanger Set is sold separately.

Order Information		
Super Pulley Force Table	ME-9447B	
Required:		
Mass and Hanger Set	ME-8979	p. 207
Additional Pulleys:		
Super Pulley with Clamp	ME-9448B	p. 151

Tension Protractor

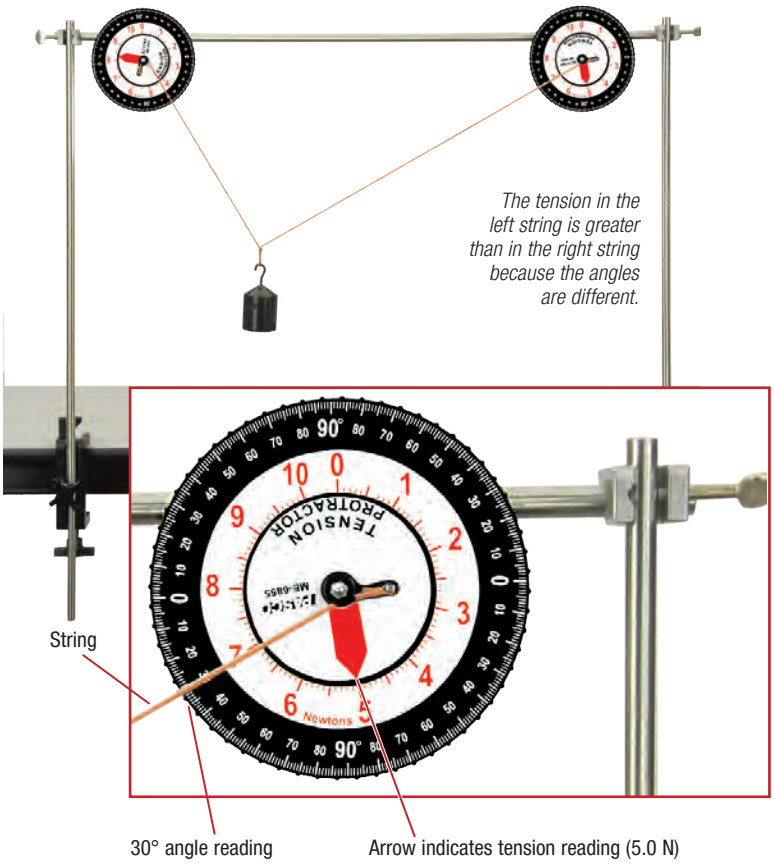
ME-6855

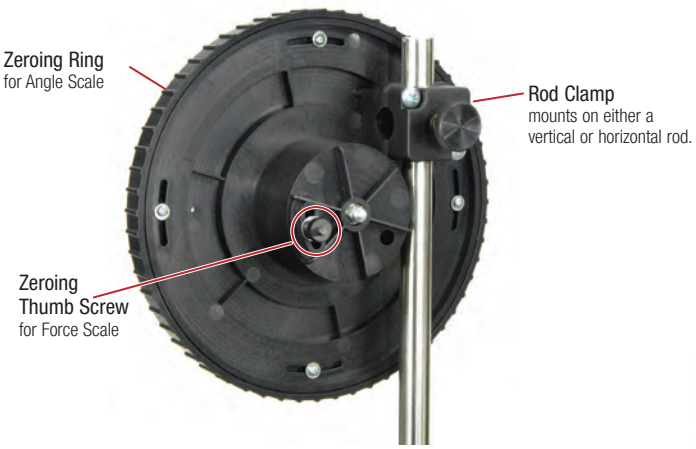
- Measure tension and angle with one device
- Large scale for viewing demonstrations
- Zero-adjust for torsion spring scale
- Built-in rod clamp

The Tension Protractor is a spring scale and a protractor integrated into one device. Perfect for static equilibrium experiments, the rotary dial indicates the tension in the string and the angle is read where the string passes over the degree scale on the outer ring. Since the Tension Protractor is supported on a rod, it has an advantage over other spring scales that tend to weigh down the string, changing the angle.

The string is wrapped once around a small pulley that is spring-loaded. The torsion spring scale is carefully calibrated at the factory and can be zeroed by the user using the thumb screw on the back. The red arrow that indicates tension is color-coded to match the Newton scale.

Even if the mounting rod is not plumb, the Tension Protractor's degree scale can be adjusted to read 90 degrees vertically by rotating the outer ring until the string with a hanging mass aligns with 90 degrees.





A 50 gram mass hangs vertically from the Tension Protractor: The tension reads 0.5 N as expected and the outer degree scale is dialed to align the 90° mark with the string. This compensates for unlevel tables or bent rods.

Specifications:
Force Range: 0 N to 10 N
Smallest Force Division: 0.1 N
Force Accuracy: ±4% of Reading
Angle Range: -90° to +90°
Smallest Angle Division: 1°
Diameter: 15 cm

Includes:
- One Tension Protractor

Order Information

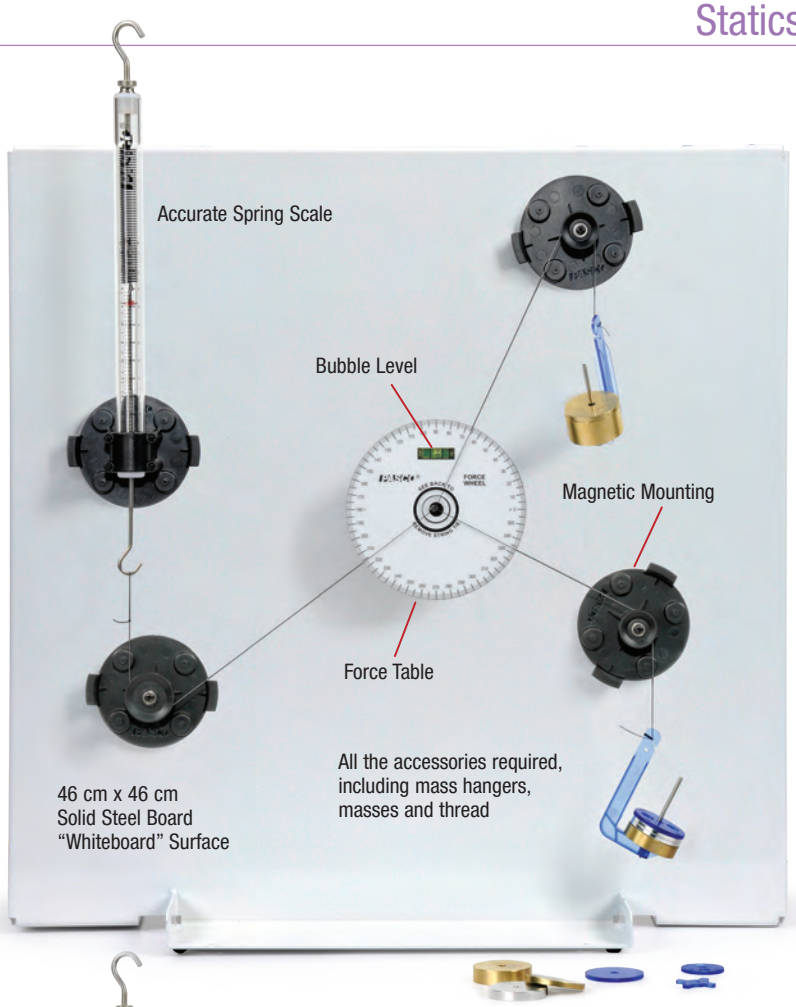
Tension Protractor	ME-6855	
Recommended:		
Large Table Clamp	ME-9472	p. 199
90 cm Stainless Steel Rod	ME-8738	p. 196
Multi-Clamp	ME-9507	p. 198
Hooked Mass Set	SE-8759	p. 207

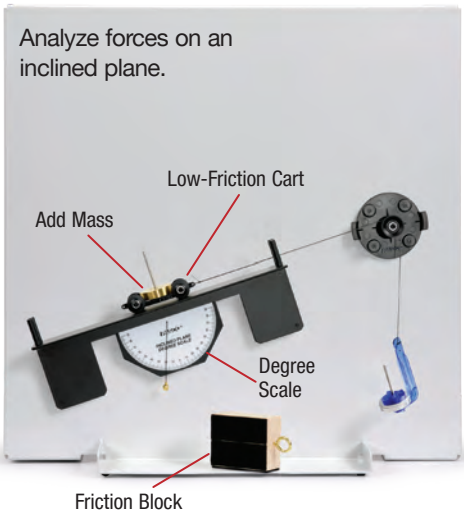
Statics System

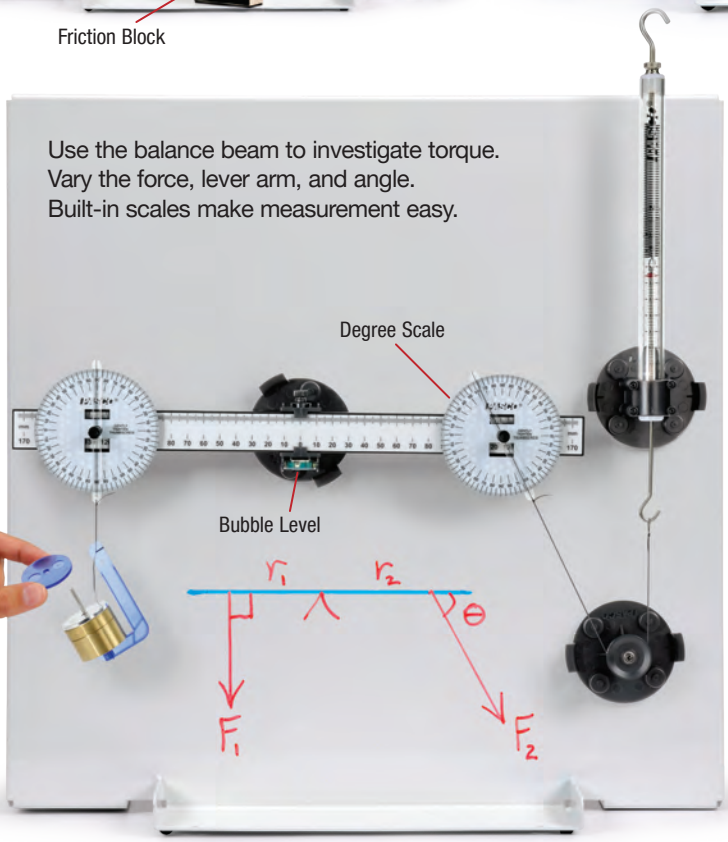
ME-9502

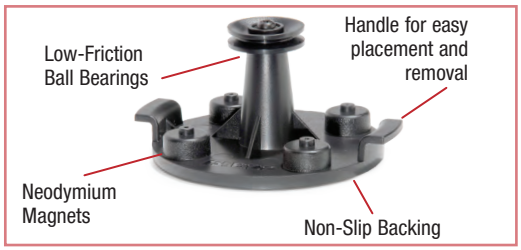
- Everything required for 15 experiments
- Comprehensive — from vector addition to simple machines
- Easy Setup — magnetic mounting

The Statics System is a versatile lab system designed for demonstrating the basic concepts of vector forces, torques, center of mass, simple machines, and more. When combined with the ME-9503 Statics Board (sold separately), the Statics System doubles in width, making it ideal for demonstrations.









Easy Storage

Store magnetic components on back of experiment board.

Includes:

- Experiment Board
- Components
- Mass Set
- Comprehensive Manual with 16 Copy-Ready Experiments

Order Information

Statics System	ME-9502
Additional Equipment:	
Statics Board	ME-9503
Spring Scale	ME-9824A
Statics Spares Package	ME-9504

Meter Stick Torque Set

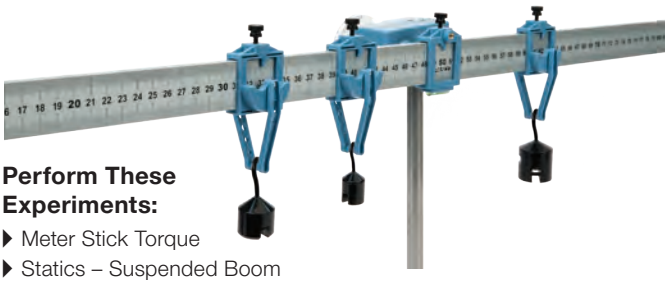
ME-7033

Create an improved version of the meter stick balance by mounting the Pivot on a rod stand and using an aluminum meter stick. The Meter Stick Clamp has a built-in bubble level to indicate when the meter stick is level.

The Meter Stick Clamp fits onto either the provided dual-ball bearing Pivot or a Rotary Motion Sensor. It has two mounting points: One is centered on the center of the meter stick for rotation and pendulum experiments and the other is offset so the center of mass of the meter stick is below the pivot point for stability in meter stick torque experiments.

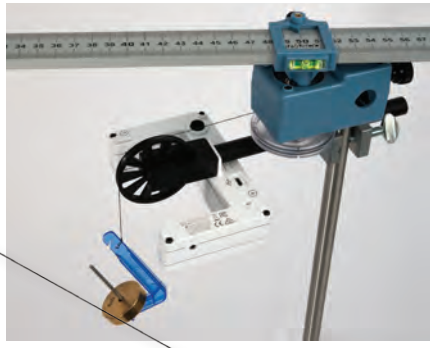
The mass hangers have a mass of 10 grams each, which makes it easy to add to the hanging mass. The Mass Hangers have a degree scale so the angle of the applied force can be read. The Mass Hangers can be used in two ways:

- As a mass hanger in a meter stick torque experiment with the masses hanging from it
- Upside-down, as an anchor point for a suspension string at any angle in a statics experiment.



Perform These Experiments:

- Meter Stick Torque
- Statics – Suspended Boom
- Physical Pendulum



The complete Meter Stick Torque Set includes the Pivot, Aluminum Meter Stick, Meter Stick Clamp, and three Mass Hangers. Shown in use with Wireless Force Sensor.

Features:

- Dual ball bearings in Pivot
- Mount at any height on any rod stand
- Mass hangers (10 g) have built-in angle indicators
- Built-in bubble level on Pivot meter stick clamp

Specifications:

Aluminum Meter Stick Dimensions: 6.95 mm x 28.0 mm x 1.0 m
Aluminum Meter Stick: Approximate mass 150 g
Pivot Slotted Shaft: 1/4-inch (6.35 mm) diameter, 16 mm long out both sides
Mass of Hangers: 10 g

Includes:

- Pivot: ME-7034
- Meter Stick Torque Mass Hanger Set: ME-7035
- Aluminum Meter Stick

Order Information

Meter Stick Torque Set ME-7033
Required:
Rod Stand ..... p. 196

Meter Stick Torque Mass Hanger Set

ME-7035

Three Mass Hangers and the Meter Stick Clamp shown in use with the Pivot and the Aluminum Meter Stick.

Replacement set of three Mass Hangers and one Meter Stick Clamp for doing meter stick torque experiments.

The meter stick clamp fits onto either a Pivot (ME-7034) or a Rotary Motion Sensor.

Includes:

- Meter Stick Clamp
- Mass Hangers (3)

Order Information

Meter Stick Torque Mass Hanger Set ME-7035
Required:
Aluminum Meter Sticks (6-pack) ..... ME-7032 p. 202

Pivot

ME-7034

The Pivot is a general purpose rotation device that allows you to mount it on a rod stand to perform rotation experiments in the horizontal or vertical planes.

Perform These Experiments:

- Meter Stick Torque
- Rotational Inertia
- Physical Pendulum
- Centripetal Acceleration

Includes:

- Pivot
- 3-step Pulley

This Pivot can be used as a fulcrum for meter stick torque experiments or as a rotational platform for rotational inertia experiments.

Order Information

Pivot ME-7034

Super Pulley

ME-9450A

- 20 N max load
- Nearly frictionless
- Durable

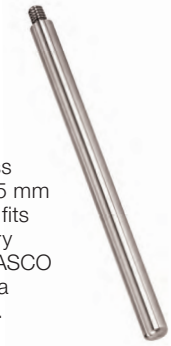
The PASCO Super Pulley is the standard in physics labs. Its low-friction design produces excellent results. The precision spacing of the 10 spokes makes it ideal for photogate monitoring with PASCO's computer interfaces and photogate systems.

Order Information

Super Pulley ME-9450A

Pulley Mounting Rod

SA-9242



This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Clamp. It has a standard 1/4"-20 thread.

Order Information

Pulley Mounting Rod SA-9242

Wireless Smart Pulley

PS-3704

The Wireless Smart Pulley attaches directly to the Wireless Smart Gate, providing a simple, low-friction system to measure position, velocity and acceleration.

Remove the pulley to use the photogate for standard photogate experiments.

Includes:

- Wireless Smart Gate (1) PS-3225
- Super Pulley (1) ME-9450A
- Super Pulley Rod (1)

Order Information

Wireless Smart Pulley PS-3704

Super Pulley with Mounting Rod

ME-9499

This Super Pulley is mounted on a rigid plastic mounting rod (12.7 mm diameter, 14 cm long) and fits most standard laboratory clamps.

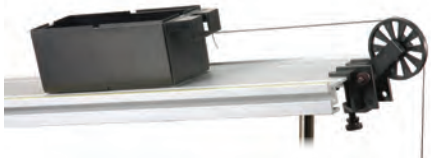
Order Information

Super Pulley With Mounting Rod ME-9499

Super Pulley with Clamp

ME-9448B

Upgrade your force table and inclined plane experiments. The Super Pulley with its integral clamp makes setup and alignment easy. The pulley height is fully adjustable, so you can skim the top of a force table for parallax-free readings. Yet you can keep the force parallel to the track on an inclined plane, as shown in the photo below. Fits tables up to 2.0 cm (13/16 in.) thick.



Order Information

Super Pulley with Clamp ME-9448B

Mounting Rods (10 Pack)

ME-9483

These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) screw into a Super Pulley.

Order Information

Mounting Rods (10 Pack) ME-9483

Photogate & Pulley System

ME-6838A

The Super Pulley attaches directly to a Photogate Head, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.

Order Information

Photogate & Pulley System ME-6838A

Atwood's Machine

SA-9241

Two Super Pulleys mounted on a 6.4 cm long rod produce a classic, low-friction introduction to Newton's Second Law. The instruction sheet fully describes both the experiment and the theory.

Includes:

- 2 Pulleys
- 1 Connecting Rod

Order Information

Atwood's Machine SA-9241

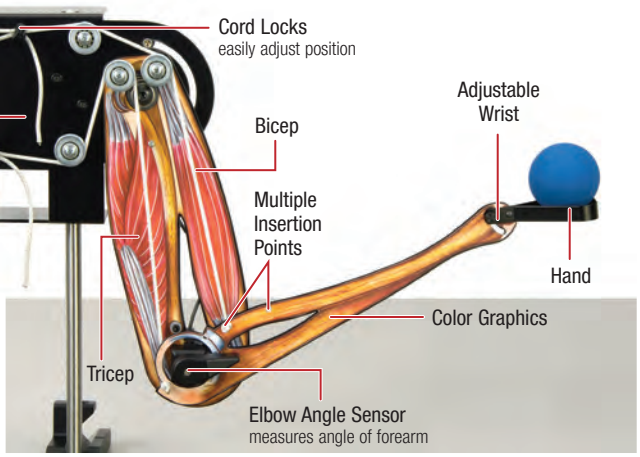
Human Arm Model

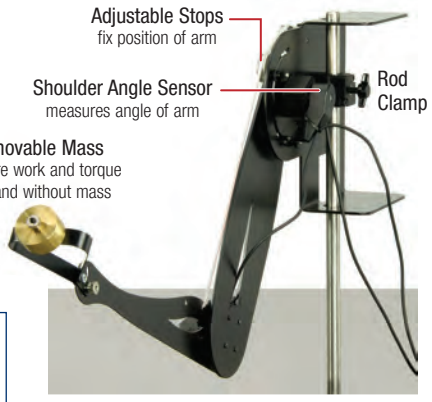
PS-2611

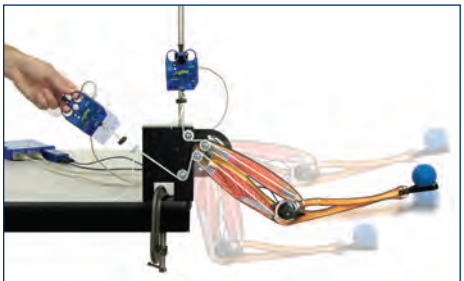
- Working Model of the Human Arm
- Associate Triceps/Biceps Muscle Action with Arm Motion
- Measure Torque Resulting from Lifting Weights
- Actually Throws a Ball

The Human Arm Model simulates the muscles and motion of an actual human arm. To activate the arm motion, students pull on the cord with a Force Sensor. Changes in position are measured at the shoulder and elbow using the two built-in potentiometers plugged into one Angle Sensor (PS-2139), included with PS-2611. From this information, the torque applied when lifting an object can be determined. Also, students can evaluate the work done by the arm in throwing a ball and the resulting kinetic energy delivered to the ball.

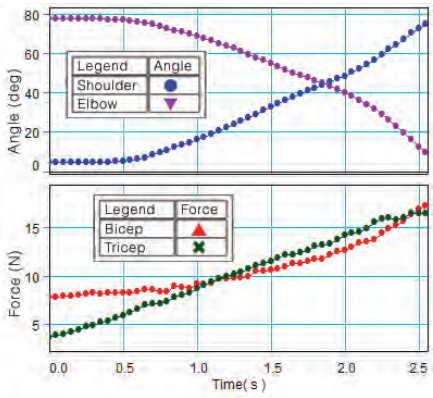
The Arm can perform many types of motion such as extending and lifting an object, curling, or throwing a ball overhand. Different arm muscles are activated depending on which pulleys are selected. Static force measurements can also be made to see how the muscle tension changes at various arm positions.





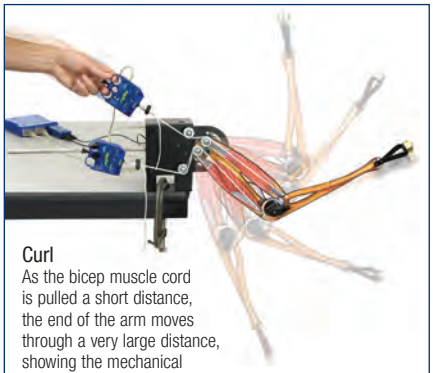


Extension
As the tricep muscle is pulled with a Force Sensor, another fixed Force Sensor records the tension in the bicep muscle cord.

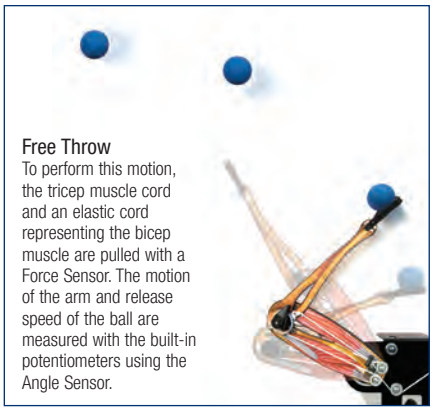


Angles and Forces During Extension
The upper graph shows the angles of the elbow (violet trace) and the shoulder (blue) as the arm is extended as shown in the picture above. Shown in the lower graph, the bicep tension (red) has little change at first and then rises sharply as the arm reaches out, while the tricep tension (green) rises steadily.

Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.



Curl
As the bicep muscle cord is pulled a short distance, the end of the arm moves through a very large distance, showing the mechanical advantage of the arm. The load at the end of the arm can be varied.



Free Throw
To perform this motion, the tricep muscle cord and an elastic cord representing the bicep muscle are pulled with a Force Sensor. The motion of the arm and release speed of the ball are measured with the built-in potentiometers using the Angle Sensor.

Includes:

- Arm
- Angle Sensor
- Removable Mass
- Cord & Cord Locks
- Mounting Bracket with Rod
- Force Sensor Mounting Rod
- Rubber Ball

Order Information

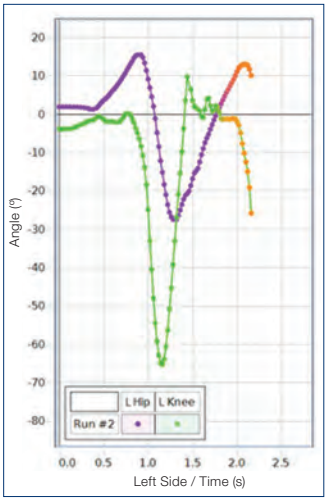
Human Arm Model PS-2611
Human Arm Model
Without Sensors ME-6807A
Required:
"C" Clamp or Large Table Clamp
PASPORT
Force Sensor .....PS-2104 p. 42
850 Universal
Interface .....UI-5000 p. 26

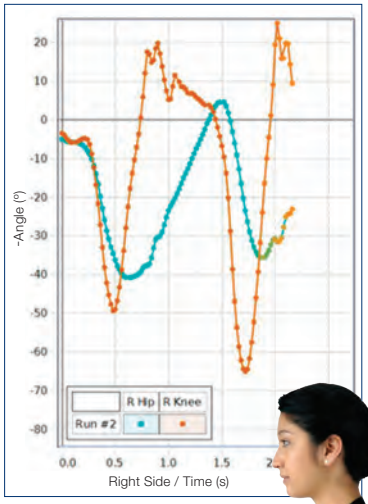
Goniometer

PS-2137

- Accurately measures joint movements
- Flexible mounting options for hip, knee, and elbow

The SPARKlink Air Interface is used here with two Angle Sensors, part of the PS-2137 Goniometer System. The data is sent via Bluetooth® to a desktop computer and displayed live with the video being recorded by a web cam.





Data shows position of both left and right knee and hip joints during walking.

Capture data remotely!

The SPARKlink Air Interface records the sensor data and sends it to the computer via Bluetooth.

Goniometer Probes

The probes are fastened in place using the blue Velcro® straps and can be positioned to measure the motion of the knee, hip, or elbow.

Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.

Specifications:
Range: 0 to 340°
Accuracy: ±1° (calibrated), ±3° (uncalibrated)
Resolution: 0.1°
Maximum Sample Rate: 500 Hz

Includes:
- Goniometer Probe
- Angle Sensor
- Velcro Straps

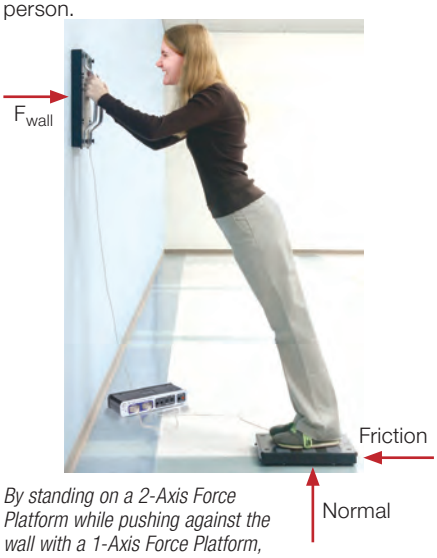
Order Information

Goniometer Sensor	PS-2137	
Recommended:		
SPARKlink Air	PS-2011	p. 60
Additional Goniometer Straps	PS-2547	
Additional Goniometer Probe	PS-2138	p. 53

Forces on the Human Body

- Measure forces on human body
- 1-axis and 2-axis force platforms
- Precise and fast

Explore the forces exerted on the human body in everyday situations, sports, and large-scale physics experiments. The force platforms are designed to measure large forces, such as the weight of a person.



By standing on a 2-Axis Force Platform while pushing against the wall with a 1-Axis Force Platform, a real-life statics problem can be analyzed.

Confirm Newton's Third Law by pushing on a Force Platform using two sets of handles (available separately). Handles bolt onto the Force Platform (1-axis or 2-axis) and can be mounted on one or both sides.

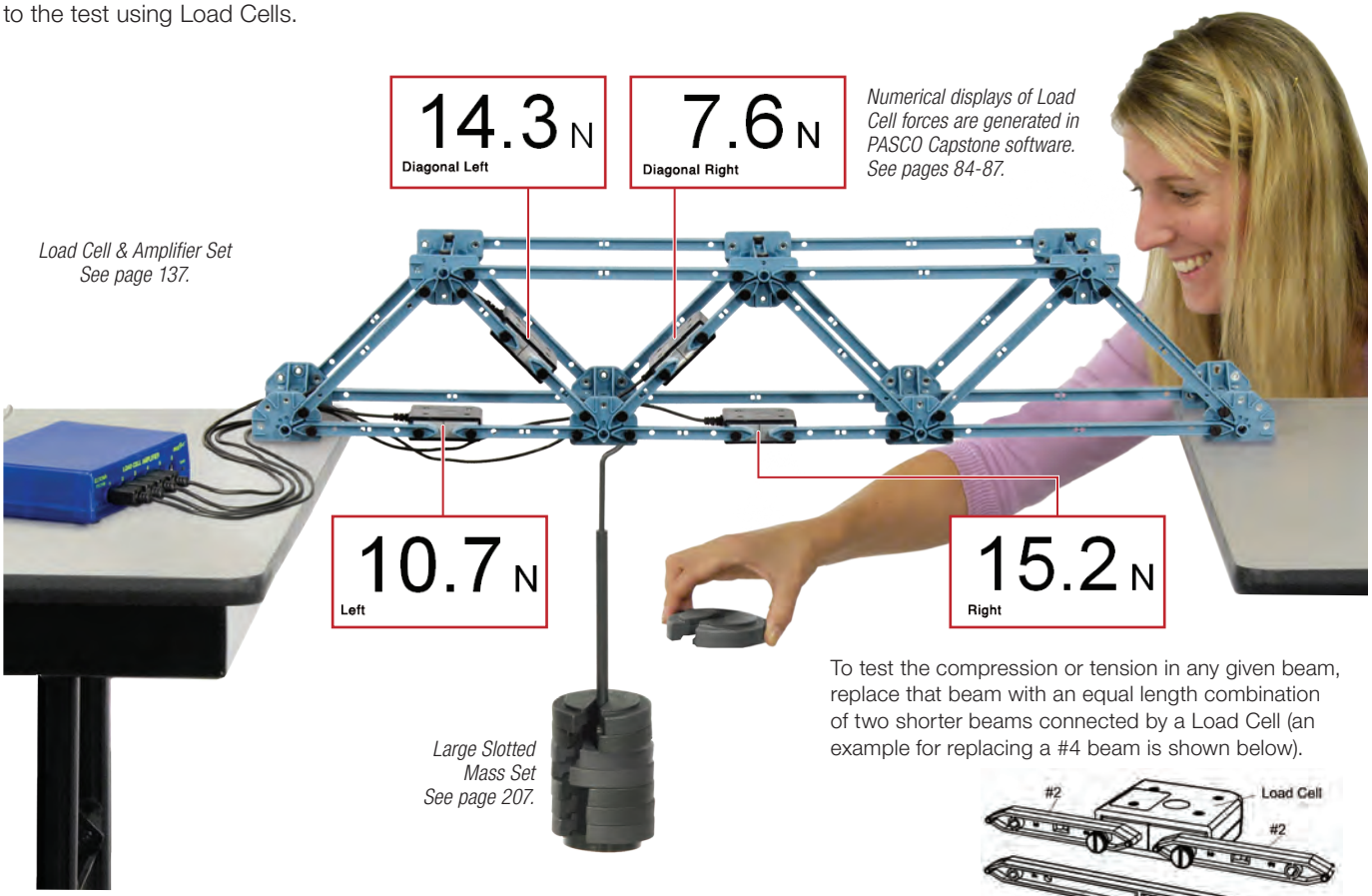
Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.

Order Information

PASPORT 2-Axis Force Platform	PS-2142	p. 43
PASPORT Force Platform	PS-2141	p. 43
Handle Set, Force Platform	PS-2548	p. 43

Construct and study real-world designs with PASCO's Structures System.

The PASCO Structures System is a one-of-a-kind learning tool designed especially for engineering education. With just a few simple pieces, these sets take students beyond traditional toothpick models, empowering them to construct and measure a variety of structures that look and behave like real-world designs. Engineer a simple truss, working crane, or towering skyscraper; then put it to the test using Load Cells.

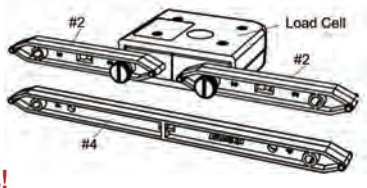


Numerical displays of Load Cell forces are generated in PASCO Capstone software. See pages 84-87.

Load Cell & Amplifier Set See page 137.

Large Slotted Mass Set See page 207.

To test the compression or tension in any given beam, replace that beam with an equal length combination of two shorter beams connected by a Load Cell (an example for replacing a #4 beam is shown below).



Explore the full PASCO Structures System – from trusses to towers to bridges!

Truss Set See page 156.

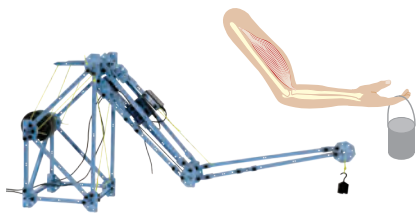
Bridge Set See page 157.

Materials Tester
Cast Beams Set
See page 162.
See page 168.

Advanced Set See pages 158-159.

Large Structures Set
See pages 160-161.

Human Structures Set See page 165.



Wired Load Cells and Amplifiers

Load Cell 100 N PS-2200
Load Cell 5 N PS-2201

Load Cells are available in two different ranges: ±100 N and ±5 N. These Load Cells are designed to be inserted into structures without changing the length of the member. A Load Cell attached to two shorter beams is equal in length to a longer beam.

These Load Cells require an amplifier (shown below). Load Cells of different capacities can be used with the same amplifier in any combination.

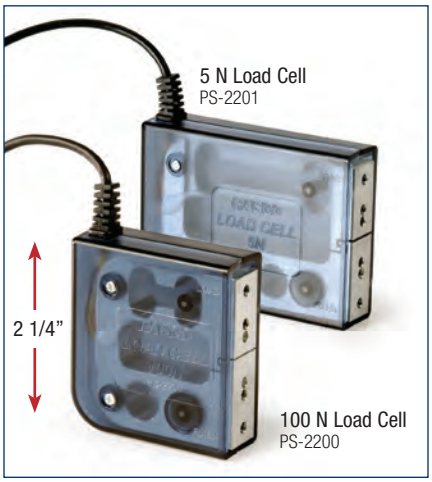
These Load Cells are constructed to reject side-loading, giving a reading of pure compression or tension. The semi-transparent case lets students see the strain gauge and beam inside.

PS-2200 Specifications:
Range: ±100 N
Accuracy: ±1% (±1 N)
Resolution: 0.02 N
Safe Overload: ±150 N

PS-2201 Specifications:
Range: ±5 N
Accuracy: ±1% (±0.05 N)
Resolution: 0.001 N
Safe Overload: ±7.5 N

Order Information

100 N Load Cell PS-2200
5 N Load Cell PS-2201



Mix 5 N and 100 N load cells on the same amplifier.

PASPORT Dual Load Cell Amplifier

PS-2205

The Dual Load Cell Amplifier is for applications where only one or two load cells are required, such as measuring the force acting on the top of a roller coaster loop. If you only want to examine the forces in a bridge one at a time, a single load cell can be moved around the bridge. The Amplifier accepts 100 N and 5 N load cells. Each port has a maximum data sample rate of 1000 Hz.

Order Information

PASPORT Dual Load Cell Amplifier PS-2205
Required for use:
PASPORT Interface ..... p. 24
100 N Load Cell PS-2200
5 N Load Cell PS-2201

Also available at a discount:

PASPORT Load Cell and Dual Amplifier Set PS-2206
Set includes:
Dual Load Cell Amplifier (PS-2205)
Load Cell 100 N (PS-2200)
Requires PASPORT Interface (p. 24)

PASPORT Load Cell Amplifier

PS-2198

This Load Cell Amplifier can accommodate up to six load cells and utilizes a single PASCO interface port to connect to a computer's USB port. Students can insert up to six load cells at various points of their structures to extensively analyze their bridges. The Amplifier is compatible with both 5 and 100 N Load Cells, and features a maximum data sampling rate of 500 Hz per port.

Order Information

PASPORT Load Cell Amplifier PS-2198
Required for use:
PASPORT Interface ..... p. 24
100 N Load Cell PS-2200
5 N Load Cell PS-2201

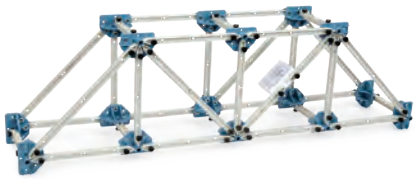
Also available at a discount:

Load Cell and Amplifier Set PS-2199
Set includes:
Load Cell Amplifier (PS-2198)
Load Cell 100 N (PS-2200)
Requires PASPORT Interface (p. 24)

Wireless Load Cell and Accelerometer

PS-3216

- Measures loads in structures
- Built-in 3-axis accelerometer measures bridge vibrations
- No wires to interfere with motion



The Wireless Load Cell and Accelerometer is designed to measure loads in all PASCO Structures Systems. It is particularly useful for measuring vibrations because it includes an accelerometer and has no wires to impede movement.

Specifications:
Load Cell
Range: ±50 N
Resolution: 0.03 N
Accuracy: 0.1 N
Maximum Sample Rate: 2 kHz
Acceleration
Range: ±16 g (three axis)
Maximum Sample Rate: 500 Hz
Measurements: Force; Acceleration (3 axes and resultant)
Logging: Yes
Battery: Rechargeable Lithium-Polymer
Connectivity: Direct USB or via Bluetooth 4.0

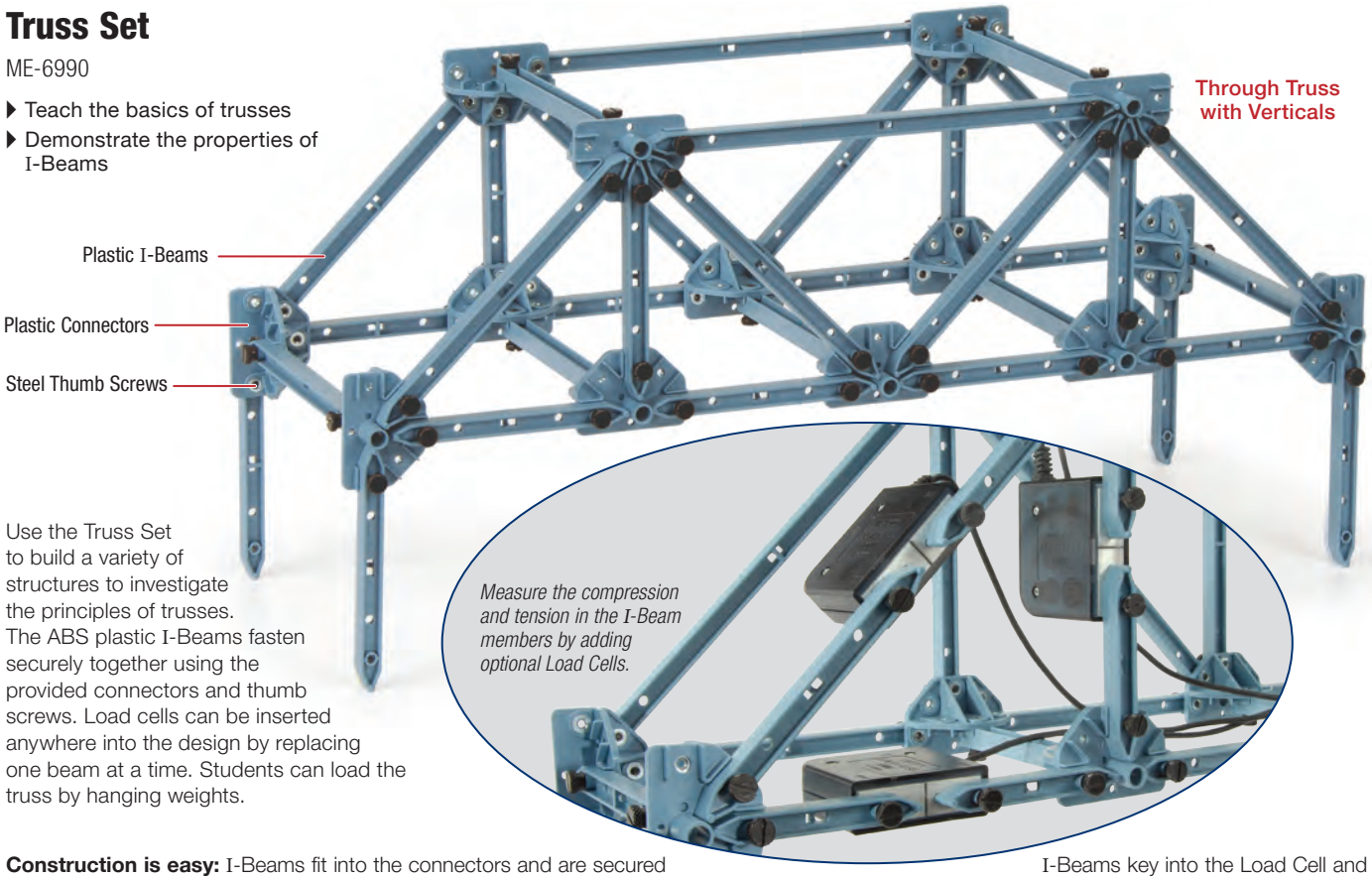
Order Information

Wireless Load Cell and Accelerometer PS-3216
Shown in use with:
Building Better Bridges Kit ME-3581
(Includes PS-3216)

Truss Set

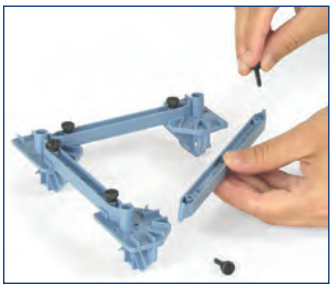
ME-6990

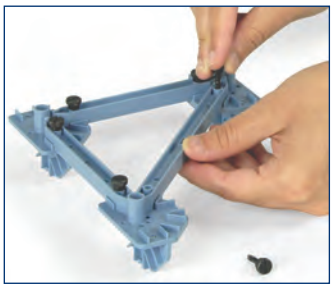
- Teach the basics of trusses
- Demonstrate the properties of I-Beams

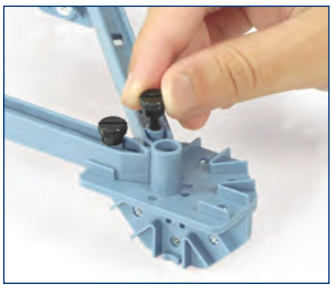


Use the Truss Set to build a variety of structures to investigate the principles of trusses. The ABS plastic I-Beams fasten securely together using the provided connectors and thumb screws. Load cells can be inserted anywhere into the design by replacing one beam at a time. Students can load the truss by hanging weights.

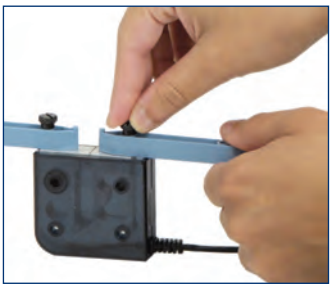
Construction is easy: I-Beams fit into the connectors and are secured with thumbscrews. Thumbscrews are also slotted so a screwdriver can be used.

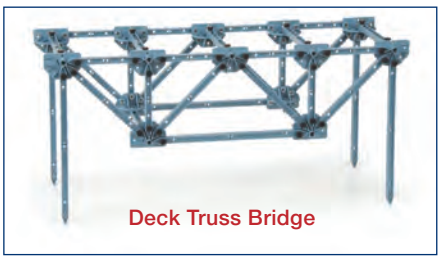




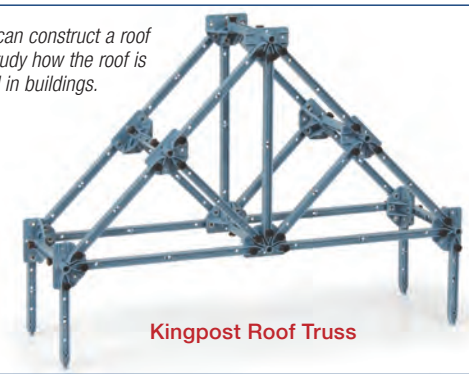


I-Beams key into the Load Cell and are fastened with thumbscrews.




Deck Truss Bridge

Students can construct a roof truss to study how the roof is supported in buildings.


Kingpost Roof Truss

Includes:

- I-Beam #5 24 cm long (8)
- I-Beam #4 17 cm long (18)
- I-Beam #3 11.5 cm long (18)
- I-Beam #2 8 cm long (8)
- I-Beam #1 5.5 cm long (8)
- Connectors (14)
- Screws (75)
- Instruction Manual

Order Information

Truss Set ME-6990

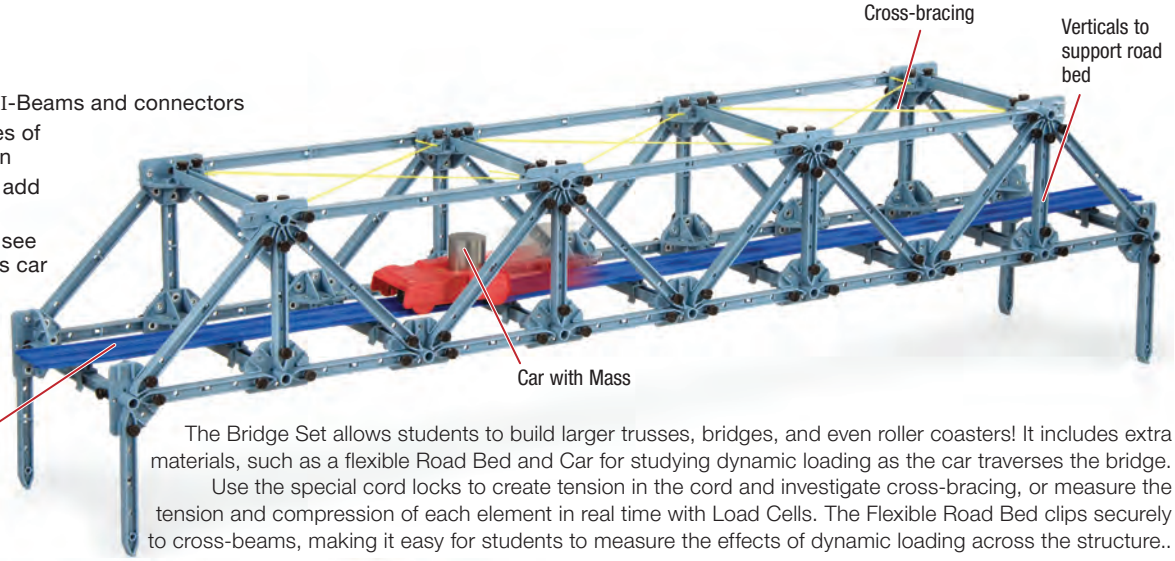
Recommended:

Load Cell and Amplifier Set ..... PS-2199 p. 44

Bridge Set

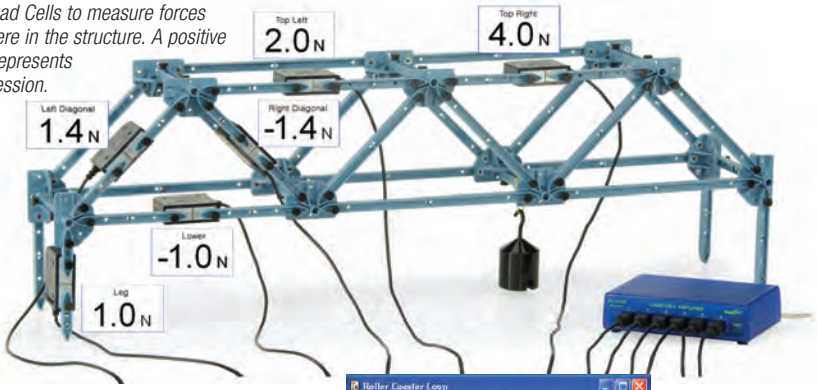
ME-6991

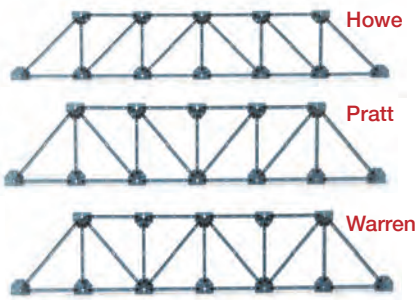
- Larger quantity of I-Beams and connectors
- Study the principles of bridge construction
- Road bed and car add realism to bridges
- Add Load Cells to see dynamic loading as car traverses bridge



The Bridge Set allows students to build larger trusses, bridges, and even roller coasters! It includes extra materials, such as a flexible Road Bed and Car for studying dynamic loading as the car traverses the bridge. Use the special cord locks to create tension in the cord and investigate cross-bracing, or measure the tension and compression of each element in real time with Load Cells. The Flexible Road Bed clips securely to cross-beams, making it easy for students to measure the effects of dynamic loading across the structure..

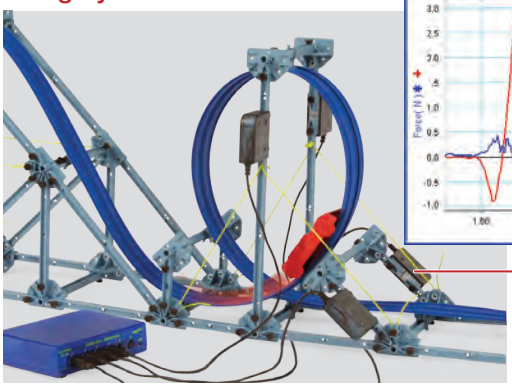
Add Load Cells to measure forces anywhere in the structure. A positive value represents compression.

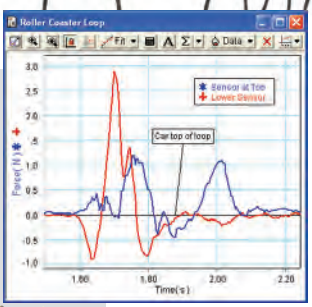




Students can build several types of fundamental bridges including Howe, Pratt, and Warren bridges.

Design your own roller coaster!

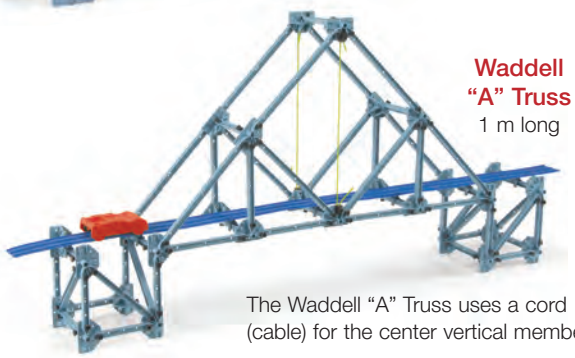




Add Load Cells to measure the forces needed to support the track as the car goes up and over the loop.

Deck Truss

80 cm long



Waddell "A" Truss

1 m long

The Waddell "A" Truss uses a cord (cable) for the center vertical member.

Includes:

- I-Beam #5 (16) 24 cm long (16)
- I-Beam #4 (36) 17 cm long (36)
- I-Beam #3 (36) 11.5 cm long (36)
- I-Beam #2 (16) 8 cm long (16)
- I-Beam #1 (16) 5.5 cm long (16)
- Connectors (28)
- Screws (150)
- Flexible road bed (3 m)
- Track coupler
- Road bed clips (24)
- Car with flag and mass
- Starter bracket
- Cord tensioning clips (32)
- Yellow cord (1 roll)
- Instruction manual

Order Information

Bridge Set.....ME-6991

Recommended:

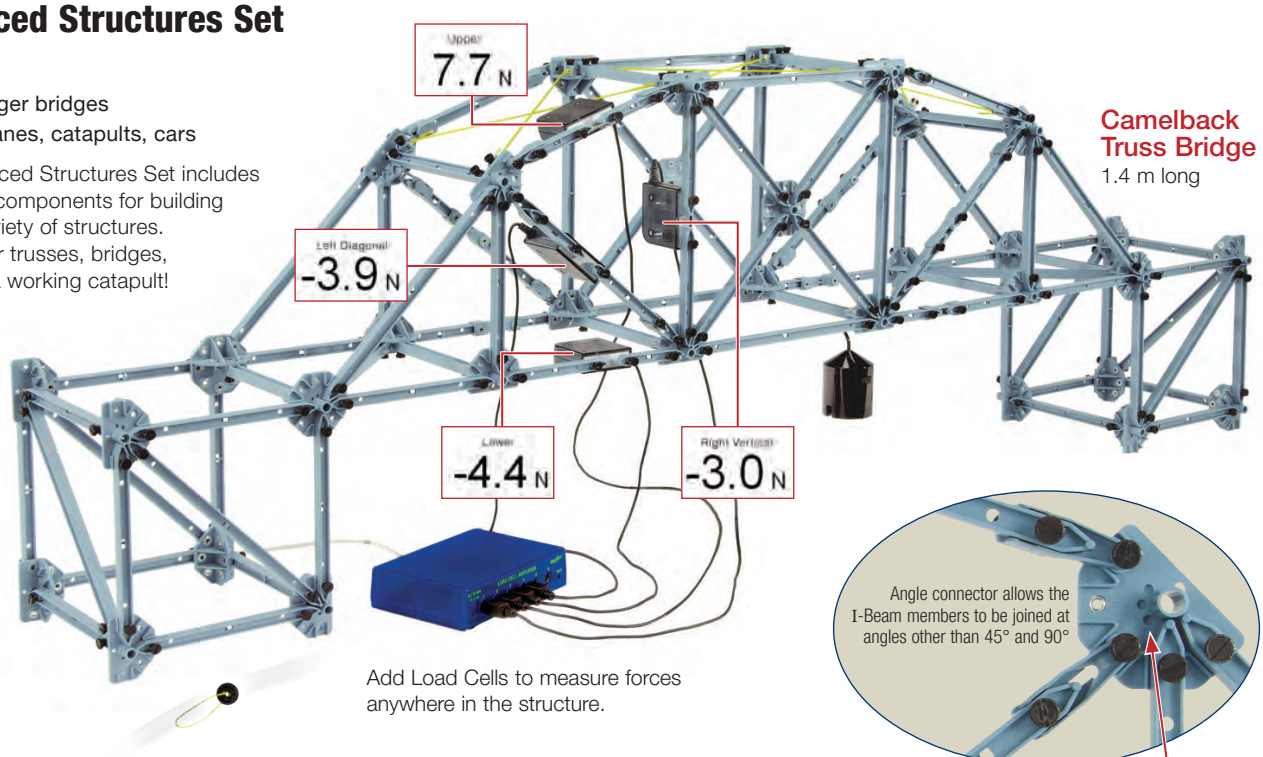
Load Cell and Amplifier Set.....PS-2199 p. 44

Advanced Structures Set

ME-6992B

- Build larger bridges
- Build cranes, catapults, cars

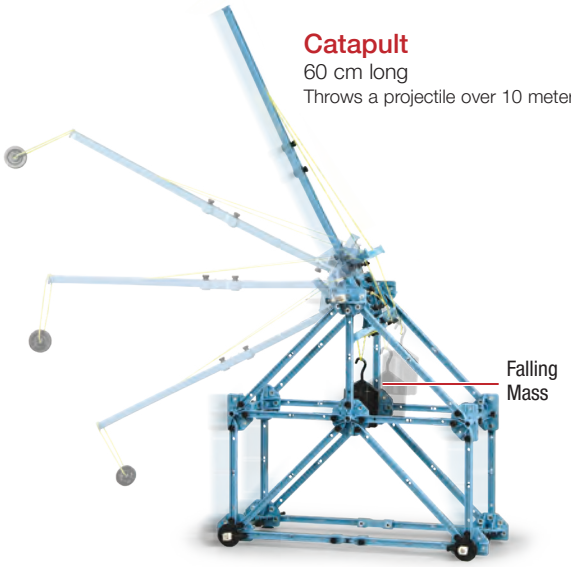
The Advanced Structures Set includes additional components for building a wider variety of structures. Build larger trusses, bridges, and even a working catapult!



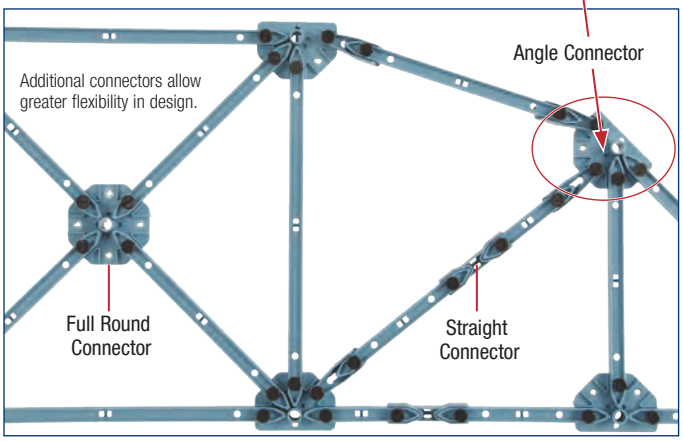
Camelback Truss Bridge
1.4 m long

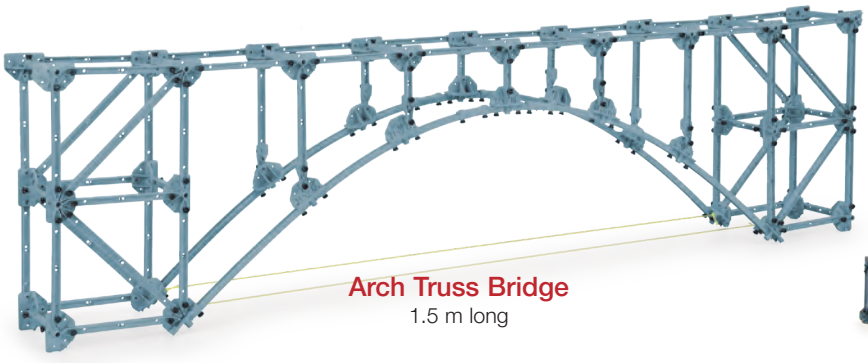
Add Load Cells to measure forces anywhere in the structure.

Catapult
60 cm long
Throws a projectile over 10 meters!

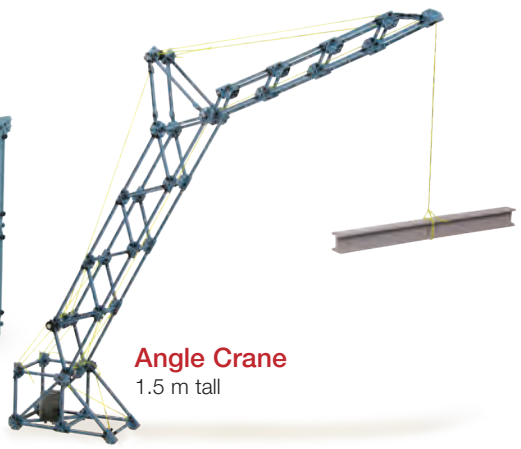


Wheels allow catapult to move.





Arch Truss Bridge
1.5 m long

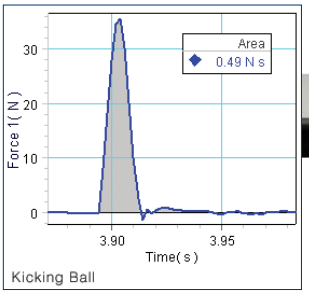


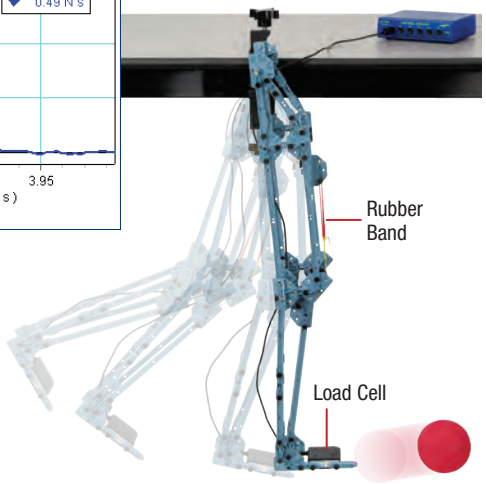
Angle Crane
1.5 m tall

Also see the Tower Crane on page 161.

Human Leg Model

The articulated leg, shown below, uses a rubber band (not included) for the quadriceps and has a load cell on the foot to measure the force that the "toe" exerts on the ball. The impulse (area under the curve) is equal to the resulting momentum of the ball.

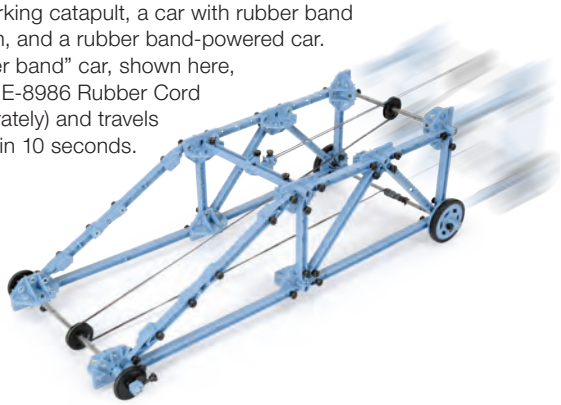




See page 165 for more Human Structures.

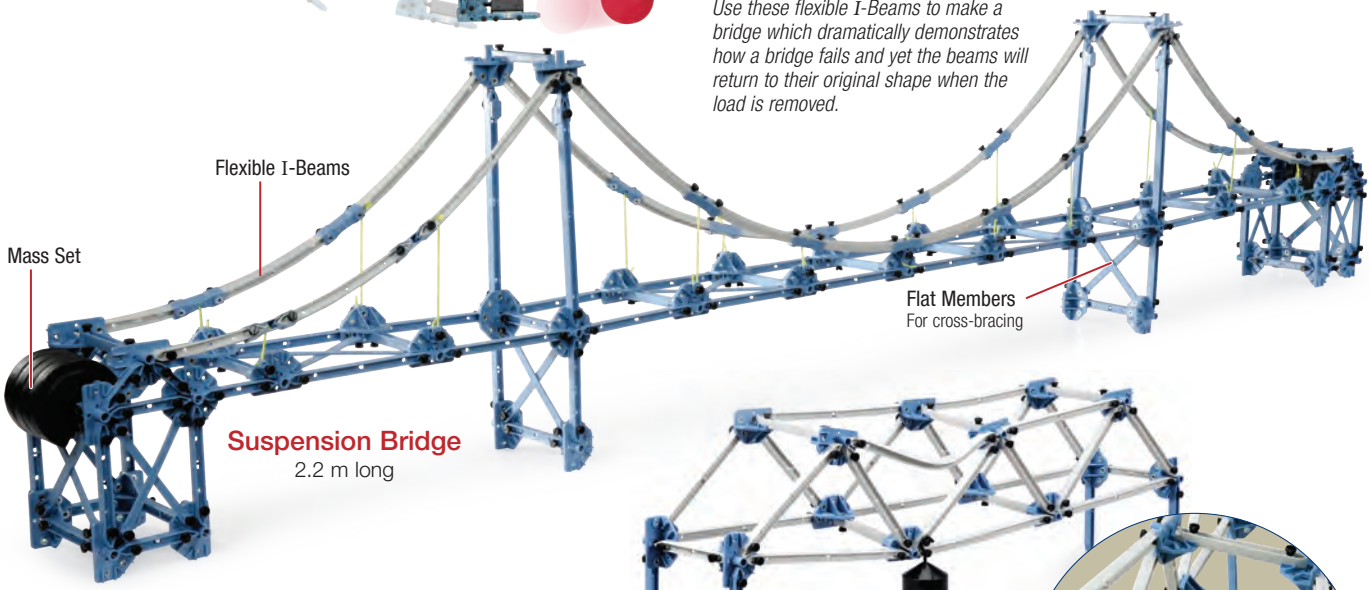
Rubber Band Car

Build a working catapult, a car with rubber band suspension, and a rubber band-powered car. The "rubber band" car, shown here, uses the ME-8986 Rubber Cord (sold separately) and travels over 50 ft. in 10 seconds.

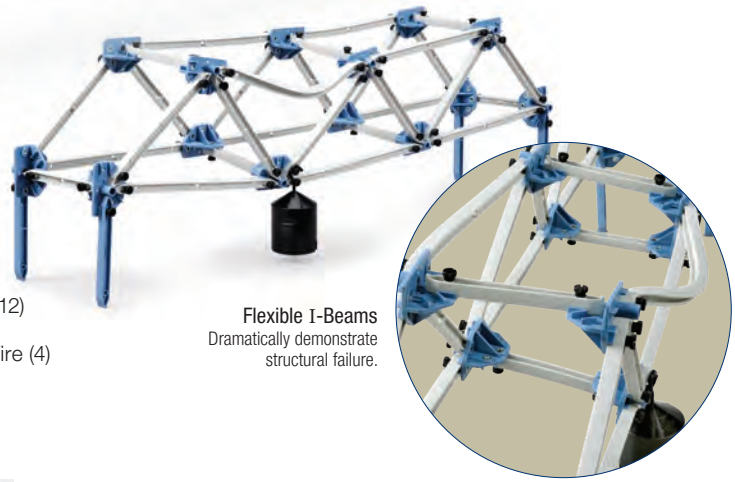


Use these flexible I-Beams to make a bridge which dramatically demonstrates how a bridge fails and yet the beams will return to their original shape when the load is removed.

For more examples using the Advanced Structures Set go to pasco.com/structures



Suspension Bridge
2.2 m long



Flexible I-Beams
Dramatically demonstrate structural failure.

Includes:

- Force Platform Bracket (2)
- I-Beam #5 24 cm long (24)
- I-Beam #4 17 cm long (54)
- I-Beam #3 11.5 cm long (54)
- I-Beam #2 8 cm long (24)
- I-Beam #1 5.5 cm long (24)
- Flex I-Beam #5 24 cm long (10)
- Flex I-Beam #4 17 cm long (18)
- Flex I-Beam #3 11.5 cm long (18)
- Flat Beams (3 lengths) (16)
- Axles (3 lengths) (2)
- Connectors (42)
- Cord Tensioning Clips (32)
- Round and Flat Connectors (6)
- PAStrack Fasteners (6)
- Angle and Straight Connectors (24)
- Sliding Connector (12)
- Pulleys, O-rings, Spacers (12)
- Collets (24)
- Drive Wheel with Rubber Tire (4)
- Structures Rod Clamps (2)
- Screws (300)
- Yellow Cord (1 roll)
- Instruction Manual

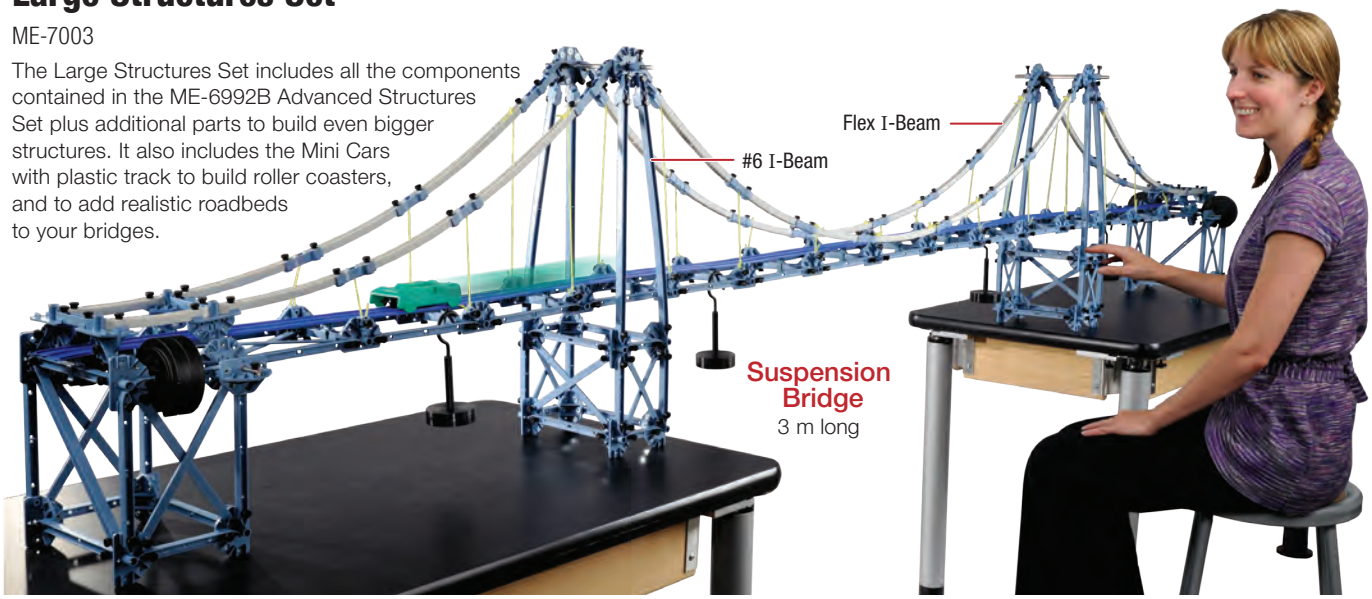
Order Information

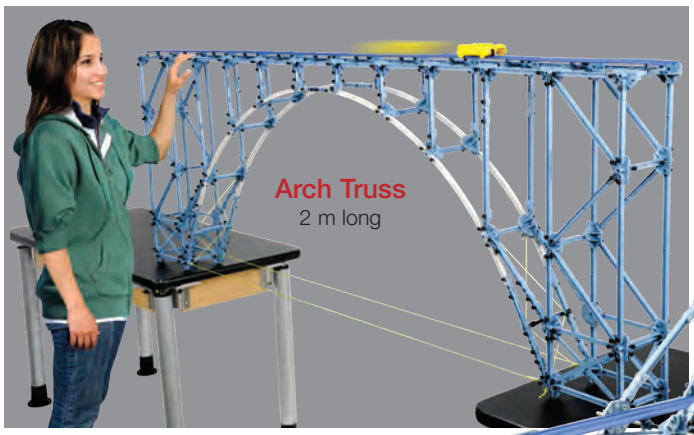
Advanced Structures Set	ME-6992B	
Shown in use with:		
Load Cell and Amplifier Set (includes four load cells)	PS-2199	p. 44
100 N Load Cell	PS-2200	p. 44
Large Slotted Mass Set	ME-7566	p. 207
Rubber Cord for IDS System (30m Spool)	ME-8986	p. 122

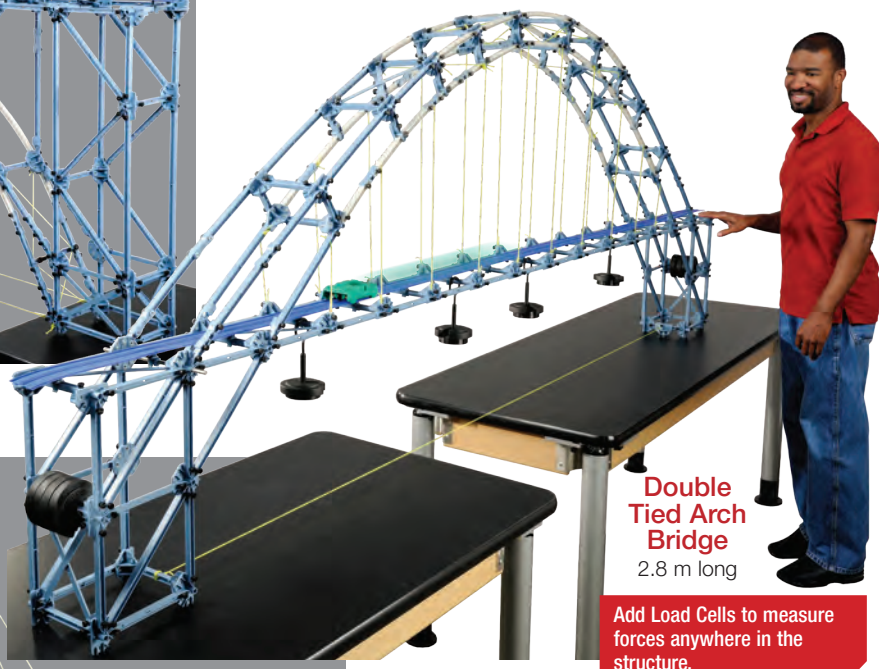
Large Structures Set

ME-7003

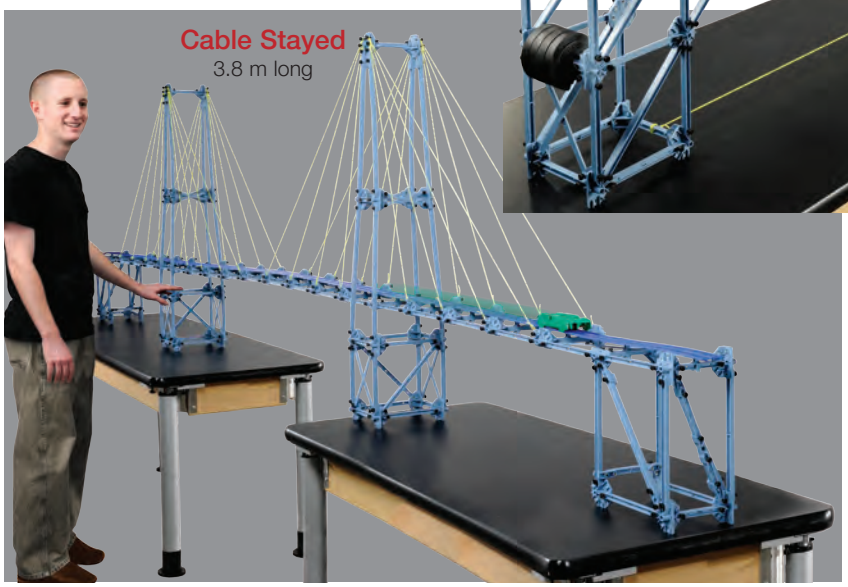
The Large Structures Set includes all the components contained in the ME-6992B Advanced Structures Set plus additional parts to build even bigger structures. It also includes the Mini Cars with plastic track to build roller coasters, and to add realistic roadbeds to your bridges.

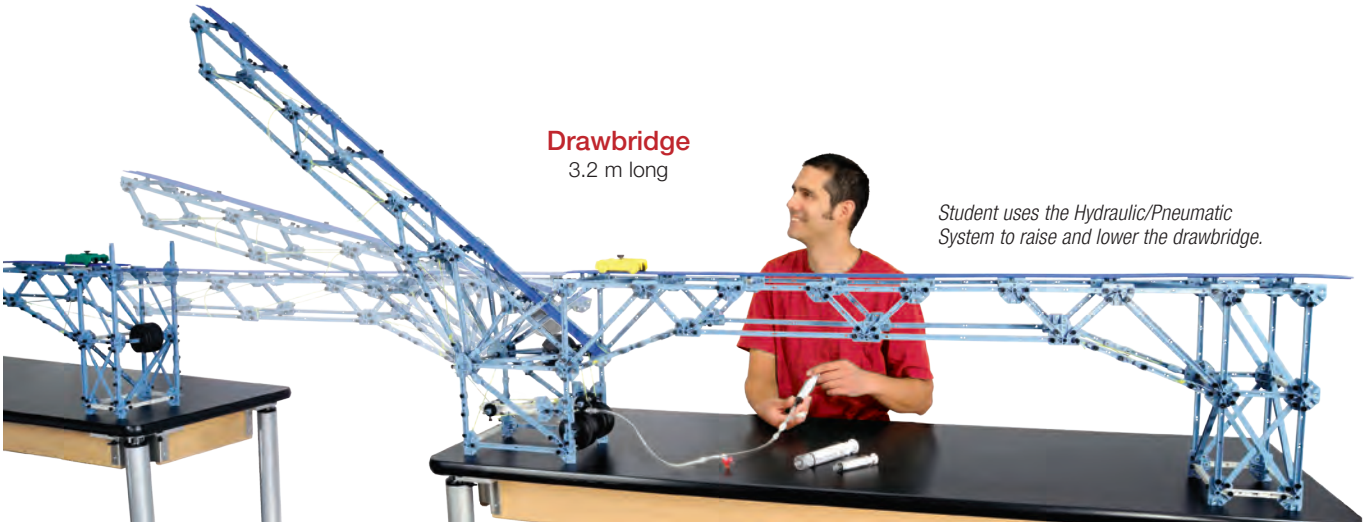






Add Load Cells to measure forces anywhere in the structure.





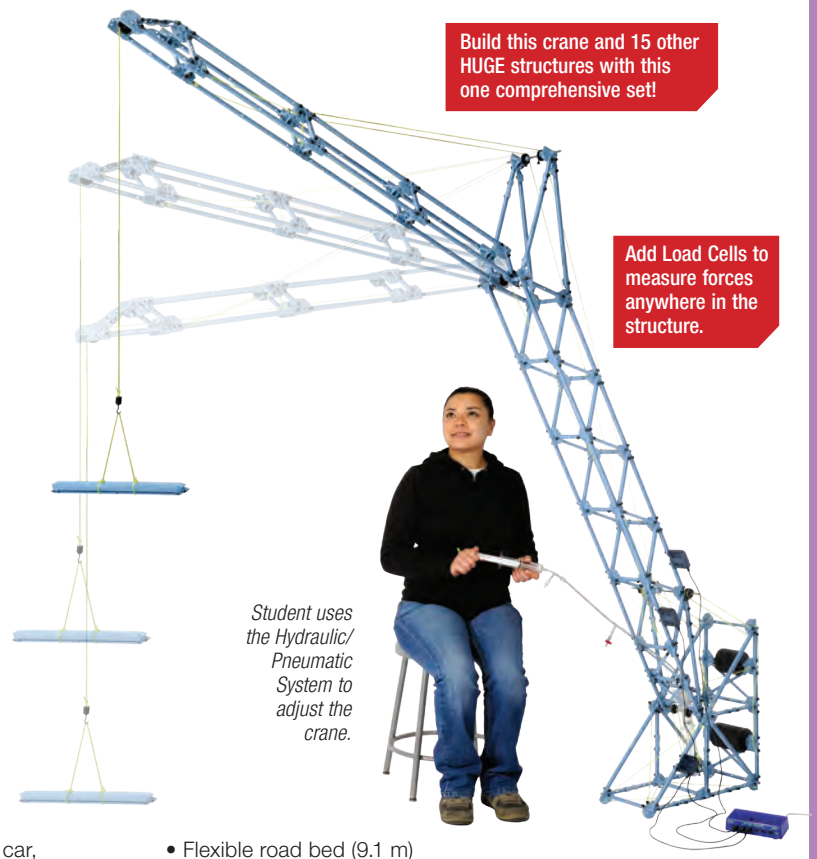
Drawbridge
3.2 m long

Student uses the Hydraulic/Pneumatic System to raise and lower the drawbridge.

Tower Crane
1.2 m tall

Build this crane and 15 other HUGE structures with this one comprehensive set!

Add Load Cells to measure forces anywhere in the structure.



Student uses the Hydraulic/ Pneumatic System to adjust the crane.

Includes:

- I-Beam #6 35 cm long (24)
- I-Beam #5 24 cm long (24)
- I-Beam #4 17 cm long (54)
- I-Beam #3 11.5 cm long (54)
- I-Beam #2 8 cm long (24)
- I-Beam #1 5.5 cm long (24)
- Flex I-Beam #5 24 cm long (10)
- Flex I-Beam #4 17 cm long (18)
- Flex I-Beam #3 11.5 cm long (18)
- Flat Beams (3 lengths) (16)
- Axles (3 lengths) (2)
- Connectors (70)
- Cord Tensioning Clips (32)
- Yellow car and green car, each with flag
- Force Platform Bracket (2)
- Round and Flat Connectors (6)
- Angle and Straight Connectors (24)
- Drive Wheel with Rubber Tire (4)
- Pulleys, O-rings, Spacers (12)
- Structures Rod Clamps (2)
- Sliding Connector (12)
- PAStrack Fasteners (6)
- Collets (24)
- Screws (450)
- Yellow Cord (1 roll)
- Flexible road bed (9.1 m)
- Road bed clips (24)
- Starter bracket
- Track coupler (2)
- Instruction Manual

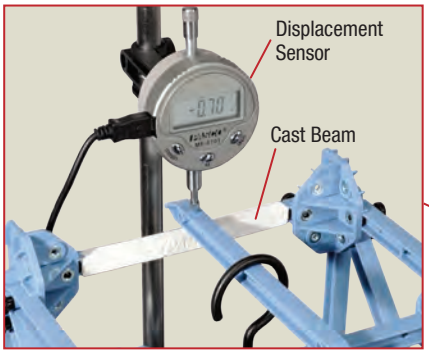
Order Information

Large Structures Set	ME-7003	
Shown in use with:		
Load Cell and Amplifier Set (includes four load cells)	PS-2199	p. 44
Structures Hydraulic System	ME-6984	p. 166
Large Slotted Mass Set (2 kg Set)	ME-7589	p. 207

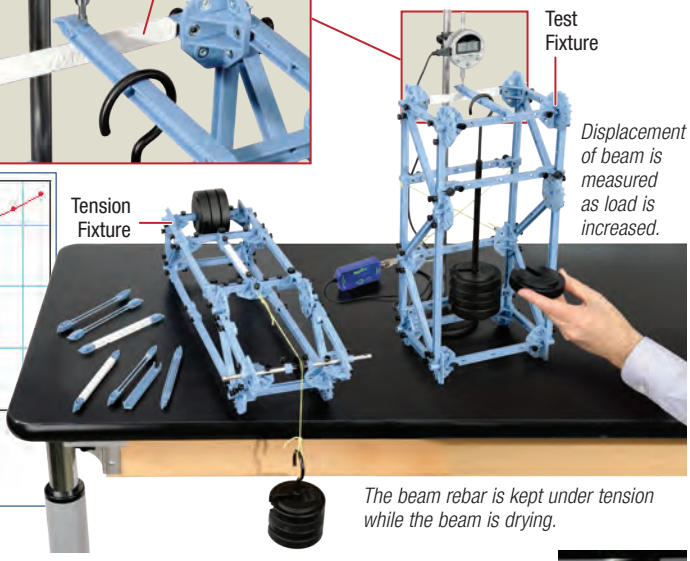
Structures Cast Beam Set

ME-7009

Make your own cast beams that look like pre-stressed concrete beams. Test them and you'll find they perform like them, too. These beams are cast with a mixture of sand and plaster of paris (not included). The rebar is made of the same plastic used for the I-beams. Students can explore how the strength of the beam is affected by the amount of tension put on the rebar, the mixture of sand and plaster of paris, or the number of rebar used.

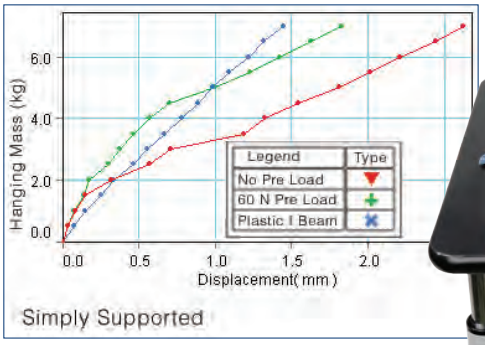


The tension fixture and the test fixture can be built concurrently with this set.

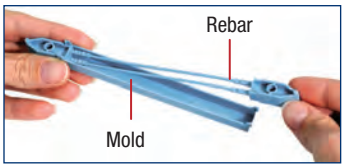


Displacement of beam is measured as load is increased.

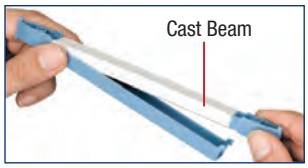
The graph of hanging mass versus displacement shows the relative strengths of three beams: one cast beam made with no pre-load; one cast beam made with 60 N of pre-load; and one normal plastic I-beam. Notice that the traces for the cast beams show discontinuities when the beams cracked. Also notice that the pre-loaded cast beam is stronger than the plastic I-beam until the cast beam cracks.



The beam rebar is kept under tension while the beam is drying.



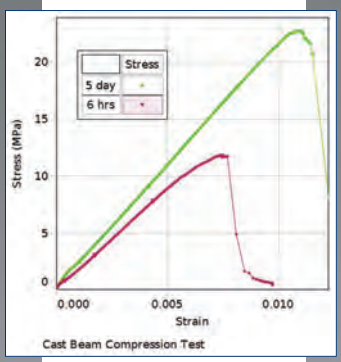
Step 1: The rebar with connecting ends snaps into the plastic mold. Pour a mixture of sand and plaster of paris into the mold.



Step 2: After it dries, the cast beam is easily removed from the plastic mold.

The cast beam shown here is tested to destruction under compression using the Materials Testing Machine on page 170.

Close-up of beam after destruction showing plastic "rebar."



PASCO Capstone graph shows that the strength of plaster of paris increases with cure time.

Includes:

- I-Beam #5 24 cm long (8)
- I-Beam #4 17 cm long (18)
- I-Beam #3 11.5 cm long (18)
- I-Beam #2 8 cm long (8)
- I-Beam #1 5.5 cm long (8)
- Axles (3 lengths) (2)
- Connectors (14)
- Cord Tensioning Clips (32)
- Round and Flat Connectors (6)
- PAStrack Fasteners (6)
- Angle and Straight Connectors (24)
- Collets (24)
- Screws (150)
- Pulley, O-rings, Spacers (12)
- Sliding Connector (12)
- Reusable Plastic Molds (10)
- Rebar (30)
- Yellow Cord (1 roll)
- Instruction Manual

Required but not included:

- Sand and Plaster of Paris

Order Information

Structures Cast Beam Set	ME-7009	
Also shown:		
PASPORT Displacement Sensor	PS-2204	p. 44
Large Slotted Mass Set	ME-7566	p. 207

Not shown, but required:
Interface and PASCO Capstone Software, see pages 84-87.

Cast Beam Spares Set

ME-6983

Consumable replacement parts for Cast Beams.
These can also be used with the Advanced Structures Set.

Includes:

- Reusable Plastic Molds (10)
- Rebar with Connectors (30)

Order Information

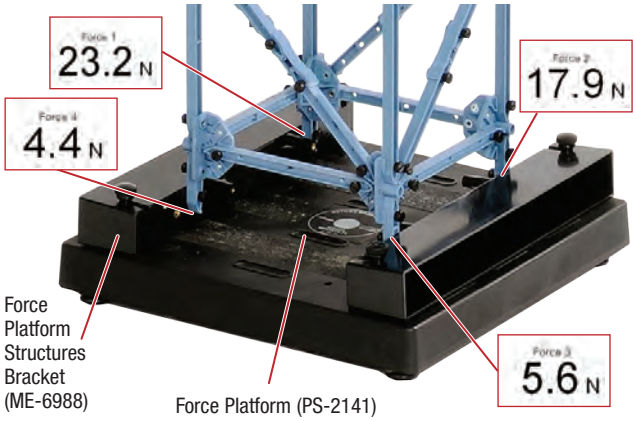
Cast Beam Spares Set	ME-6983

Measure support forces with a Force Platform

PASPORT Force Platform

PS-2141

Measure the support forces of a crane by connecting it to a Force Platform (PS-2141) using the special Force Platform Structures Bracket (ME-6988). The Force Platform is supported by four individual load cells which combine to measure the total vertical force on the platform. These four readings can also be viewed separately to measure the unequal forces on the crane supports.



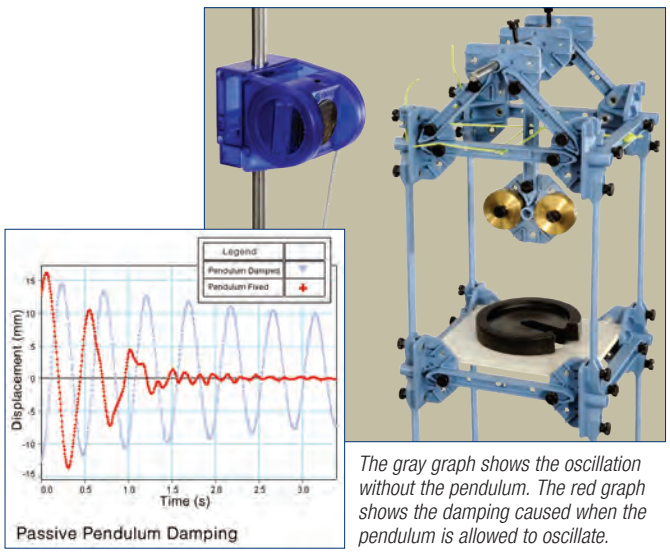
Build the crane using the Large Structures Set (ME-7003), shown on pages 160-161.

Order Information

PASPORT Force Platform	PS-2141
Force Platform Structure Bracket	ME-6988A

Measure passive damping with a Motion Sensor

This building frame is built with an Advanced Structures Set using the Flat Members. A pendulum with drag caused by strings is suspended from the top of the building. The Motion Sensor is positioned to record the oscillation of the building.



The gray graph shows the oscillation without the pendulum. The red graph shows the damping caused when the pendulum is allowed to oscillate.

Order Information

Equipment shown:

Advanced Structures Set*	ME-6992B	
PASPORT Motion Sensor	PS-2103A	
Large Slotted Mass Set	ME-7566	p. 207

*Patents pending

Measure bridge deflection with a Displacement Sensor

PASPORT Displacement Sensor

PS-2204

The Displacement Sensor measures the travel of a spring-loaded indicator as a bridge is loaded with weight. The included PASPORT Sensor plugs into the included Digital Indicator, which has its own digital LED readout and can be used as a standalone device. To record your data, simply plug the PASPORT sensor into an interface.

Specifications:

Maximum Travel: 10 mm
Maximum Sample Rate: 5 Hz
Resolution:
0.013 mm
(0.0005 in)

Order Information

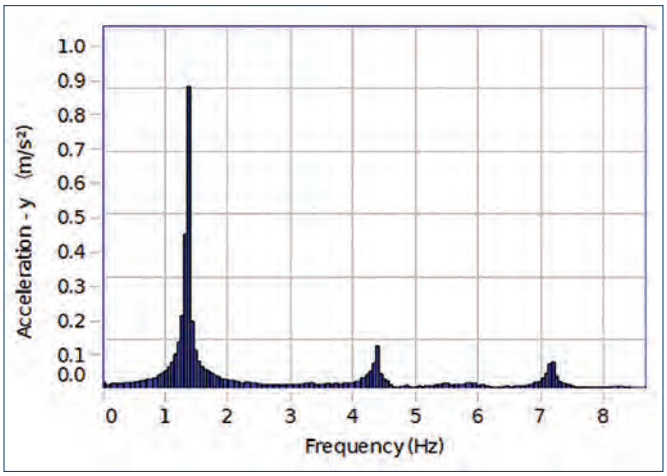
PASPORT Displacement Sensor	PS-2204	
Shown in use with:		
Hooked Mass Set	SE-8759	p. 207
Small "A" Base	ME-8976	p. 196
Stainless Steel Rod, 60 cm Threaded	ME-8977	p. 196
Required:		
PASPORT Interface		p. 24

Shaking Tower

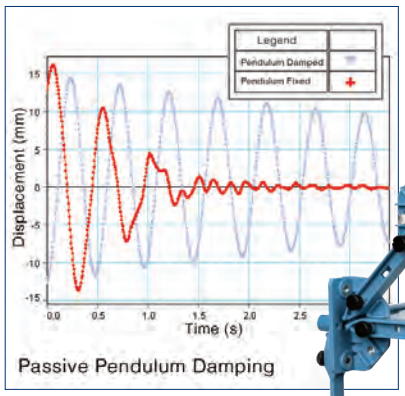
ME-7018

- Explore the resonance modes
- Measure accelerations with Wireless Sensors
- Demonstrate passive damping

Built from PASCO Structures beams, this tower is made to oscillate in its various resonance modes by a driver attached by a rubber band to the first floor of the tower. Wireless Load Cells with Accelerometers are attached to each floor to record how much shaking each floor experiences.

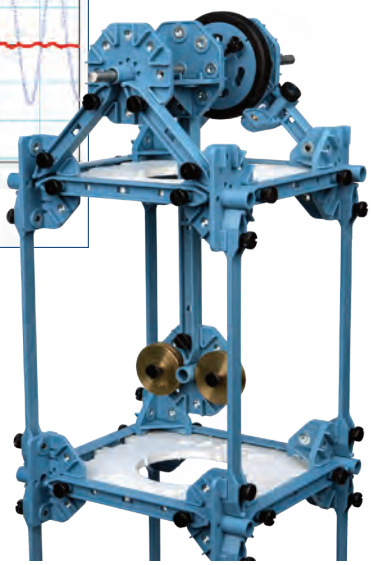


This FFT, generated in PASCO Capstone software, shows the frequency responses of the top Wireless Load Cell/Accelerometer.

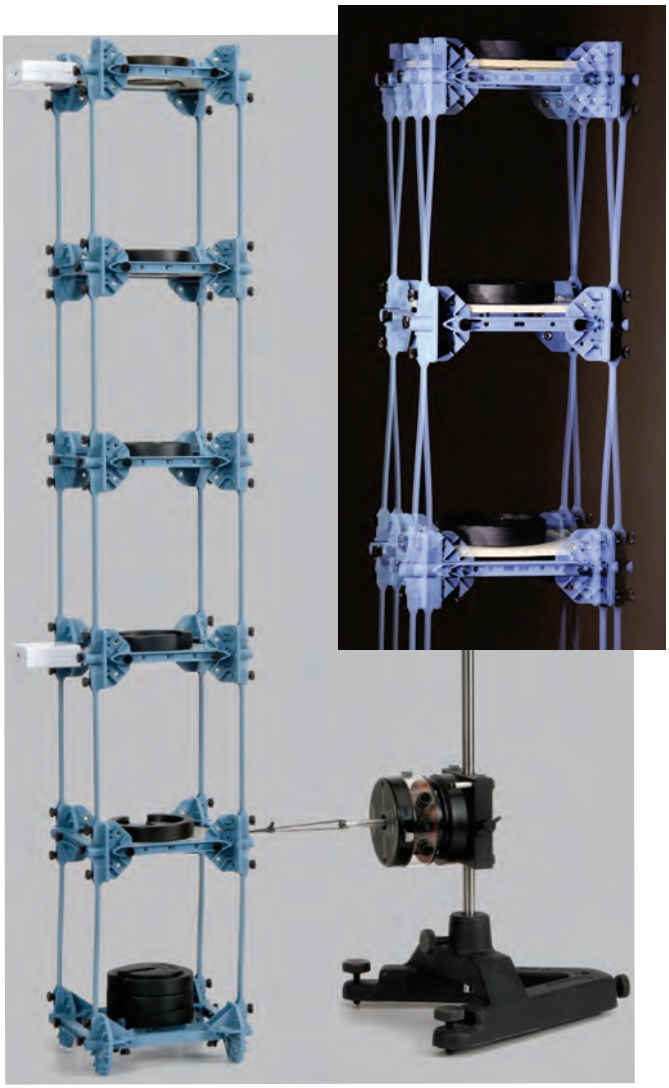


The gray graph in PASCO Capstone software shows the oscillation without the pendulum. The red graph shows the damping caused when the pendulum is allowed to oscillate.

See the Shaking Tower Experiment (EX-5555) on page 350.



In modern buildings, passive damping mechanisms are installed to damp out oscillations during earthquakes. The damping pendulum in this tower quickly stops oscillations.



The tower is shaken by the Mechanical Wave Driver, which is powered by an 850 Universal Interface or Function Generator.

Includes:

- #1 I-Beams (10)
- #2 I-Beams (8)
- #3 I-Beams (24)
- #4 I-Beams (1)
- Nylon Spacers (2)
- Connectors (20)
- (F4) Flat Beam (20)
- Flat Round Connector (4)
- Full Round Connectors (5)
- Floors (5)
- Mass, 20 gram (2)
- Mass, 50 gram (2)
- Medium Shaft, Structures
- Screws (2 sets) (150)
- Sliding Connector
- Tire, Structures
- Wheel, Structures

(Large Slotted Mass Set, shown in photo above, not included.)

Order Information

Shaking Tower	ME-7018	
Required:		
Large Slotted Mass Set	ME-7566	p. 207
Mechanical Wave Driver	SF-9324	p. 272
2 Meter Patch Cord Set	SE-9415A	p. 238
Large Rod Base	ME-8735	p. 196
Round Base with Rod	ME-8270	p. 196
Wireless Load Cell and Accelerometer	PS-3216	p. 65
850 Universal Interface	UI-5000	p. 26
PASCO Capstone Software		pp. 84-87

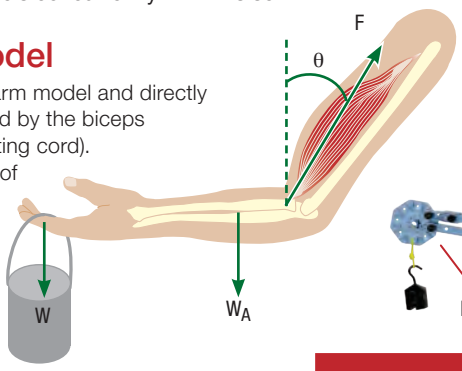
Human Structures Set

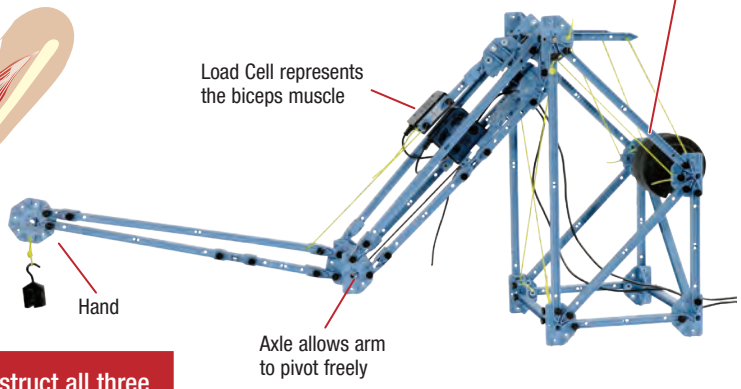
ME-7001

- Bring kinesiology topics to life!
- Build models that represent real life examples.
- Construct all three models concurrently with this set.

Human Arm Model

Students build a realistic arm model and directly measure the forces exerted by the biceps muscle (tension in supporting cord). Vary the length and angle of the upper and lower arm, as well as the point of attachment of the muscle.

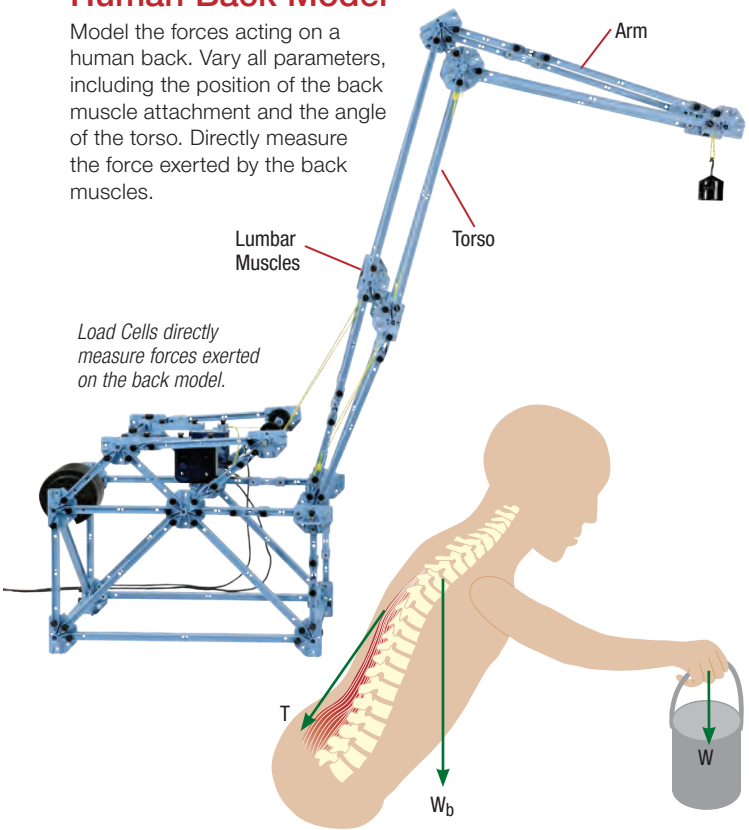




Construct all three models concurrently with this set.

Human Back Model

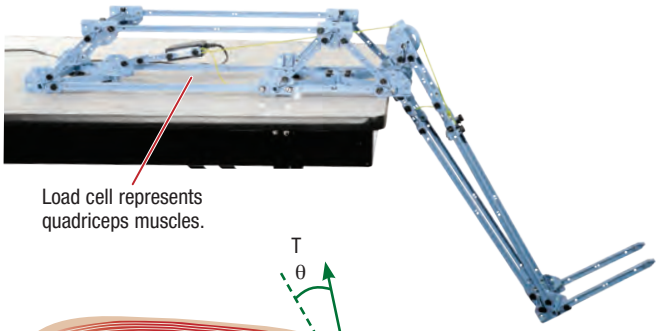
Model the forces acting on a human back. Vary all parameters, including the position of the back muscle attachment and the angle of the torso. Directly measure the force exerted by the back muscles.

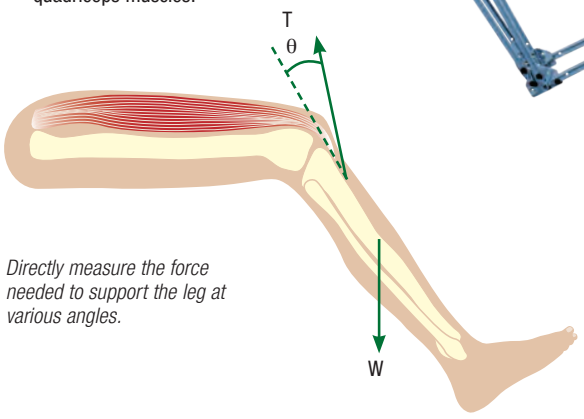


Load Cells directly measure forces exerted on the back model.

Human Leg Model

The leg model shown below uses a Load Cell for the quadriceps muscle to directly measure the force needed to support the leg at various angles.





Directly measure the force needed to support the leg at various angles.

Includes:

- Truss Set Screws (5-pack)
- Truss Set Members (2-pack)
- Connector Spares (2-pack)
- #6 I-Beam Spares (1 pkg.)
- Cord Lock Spares (1 pkg.)
- Axle Spares (1 pkg.)
- Round Connector Spares (1 pkg.)
- Angle Connector Spares (1 pkg.)
- Roll of rubber cord

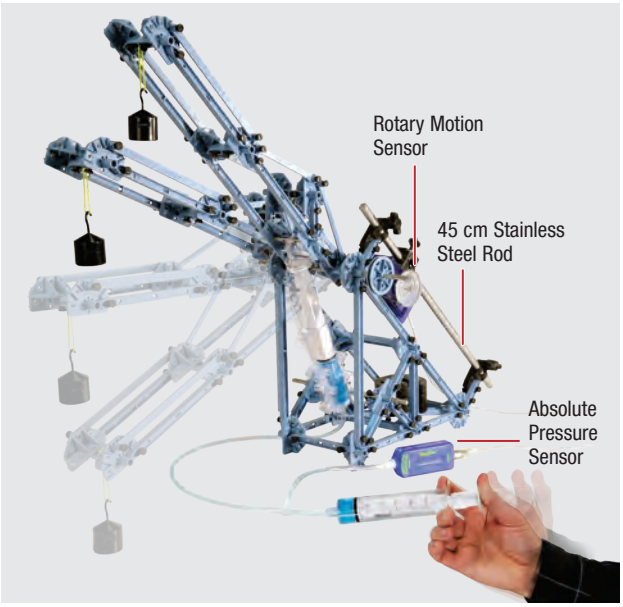
Order Information

Human Structures Set	ME-7001	
Shown in use with:		
Load Cell and Amplifier Set (includes four load cells)	PS-2199	
Hooked Mass Set	SE-8759	p. 207
Large Slotted Mass Set	ME-7566	p. 207

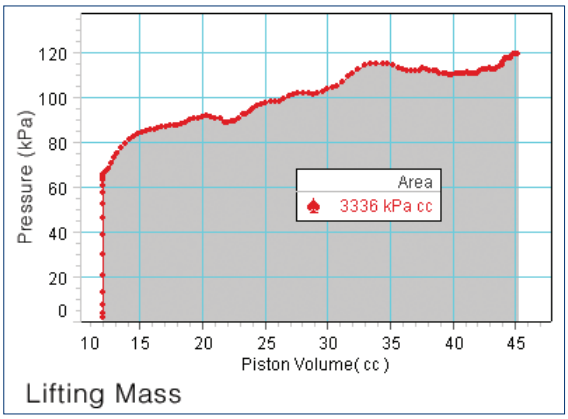
Structures Hydraulic System

ME-6984

Add a hydraulic/pneumatic ram to make your structures move and do work. Not only will students see the cranes and jacks in action, they can directly measure the pressure and volume to calculate how much work was done.



The weight is lifted using a syringe of water to fill the master cylinder. An Absolute Pressure Sensor measures the pressure and a Rotary Motion Sensor records the movement of the piston.



Pressure and volume are recorded as the weight is lifted, and the work done is the area under the curve.

Includes:

- Master Cylinder
- Pressure Sensor "T"
- Check Valves and Tubing
- Syringes (10, 20, 60 ml)
- Drive Belt for Rotary Motion Sensor (not shown)

Order Information

Structures Hydraulic System	ME-6984	
Advanced Structures Set	ME-6992B	p. 158
45 cm Stainless Steel Rod	ME-8736	p. 196
PASPORT Absolute Pressure Sensor	PS-2107	p. 45
PASPORT Rotary Motion Sensor	PS-2120A	p. 41

6-Way Structures Connector (Set of 6)

NEW PRODUCT!

ME-7019

- For multi-room, multi-level buildings

This connector is for construction of multi-room, multi-level buildings using PASCO Structures. The 6-Way Structures Connector allows connections in six directions (positive and negative x-, y-, and z-directions).

Order Information

6-Way Structures Connector (Set of 6)	ME-7019

Building Better Bridges Kit

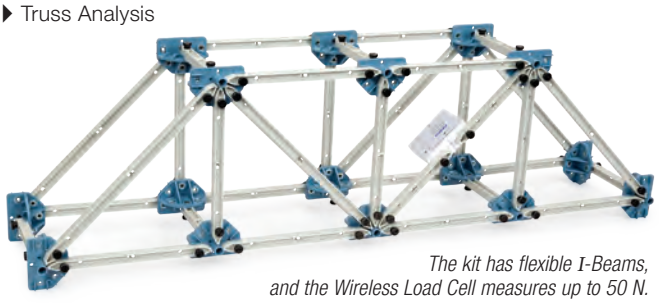
ME-3581

- A complete STEM kit to teach bridge-building
- Compatible with PASCO Structures System

Now is the perfect time for your students to learn about bridge-building and how bridges really work. This complete STEM kit allows students to learn and apply engineering design concepts. They can use the included I-Beams to build bridges and structures that behave like the real thing! And with the included Wireless Load Cell, students can measure forces under tension or compression anywhere in their structures.

Concepts:

- Forces in Equilibrium
- Internal Forces
- Moments in Equilibrium
- Strength of Members
- Truss Analysis



The kit has flexible I-Beams, and the Wireless Load Cell measures up to 50 N.

Includes:

- Lab Activities
- Wireless Load Cell and Accelerometer PS-3216
- Flexible I-Beams (various sizes)
- Connectors
- Truss Screws
- Weight Set
- Gratnells® Storage Tray

Order Information

Building Better Bridges Kit	ME-3581	
Want an additional Load Cell?		
Wireless Load Cell and Accelerometer	PS-3216	p. 65

Flexible I-Beam Set

ME-6985

Use the flexible I-Beams to make a bridge that dramatically demonstrates how a bridge fails. The beams return to their original shape once the load is removed.

Dramatically demonstrate structural failure.

Includes:
- Flexible I-Beam #5, 24 cm long (10)
- Flexible I-Beam #4, 17 cm long (18)
- Flexible I-Beam #3, 11.5 cm long (18)

Order Information

Flexible I-Beam Set ME-6985
Shown in use with:
Truss Set ..... ME-6990 p. 156

Mini Car Track Spares

ME-6974

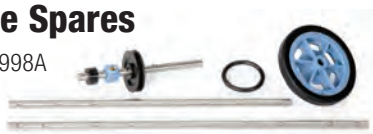
Includes two gates, two track couplers and one bag (24) of roadbed clips.

Order Information

Mini Car Track Spares ME-6974

Axle Spares

ME-6998A



Includes drive wheel with rubber tire (4), pulleys with "O" rings (12 each), axles (two each of three lengths), spacers (12) and collets (24).

Order Information

Axle Spares ME-6998A

Cord Lock Spares

ME-6996

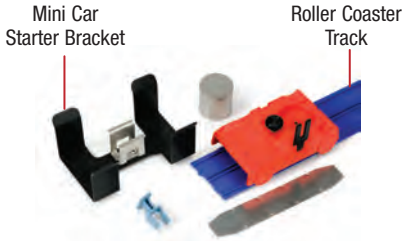
Includes 32 cord-tensioning clips and a spool of yellow cord.

Order Information

Cord Lock Spares ME-6996
Yellow String (2 Pack) ME-9876

Road Bed Spares

ME-6995



Includes flexible roadbed (3 m), roadbed clips (24), car with flag, extra mass, mini car starting bracket, and track couples (2).

Order Information

Road Bed Spares ME-6995
Sold separately:
Roller Coaster Track..... ME-9814

Force Platform Structure Bracket

ME-6988A

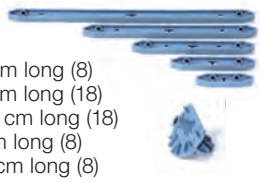
Includes:
- Brackets (2)
- Screws (4)

Order Information

Force Platform
Structure Bracket..... ME-6988A

Truss Set Members

ME-6993



Includes:
- I-Beam #5 24 cm long (8)
- I-Beam #4 17 cm long (18)
- I-Beam #3 11.5 cm long (18)
- I-Beam #2 8 cm long (8)
- I-Beam #1 5.5 cm long (8)
- Connectors (14)

Order Information

Truss Set Members..... ME-6993

Truss Set Screws

ME-6994

Includes 80 screws. All components in the Structures System use this same 6-32 thumbscrew.

Order Information

Truss Set Screws..... ME-6994

Structures Rod Clamp

ME-6986

Connects structure members to 1/2" rod. Includes a set of two.

Order Information

Structures Rod Clamp..... ME-6986

Beams & Connectors

Thin I-Beams

ME-7012

Set of 48 thin I-Beams, for use with PASCO Structures. 24 each of #4 beams (17 cm length) and #3 beams (11.5 cm length).

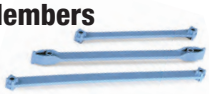
Flexible I-Beam Set

ME-6985

Includes 18 each of:
Flexible I-Beam #4 (17 cm long)
Flexible I-Beam #3 (11.5 cm long)
and 10 Flexible I-Beam #5 (24 cm long)

Flat Structures Members

ME-6987



Includes 16 each of:
2x3 beams (12.5 cm long); F4 beams (17 cm long); 3x4 beams (19 cm long)

Structures #6 I-Beam Spares

ME-7008

Includes 24 #6 I-Beams (35 cm)

Structures #5 I-Beam Spares

ME-7017

Includes 24 #5 I-Beams (24 cm)

Photoelastic I-Beam Set

ME-7011

Clear plastic I-Beams that display stress lines. Includes 24 each of:
#3 I-Beam (11.5 cm long)
#4 I-Beam (17 cm long)

Order Information

Thin I-Beams ME-7012
Flexible I-Beam Set ME-6985
Flat Structures Members ME-6987
Structures #6 I-Beam Spares ME-7008
Structures #5 I-Beam Spares ME-7017
Photoelastic I-Beam Set ME-7011

Connector Spares

ME-7002

Set of 14 Connector Spares used to join truss members.

Angle Connector Spares

ME-6999A

Includes 24 each of Angle Connectors, Straight Connectors and 12 Sliding Connectors.

Full Round and xyz Connector Spares

ME-6997

Includes 6 each of: full round connectors, xyz connectors, and bolts & nuts.

Order Information

Connector Spares ME-7002
Angle Connector Spares..... ME-6999A
Full Round and xyz
Connector Spares ME-6997

Comprehensive Materials Testing System

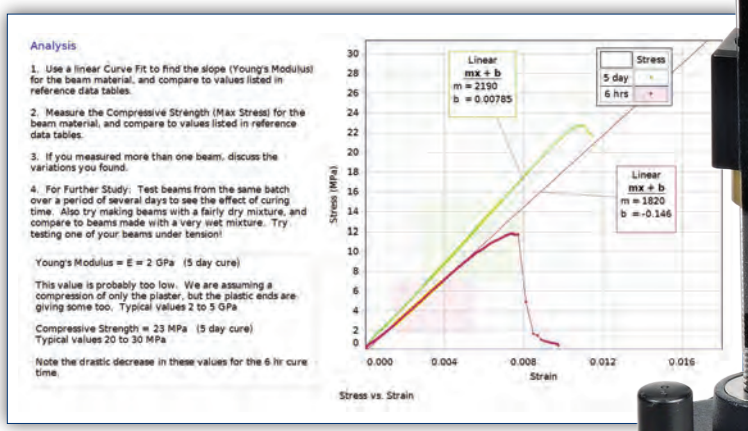
ME-8244

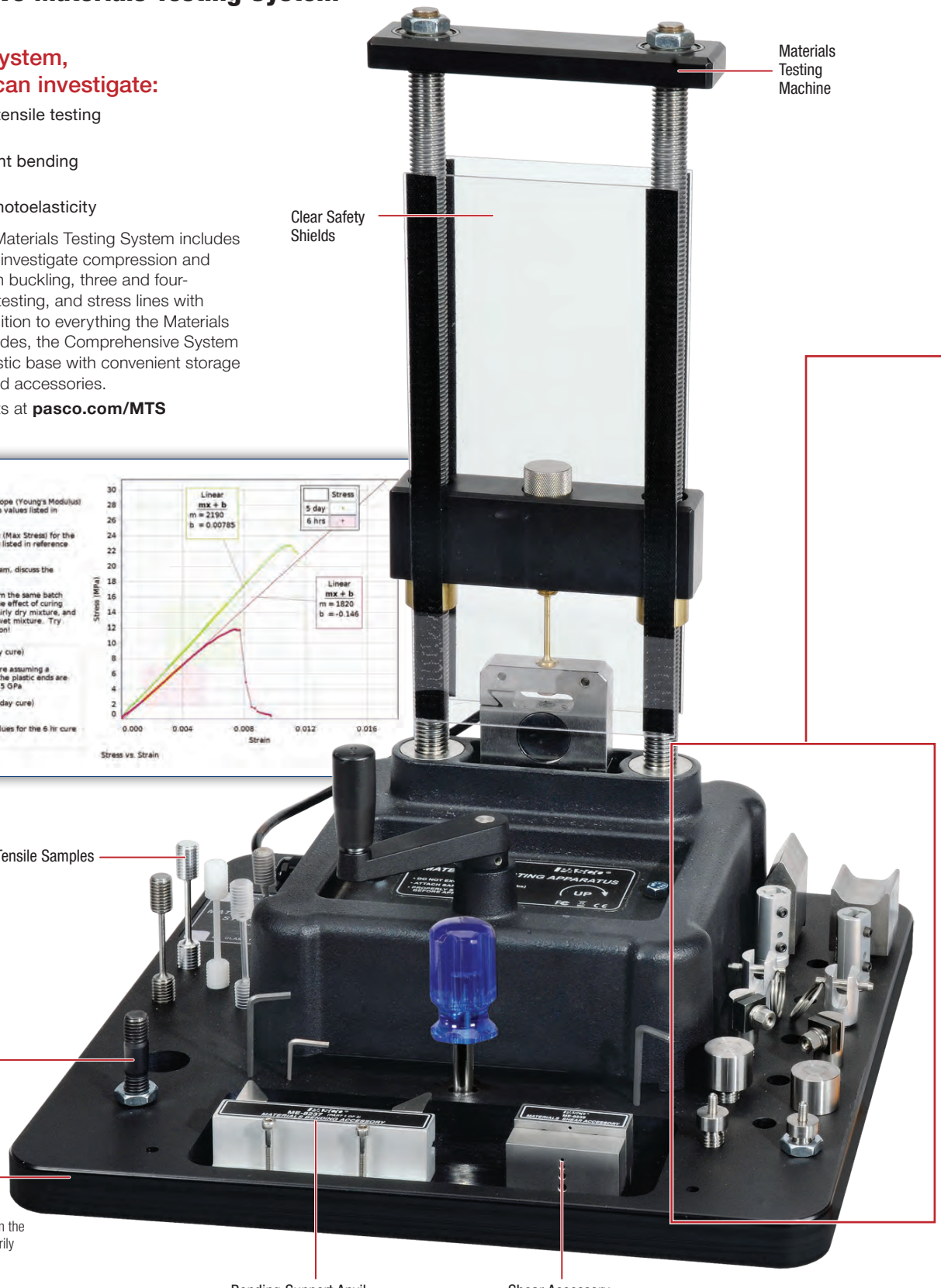
With this one system, your students can investigate:

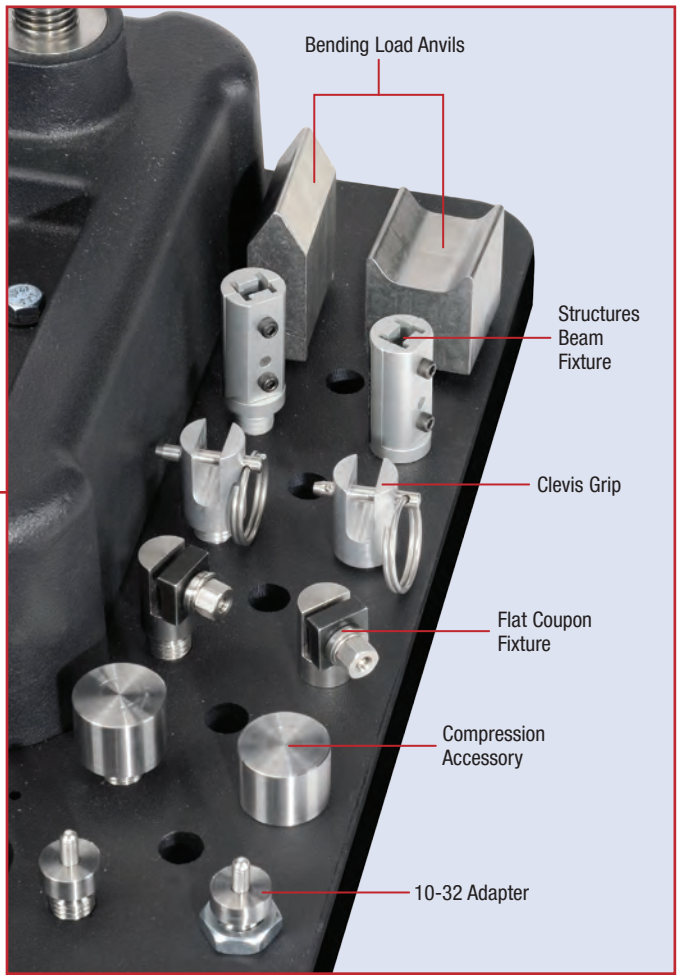
- Compression and tensile testing
- Column buckling
- Three and four-point bending
- Shear testing
- Stress lines with photoelasticity

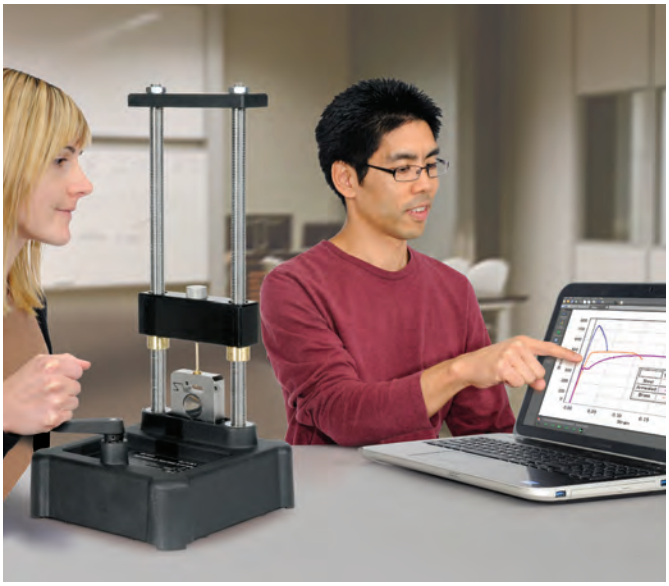
The Comprehensive Materials Testing System includes everything needed to investigate compression and tensile testing, column buckling, three and four-point bending, shear testing, and stress lines with photoelasticity. In addition to everything the Materials Testing Machine provides, the Comprehensive System includes a sturdy, plastic base with convenient storage for all components and accessories.

Download experiments at **pasco.com/MTS**









Includes:

- Materials Testing Machine ME-8236
- Tensile Samples: Aluminum, Brass, Annealed Steel, Steel, Acrylic, Polyethylene (10 of each)
- Bending Accessory ME-8237
- Four-point Load Anvil ME-8249
- Photoelasticity Accessory ME-8241
- Shear Accessory ME-8239
- Materials System Storage Base ME-8229
- Structures Beam Fixture ME-8242
- Thin I-Beams ME-7012
- Cast Beam Spares Set ME-6983
- Compression Accessory ME-8247
- Flat Coupon Fixture ME-8238
- Stress Strain Apparatus Coupons – Plastic AP-8222
- Stress Strain Apparatus Coupons – Metal AP-8223
- Clevis Grip ME-8245
- 10-32 Adapter ME-8246
- AirLink Interface PS-3200
- PASCO Capstone Single User License UI-5401

Order Information

Comprehensive Materials Testing System ME-8244
Materials Testing Machine ME-8236

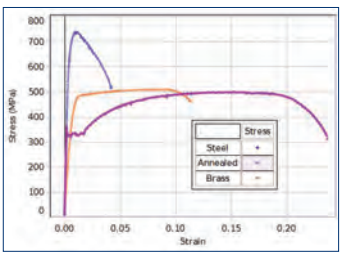
Materials Testing Machine

ME-8236

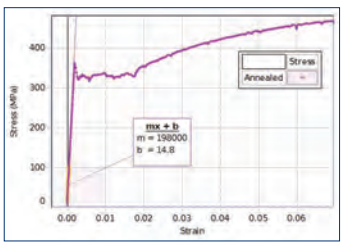
- 7100 N max load
- Hand-cranked so students can feel samples break
- Inexpensive samples make it possible for each student to experience it firsthand

Measure force and displacement for various materials as they are stretched, compressed, sheared, or bent. Investigate material properties including Young's Modulus, Tensile Strength, Yield Strength, Ductility and Modulus of Resilience.

The Materials Testing Machine measures force with a 7100 N load cell and displacement with an optical encoder. It runs on PASCO Capstone software, which has a built-in compliance calibration wizard and has all the tools to record and display stress vs. strain, apply linear fits to find Young's Modulus, and to record and play back video of the samples breaking in sync with the data.

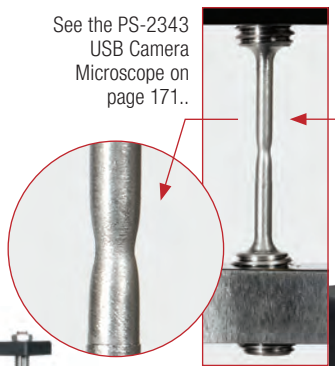


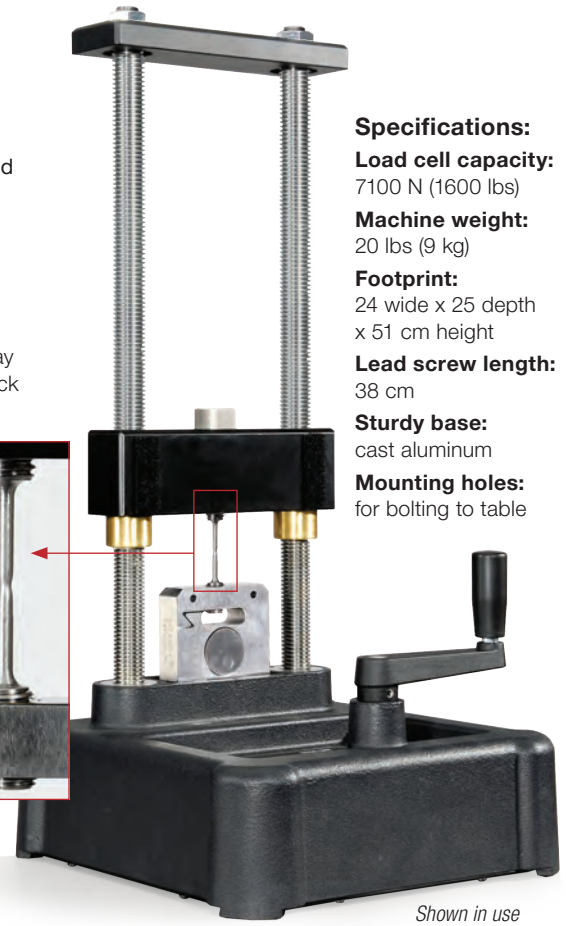
Tensile Stress vs. Strain is plotted in PASCO Capstone software for steel, annealed steel, and brass.



For annealed steel, a linear fit is applied to find Young's Modulus.

See the PS-2343 USB Camera Microscope on page 171..





Specifications:

Load cell capacity:
7100 N (1600 lbs)

Machine weight:
20 lbs (9 kg)

Footprint:
24 wide x 25 depth x 51 cm height

Lead screw length:
38 cm

Sturdy base:
cast aluminum

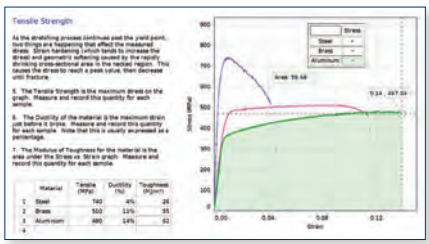
Mounting holes:
for bolting to table

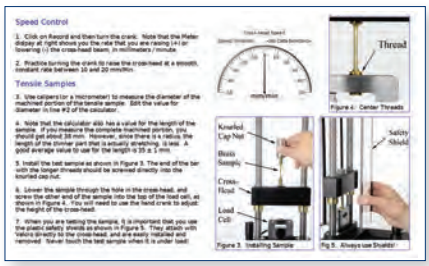
Shown in use without the included safety shields.

ME-8236 Includes

- Machine
- Compliance calibration rod
- Safety shields

(requires Capstone software)





FREE Download
www.pasco.com/MaterialsTester

Workbooks include all instructions needed to perform the experiment:

- Introduction and theory
- Setup instructions
- Detailed analysis and summary questions

Tensile Samples

Set of 10 each

Order Information

Aluminum Tensile Sample	ME-8231
Brass Tensile Sample	ME-8232
Annealed Steel Tensile Sample	ME-8233
Steel Tensile Sample	ME-8243
Acrylic Tensile Sample	ME-8234
Polyethylene Tensile Sample	ME-8235

Order Information

Materials Testing Machine	ME-8236	
Required:		
PASCO Capstone Software		pp. 84-87
AirLink Interface	PS-3200	p. 60
Tensile Samples (at left)		

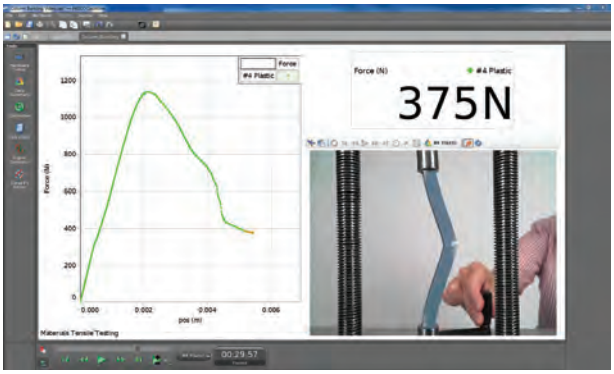
PASCO capstone™

Software

Simultaneously combine video with data graphs for more powerful analysis.

- PASCO Capstone is data collection and analysis software that has a special built-in compliance calibration routine for the Materials Tester.
- It is shown here plotting a graph and recording a video that are synced together in real time. Data analysis tools such as curve fits and area under the curve are available.
- Discover the powerful capabilities of PASCO Capstone by pairing it with any of our interfaces and 80+ sensors.

Download a **FREE** PASCO Capstone trial at **www.pasco.com/capstone**



Enhance student understanding of the behavior of materials. PASCO Capstone software has the ability to embed live video from a webcam and sync the Materials Tester data to the recorded video. Then you can play back the video along with the data on the graph, stepping through one frame at a time to see the exact breaking point.

Order Information

PASCO Capstone
Single User License UI-5401
PASCO Capstone Site License .....UI-5400 or UI-5400-DIG

USB Camera Microscope

PS-2343

- Use as a web camera
- Optical zoom from 1x to 60x
- Built-in LED lighting

The versatile USB Camera Microscope can take pictures and video just like a digital camera, but it can also magnify like a microscope when it's up close to a specimen. You can use it to take pictures of lab setups, or document the appearance of materials before and after an experiment.

Use it with the video and image capture features in PASCO Capstone. Change the magnification by adjusting the dial located on the front of the camera.

Specifications:

Magnification:
1x to 80x, 320x on 22" monitor

Lens & CMOS sensor: 2M pixels

Still Image Resolution:
1600x1200 pixels

Formats: JPEG, BMP

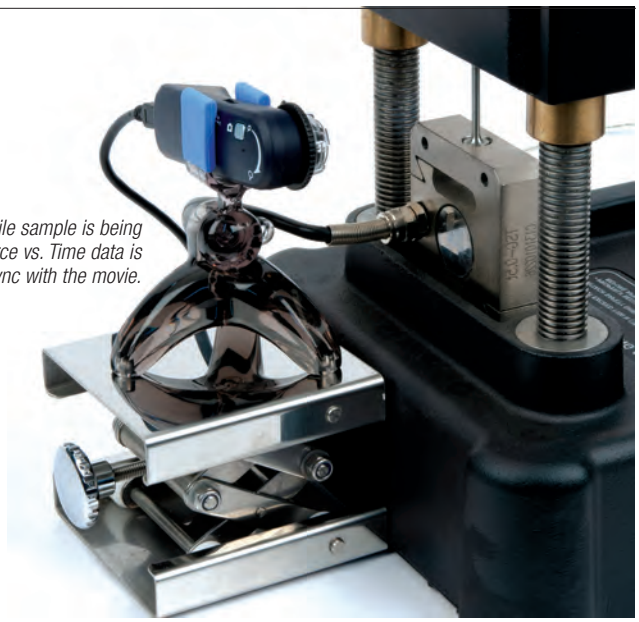
Video Resolution: 1600x1200 pixels

Formats: AVI

Frame rate: 30 FPS on 640x480 pixels: AVI

PC Interface:
USB 2.0; works on Windows, MacBooks, and Android phones with OTG functions

Light Source:
4 white LED lights



As the tensile sample is being stretched, the Force vs. Time data is graphed in sync with the movie.

Includes:

- Camera
- Microscope
- Stand

Image of broken steel tensile sample taken with the microscope.

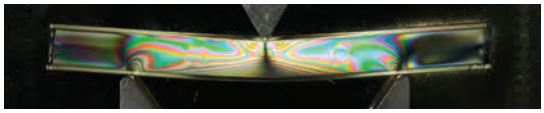
Order Information

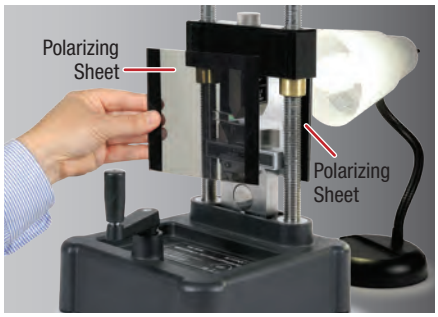
USB Camera Microscope PS-2343

Photoelasticity Accessory

ME-8241

See stress lines by bending a clear, colorless photoelastic I-Beam between two polarizing sheets. As the beam is bent, areas of greater stress show up as patterns of colored lines.





Photoelasticity Accessory consists of two crossed polarizing sheets that are placed in front of and behind the clear beam. When illuminated from behind by a bright white light, fringes due to the stress lines become visible.

Lamp not included.

Includes:
- One Photoelastic I-Beam Set: ME-7011
- Two polarizing sheets, 5 3/8" x 5 3/8" x 1/8"

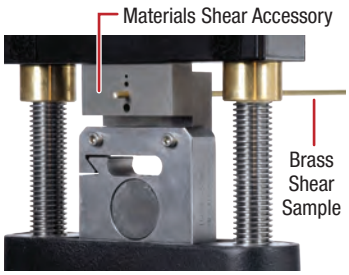
Order Information

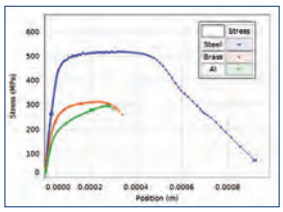
Photoelasticity Accessory	ME-8241
Photoelastic I-Beam Set	ME-7011
Shown in use with:	
Bending Accessory	ME-8237

Shear Accessory

ME-8239

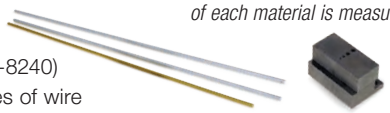
Perform shear tests for a variety of wires. Accessory accepts diameters of 1/16", 3/32", 1/8," and 5/32". The Shear Accessory includes the ME-8240 Shear Samples, three each of 1/8" diameter, 12" long, aluminum, brass and mild steel.





The graph shows shearing of steel, brass, and aluminum rods, all having an 1/8" diameter. The shear strength of each material is measured.

Includes:
- Shearing Block and Shear Samples (ME-8240)
- 3 Each of three types of wire



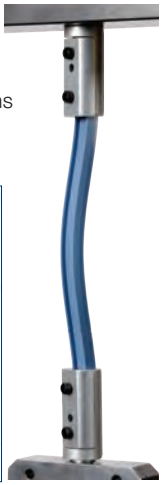
Order Information

Shear Accessory	ME-8239
Replacement Supplies:	
Shear Samples	ME-8240

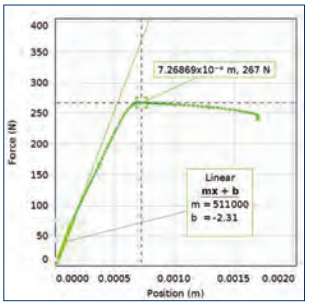
Structures Beam Fixture

ME-8242

The Structures Beam Fixture allows any of the I-Beams from PASCO's Structures System to be stretched or compressed in the Materials Testing Machine.



Includes:
- Clamps (2)



Find the critical load that causes the beam to buckle.

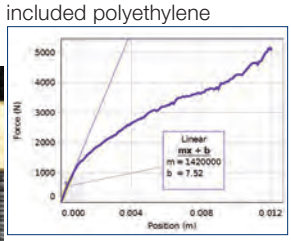
Order Information

Structures Beam Fixture	ME-8242

Compression Accessory

ME-8247

This one-inch diameter platform provides a sturdy base to investigate compression of a variety of materials. It is shown here in a compression test on one of the included polyethylene test samples.



Before and after photo of compression sample

Includes:
- Platform
- 20 Polyethylene cylinders (ME-8284), 1.3 cm dia. x 2 cm long

Order Information

Compression Accessory	ME-8247
Replacement Supplies:	
Compression Samples	ME-8248

Materials System Storage Base

ME-8229

The plastic base is made of High Density Polyethylene (HDPE). Includes base and mounting hardware.

Order Information

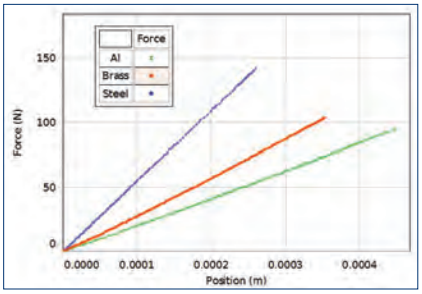
Materials System Storage Base	ME-8229

Bending Accessory

ME-8237

Perform three-point bending tests of various materials, including beams from the PASCO Structures System. Support anvils have adjustable separation up to 10 cm.

A Three-Point Bend Test is performed on a brass rod from the ME-8240 Shear Samples. The support anvils have adjustable separation up to 10 cm.



This Force vs. Position graph shows three-point bending for aluminum, brass, and steel samples, all with the same anvil spacing. From this graph, the flexural elastic modulus for each material is measured.

Four-Point Load Anvil

ME-8249

Add the optional Four-Point Bending Accessory to the ME-8237 to perform both three-point and four-point bending.

Perform a Four-Point Bend Test on the Cast Beams from the PASCO Structures System. Quantities measured include the Flexural Elastic Modulus and the Modulus of Rupture for the material.

ME-8249 Includes:

- A two-point fixture that, when added to the Bending Accessory, allows four-point bending.

ME-8237 Includes:

- Base
- Adjustable support anvil
- Load anvil

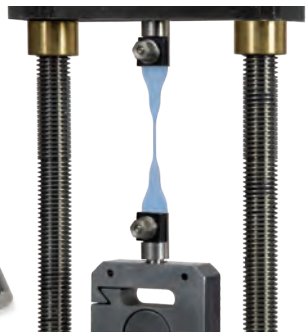
Order Information

Bending Accessory	ME-8237
Four-Point Load Anvil	ME-8249
Shown in use with:	
Shear Samples	ME-8240
Thin I-Beams	ME-7012
Cast Beam Spares Set (includes 30 rebar members)	ME-6983

Flat Coupon Fixture

ME-8238

Test any flat material, such as paper, foil, or plastic. Shown using the Flat Plastic Test Coupons (AP-8222).



Includes:

- Clamps (2)
- Wrench

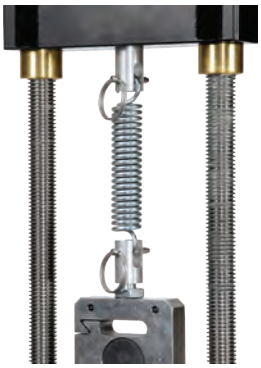
Order Information

Flat Coupon Fixture	ME-8238	
Stress Strain Apparatus Coupons (40) - Plastic	AP-8222	p. 174
Stress Strain Apparatus Coupons (40) - Metal	AP-8223	p. 174

Clevis Grip

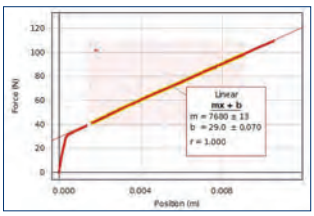
ME-8245

This generic pin and clevis adapter allows the user to tensile test a wide variety of samples with hooked ends or through-holes. It is shown here testing an extension spring (not included).



Includes:

- Clevis adapter and pin. Pin diameter is 0.187 in. Max width of sample is 0.300 in.



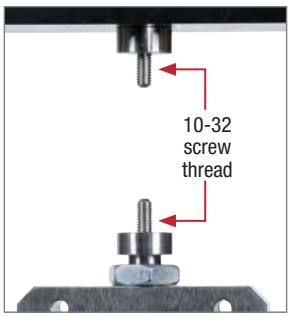
Order Information

Clevis Grip	ME-8245

10-32 Adapter

ME-8246

Allows use of grips and attachments from other vendors that require a 10-32 male thread.



Includes:

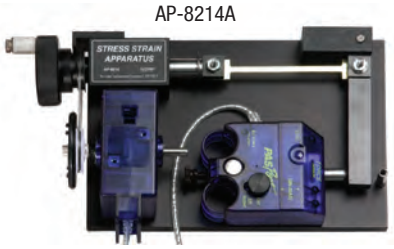
- Upper and lower adapters

Order Information

10-32 Adapter	ME-8246

Looking for Tensile Samples for the legacy Stress/Strain Apparatus?

AP-8214A



Although the AP-8214A Stress/Strain Apparatus is obsolete, we will continue to supply the test coupons indefinitely to accommodate current users. These coupons are also useful in PASCO's newer Materials Testing Machine (ME-8236), shown on pages 168-169. There is an adapter, the Flat Coupon Fixture (ME-8238), which allows these coupons to be tested in the new machine.

Plastic Test Coupons

AP-8222

Comprised of a set of plastic coupons for use with PASCO's Stress/Strain Apparatus. Four types of color-coded samples, 10 pieces per sample:

- High impact polystyrene (HIPS)
- Nylon 6 (15% glass fiber reinforced)
- Acrylonitrile butadiene styrene (ABS)
- Polypropylene (PP)

Metal Test Coupons

AP-8223

Set of metal test coupons of varying strengths, designed for use with PASCO's Stress Strain Apparatus. Five types of samples, 10 pieces per sample (sample containers labeled with thickness in inches)

- Brass (thin) 0.003"
- Brass (thick) 0.005"
- Cold-rolled steel 0.003"
- Aluminum 0.003"
- Annealed steel 0.003"

Order Information

Stress Strain Apparatus Coupons – Plastic AP-8222
Stress Strain Apparatus Coupons – Metal..... AP-8223

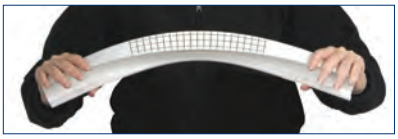
Super-Flex I-Beam

ME-8987

- Demonstrate the difference in stiffness between the two directions of bending
- Show that I-beams twist easily
- Show torsion and buckling
- Grid shows deformation

This Super-Flex I-Beam is made of plastic, so it can be visibly bent by hand. It shows the basic reasons for using this cross-section in construction. It is four times as stiff in the upright orientation as it is sideways.

Column buckling



Demonstrate lack of torsional strength.

Includes:

- Super-Flex I-Beam (24 inches long, 2 inches high)
- Instructions

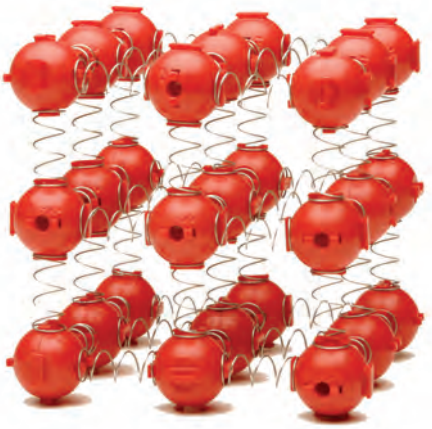
Order Information

Super-Flex I-Beam ME-8987

Matter Model

ME-9825A

The atoms of the Matter Model are brightly colored spheres with the bonds between the atoms modeled by springs, so that when forces are applied, the atoms can move in response.



Demonstrate the normal force response as a material is compressed.

Includes:

- Atoms (4.5 g each) (40)
- Heavy, light and long springs (60)
- Nuts (to increase the atom mass) (30)
- 90 cm brass rod (for longitudinal waves)

The Matter Model is shipped in component pieces, ready for assembly.

Order Information

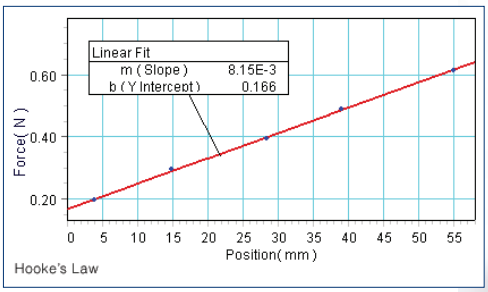
Matter Model ME-9825A

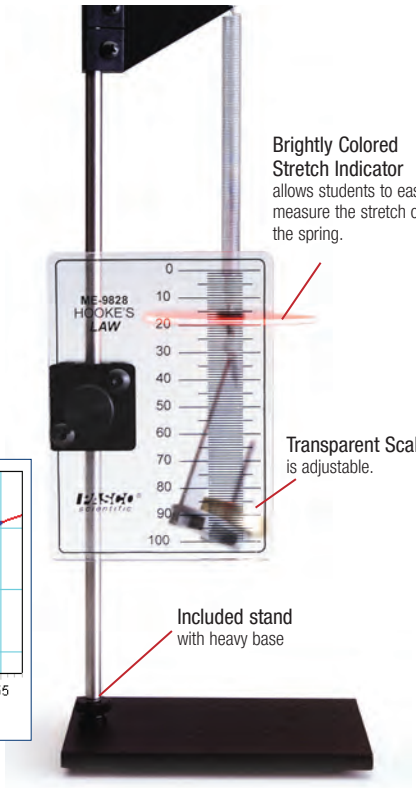
Hooke's Law Set

ME-9827

- Brightly colored stretch indicator
- Transparent measuring scale
- Compatible with PASCO mass sets

The Hooke's Law Set allows students to investigate the relationship between the force applied to a spring and the amount of stretch on the spring. This rugged set features a heavy base, so you can stretch the springs without toppling the unit. The transparent scale can be moved vertically to align zero with the brightly colored stretch indicator.





As a force is applied to the spring by placing mass on the hanger, the spring stretches. Students can graph the Applied Force vs. Spring Stretch. The slope of this graph is the spring constant of the spring. The vertical intercept shows the initial force required to begin stretching the spring.

Includes:

- Stand with heavy base
- Transparent scale with mm resolution
- Horizontal support for spring
- Brightly colored stretch indicator
- Three springs with identical diameter and length, but different spring constants
- Three of each spring included, for a total of nine springs: spring constants are 5 N/m, 8 N/m, 70 N/m

Order Information

Hooke's Law Set..... ME-9827
Recommended:
Mass and Hanger Set..... ME-8979 p. 207

Hooke's Law Spring Set

SE-8749

Includes three springs with the same diameter and length, but different spring constants. Three of each type of spring are included, and the springs fit nicely on PASCO mass hangers. All springs are 55 mm long and 7 mm in diameter. Spring constants are 5 N/m, 8 N/m and 70 N/m.

Order Information

Hooke's Law Spring Set..... SE-8749

Dropper Popper

SE-7304

Invert this half rubber ball and drop it. It will bounce up higher than the release point. Discuss conservation of energy with your students.

There is a minimum height required to trigger the popper that can be related to barrier potentials.

Order Information

Dropper Popper SE-7304

Series/Parallel Springs

ME-6842

This set of springs includes six springs with three different spring constants. These springs are 15 cm long, half the length of the Equal-Length Spring Set, making it possible to combine two series short springs in parallel with one long spring.

Shown in use with the Parallel Spring Bracket and the Hooked Mass Set.

Specifications:

The six color-coded springs, two of each color, have different spring constants:
10 N/m, 20 N/m, 40 N/m (±5%)

Includes:
- White storage box
- Six (color-coded) springs 15 cm long

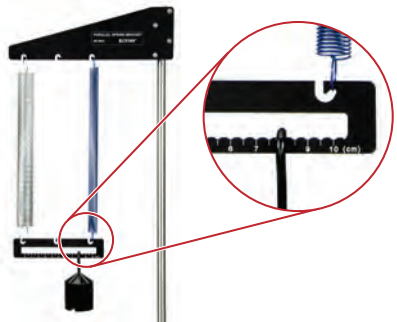
Order Information

Series/Parallel Springs	ME-6842	
Recommended:		
Hooked Mass Set	SE-8759	p. 207

Parallel Spring Bracket

ME-6844

This unique bracket allows springs of different spring constants to be hung in series and parallel. The masses can be hung in an offset position to compensate for the stronger spring.



Includes:
- Suspension bracket
- Parallel hook bar

Order Information

Parallel Spring Bracket	ME-6844

Equal Length Spring Set

ME-8970

The five color-coded equal-length springs in this set have different spring constants: 25 N/m, 30 N/m, 35 N/m, 40 N/m, 50 N/m (±5%).

These springs appear to be the same except for their colors. But, when equal masses are hung on them, each stretches a different amount. These extension springs are made of steel and are closed, requiring a slight initial force to separate the coils. The unstretched length of each spring is 30 cm and the approximate diameter is 1.4 cm. These springs are supplied with a white storage box with cardboard separators to keep the springs from touching each other.

The five color-coded springs stretch different amounts when a 1 kg mass is hung from each spring.

Includes:
- White storage box
- Five (color-coded) springs 30 cm long

Order Information

Equal Length Spring Set	ME-8970	
Recommended:		
Pendulum Clamp	ME-9506	p. 198
Hooked Mass Set	SE-8759	p. 207

Demonstration Spring Set

ME-9866

This set includes four large springs for the demonstration of Hooke's Law or Conservation of Energy. Each spring is constructed of rugged spring steel with large loops that hang from a pendulum clamp or stretch with hanging masses. Spring constants range from 4 N/m to 14 N/m. Spring lengths vary between 11 cm and 22 cm.

Order Information

Demonstration Spring Set	ME-9866	
Recommended:		
Pendulum Clamp	ME-9506	p. 198
Hooked Mass Set	SE-8759	p. 207

Double-Length Slinky

SE-8760

The Slinky is an excellent tool for demonstrating transverse and longitudinal wave phenomena. This Double-Length Slinky is twice as long as a traditional Slinky, allowing students to create well-defined wave pulses and standing wave patterns. The tension in the Slinky is very low, causing wave pulses to travel slowly throughout its length.

Order Information

Double-Length Slinky..... SE-8760

Snakey

SE-7331

This extra-long metal spring is ideal for studying mechanical waves. The Snakey has an unstretched length of 2 meters. Pull the convenient end loops more than 10 meters apart to demonstrate transverse, longitudinal, and standing waves.

Order Information

Snakey SE-7331

Longitudinal Wave Spring

WA-9401

Using the Longitudinal Wave Spring accessory, it is easy to demonstrate and visualize the nodes and antinodes of longitudinal waves. Unstretched length is 13 cm.

Order Information

Longitudinal Wave Spring.....WA-9401

Photogate Pendulum Set

ME-8752

- Great for classic pendulum experiments

Cylindrical shape allows easy calculation of the speed of the pendulum using the time it blocks the photogate. Photogate not included.

The Photogate Pendulum Set is a unique set of four pendulums that have the same shape and size, but different masses. Due to their cylindrical shape, these pendulums are ideal for use in timing experiments with the photogate. One pendulum each of brass, plastic, wood, and aluminum is included.

Applications:

- Determine relationship between period and mass
- Determine relationship between period and amplitude
- Determine relationship between period and length

Includes:

- Brass pendulum
- Aluminum pendulum
- Plastic pendulum
- Wood pendulum

Order Information

Photogate Pendulum Set..... ME-8752

Harmonic Springs 8 Pack

ME-9803B

Includes eight identical springs:
8 cm long, 3.4 N/M spring constant.

Order Information

Harmonic Springs 8 Pack..... ME-9803B

IDS Spring Kit

ME-8999

Includes 12 springs (1.6 cm diameter) with approximate spring constants of:
3.4 N/m (3 short and 3 long springs)
6.8 N/m (3 short and 3 long springs)

Order Information

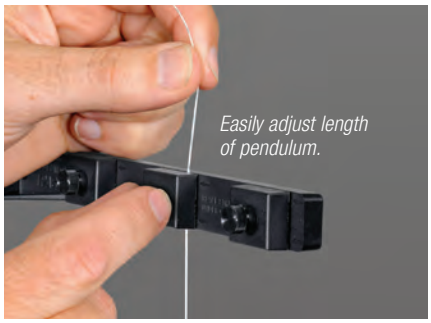
IDS Spring Kit ME-8999

Pendulum Clamp

ME-9506

Hang up to three springs or pendulums. Easily adjust the lengths of the pendulum strings.

See page 146 for more information.



Order Information

Pendulum Clamp ME-9506
Shown in use with:
Photogate
Pendulum Set ME-8752
Small "A" Base .....ME-8976 p. 196
45 cm Stainless
Steel Rod.....ME-8736 p. 196

Complete Rotational System

ME-8950A

- Most versatile rotational system available
- Stable, 4 kg cast iron base
- Dual, low-friction ball bearings

The Complete Rotational System features a cast iron base, dual ball bearings, and stainless steel shaft. It generates moments of inertia large enough to be sensed by anyone rotating the system by hand. This system is ideal for experiments pertaining to centripetal force, angular momentum, and rotational motion. Additional accessories can be added for experiments concerning torques, friction, magnetic levitation, and Faraday's Law. Angular velocity and motorized drive can be monitored using a computer.

Included Experiments

- Centripetal Force
- Rotational Inertia of a Point Mass
- Rotational Inertia of a Disk Off-Axis (fixed and rotating)
- Rotational Inertia of Disk and Ring – Two Axes
- Conservation of Angular Momentum, Using a Point Mass
- Conservation of Angular Momentum, Using a Disk and Ring
- Conservation of Angular Momentum (Projectile Version)

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Includes:

- Rotating Platform ME-8951
- Rotational Inertia Accessory ME-8953
- Centripetal Force Accessory ME-8952
- Instruction Manual

Components of this system

1. Rotating aluminum platform with 4 kg cast iron base, dual ball bearings, stainless steel shaft, three-step pulley, two rectangular sliding 300 g masses, and 50 cm track where a number of accessories may be mounted.
2. The Rotational Inertia Accessory with a 22.9 cm diameter, 1.50 kg disk (which may be rotated on two axes), a 12.7 cm diameter, 1.42 kg ring and Super Pulley with support rod and adapter.
3. The Centripetal Force Accessory with spring support and radius indicator, mass support, three masses, and Super Pulley with Clamp.

Order Information

Complete Rotational System ME-8950A
Required:
Mass and Hanger Set..... ME-8979 p. 207

Interfacing Options

It is easy to use a computer to monitor rotational motion with the PASCO Rotational System. Here are two methods:

1. **The ME-9498A Photogate Head** mounts directly to the rotating platform base and measures angular speed. This works with the 850 and 550 Universal Interfaces.
   NOTE: PASPORT interfaces require a Digital Adapter (PS-2109).

2. **The CI-6538 or PS-2120 Rotary Motion Sensor** mounts to the base with an "A" Adapter and measures both angular speed and direction.

Order Information

Recommended:
Photogate Head ..... ME-9498A p. 33

Order Information

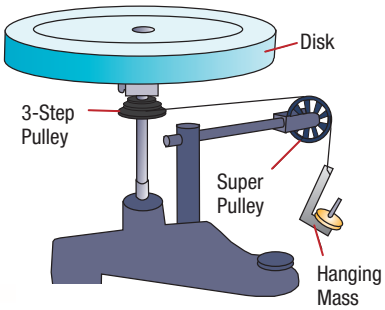
Required for use with ScienceWorkshop:
Rotary Motion Sensor CI-6538
Required for use with PASPORT:
PASPORT Rotary Motion Sensor PS-2120A
A-Base Rotational Adapter ..... CI-6690 p. 181

Experiments you can do with this rotational system:

Rotational Inertia of a Disk and Ring, 2 Axes

Center axis

With the disk mounted on the top of the vertical shaft, a torque is applied by a hanging mass. From the mass, radius, angular acceleration, and the rotational inertia of the disk can be determined.



Radial axis

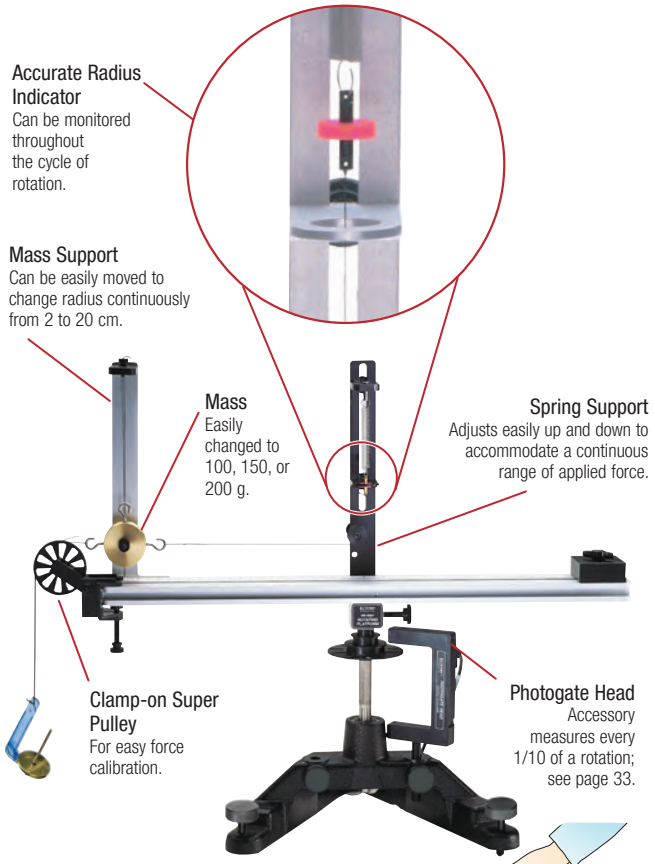
The disk can also be mounted on edge to decrease the rotational inertia by half.

Rotational Inertia of Off-axis Disk

The Rotational Inertia Adapter allows students to mount the disk anywhere along the platform. A bearing mounted on one side of the disk allows it to act either as a rigid mass or as a mass free to rotate around its point of attachment as the platform turns on the vertical shaft.

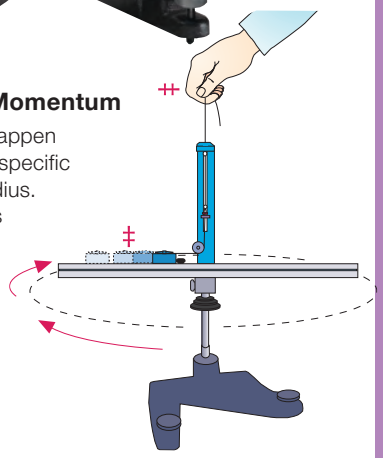
Centripetal Force

Centripetal force may be thoroughly investigated by varying both the mass and radius. The unique radius indicator allows students to continuously monitor the equilibrium position.



Conservation of Angular Momentum

Students can predict what will happen when a point mass rotating at a specific radius is pulled into a smaller radius. The rotational inertia of the mass at the inner and outer radii can be calculated and the results verified.



Rotational System Components and Accessories *see pages 180-181*

Rotating Platform and Rotational Inertia Accessory
p. 180

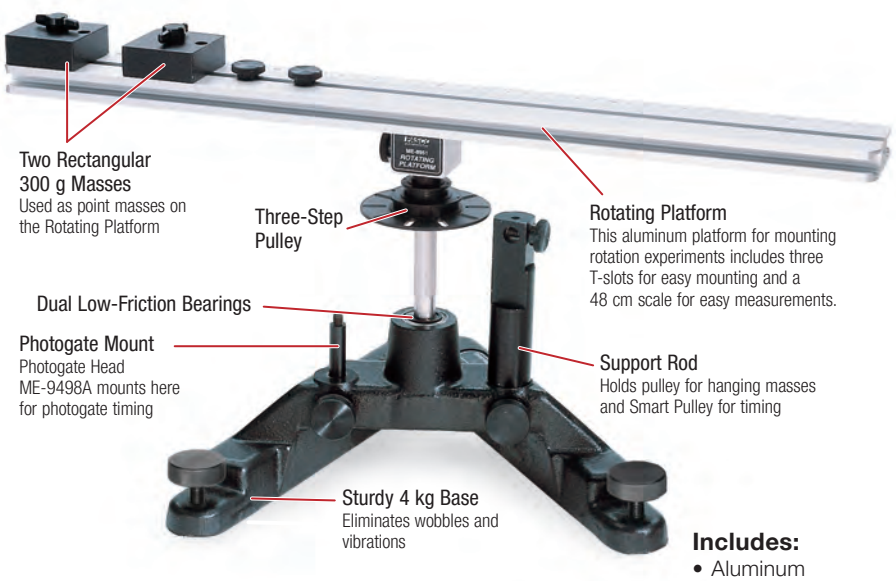
Centripetal Force Accessory
p. 180

Rotational Motor Drive
p. 181

"A"-base Rotational Adapter
p. 181

Rotating Platform

ME-8951



The stable base and precision bearings of the Rotating Platform are the foundation of PASCO's Rotational System. It serves as an excellent base for general rotation experiments.

Includes:

- Aluminum Platform for mounting rotation experiments
- 2 Rectangular 300 g Masses
- Sturdy 4 kg Cast Iron Base
- 3-step Pulley
- Support Rod

Order Information

Rotating Platform	ME-8951	
Recommended:		
Rotational Inertia Accessory	ME-8953	
Centripetal Force Accessory	ME-8952	
Rotational Motor Drive	ME-8955	p. 181

Rotational Inertia Accessory

ME-8953

A disk and a ring permit several experiments in rotational inertia. The disk may be rotated about several axes. When used in conjunction with the adapter, experiments using the parallel-axis theorem may be performed by moving the disk off from the center of rotation. The ball bearing on one side of the disk permits it to rotate freely for some experiments, while a "D" hole on the other side prevents rotation about the disk axis.

Includes:

- Heavy-Grade Plastic Disk (22.9 cm diameter, 1500 g)
- Metal Ring (12.7 cm outside diameter, 1420 g)
- Disk Adapter
- Super Pulley and Support Rod

Order Information

Rotational Inertia Accessory	ME-8953

Centripetal Force Accessory

ME-8952

With traditional centripetal units, the ability to change the variables is either impossible or limited. The PASCO Centripetal Force Accessory is designed to make changing the mass, radius, or force quick and easy.

Features:

- **Vary Parameters Independently:** Change the centripetal force, mass and radius independently of each other.
- **Change Variables over a Wide Range:** Radius can be varied continuously from 2 to 20 cm, and the rotating mass can be 100, 150 or 200 g.
- **Observe the Radius Indicator throughout the Cycle:** PASCO's design has the indicator at the center of rotation, allowing continuous observation throughout the rotation cycle, resulting in more accurate measurements.

Includes:

- Spring Support and Radius Indicator Assembly
- Mass Support
- Masses (100 g and two 50 g)
- Super Pulley with Clamp

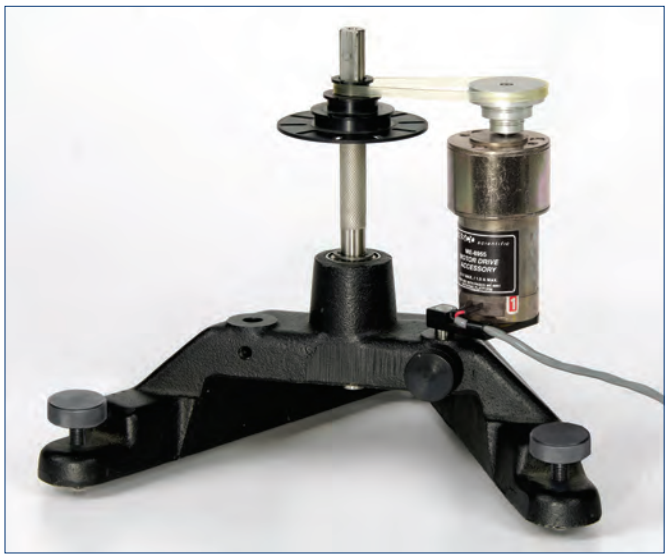
Order Information

Centripetal Force Accessory	ME-8952

Rotational Motor Drive

ME-8955

The Motor Drive is used with the Rotational Platform to power continuous rotational motion demonstrations. Use this motor to drive the Rotational Acceleration Tank at a constant speed. Power the Motor Drive with a ramp function using the DC Power Supply to smoothly increase the angular speed of the Centripetal Force Accessory. The motor requires a 12 V DC power supply or a function generator.



Easily change the gear ratio of the motor drive by moving the drive belt to one of the three possible pulley steps.

Specifications:
Motor: 12 V maximum, 0.2 A minimum
Base Spindle Speed Range: 10 to 600 rpm

Includes:
- Motor
- Three-Step Pulley
- Drive Belt

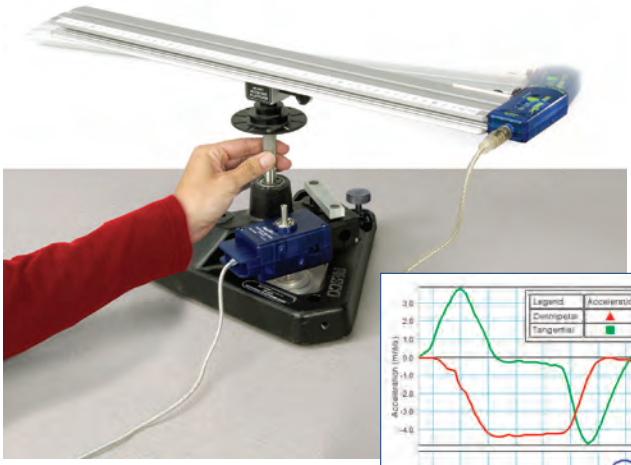
Order Information

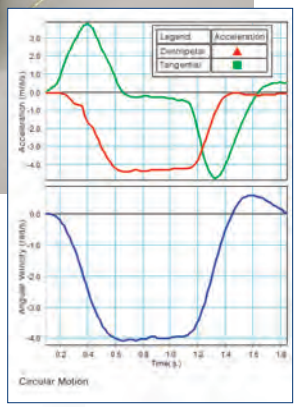
Rotational Motor Drive	ME-8955	
Required:		
Rotating Platform	ME-8951	p. 180
850 Universal Interface	UI-5000	p. 26
OR		
Function Generator	PI-8127	p. 266
OR		
DC Programmable Power Supply	PI-9880	p. 261

A-Base Rotational Adapter

CI-6690

The A-Base Adapter allows students to mount a Rotary Motion Sensor for high resolution data collection. One revolution of the vertical shaft corresponds to one revolution of the Rotary Motion Sensor, generating up to 4000 data points per revolution.





The platform is quickly rotated (from rest) and then brought to a stop. Both the tangential and centripetal acceleration is measured (using the 2-Axis Acceleration Sensor), while the platform's angular velocity is measured by the Rotary Motion Sensor.

Close-up of Rotary Motion Sensor mounted on "A"-Base

Includes:
- Rotary Motion Sensor Mounting Post
- O-Ring Drive Belt
- Three-Step Pulley
- Pulley Mounting Screw

Order Information

A-Base Rotational Adapter	CI-6690	
Required:		
Rotating Platform	ME-8951	p. 180
Rotary Motion Sensor	CI-6538	p. 32
OR		
PASPORT Rotary Motion Sensor	PS-2120A	p. 41

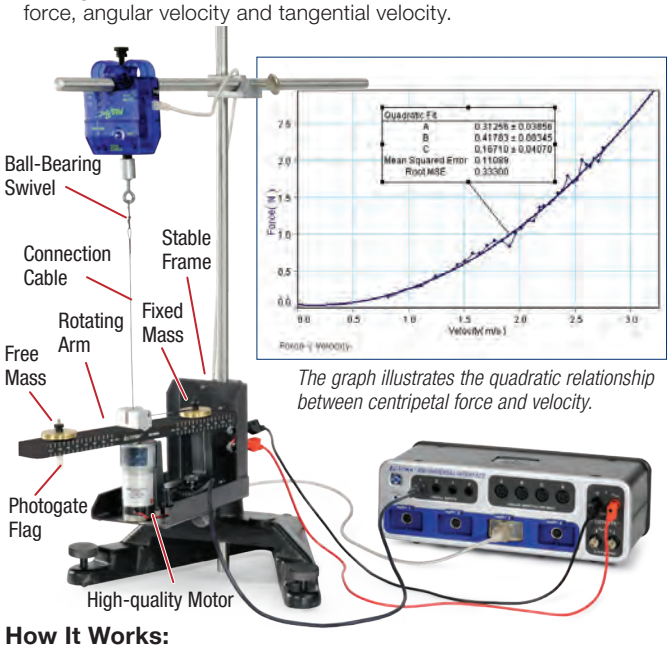
Centripetal Force Apparatus

ME-8088

- Empirically determine centripetal force
- Easy to set up
- Repeatable results

Features:

- **Stable Frame:** The metal frame can be easily attached to a ring stand using the included clamp. The frame may also be attached to a tabletop with a large table clamp.
- **High Quality Motor:** Will withstand years of student use.
- **Computer-based Measurements:** The Force Sensor and photogate facilitate accurate and repeatable measurements of force, angular velocity and tangential velocity.



The graph illustrates the quadratic relationship between centripetal force and velocity.

How It Works:

The rotating arm features a groove with two captured masses along its length. One of the masses is free to move along the length of the groove. The free mass is connected to a small cable that runs under a pulley in the center of the arm and up to a Force Sensor. A ball-bearing swivel is used to ensure the cable does not tangle as the arm rotates. The other mass is placed the same distance from the center as the free mass, thereby balancing the arm. A flag attached to the bottom of the fixed mass passes through the photogate once per revolution, allowing a calculation to be made of the angular and tangential velocity of the mass.

Includes:

- Frame with Mounted 12 VDC Electric Motor
- Connecting Cable
- Ball-Bearing Swivel
- Connecting Hardware for Photogate
- Mass Holder for Free Mass
- Mass Holder for Fixed Mass
- 5 g Mass (2)
- 10 g Mass (2)
- 20 g Mass (2)

Order Information

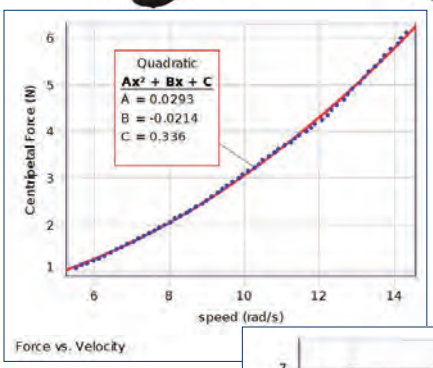
Centripetal Force Apparatus	ME-8088	
Required:		
Force Sensor		p. 32, 42, 65
Photogate Head		p. 33
Triple Output Power Supply	SE-8587	p. 262
Large Rod Base	ME-8735	p. 196
45 cm Stainless Steel Rod	ME-8736	p. 196
120 cm Stainless Steel Rod	ME-8741	p. 196
Multi-Clamp	ME-9507	p. 198

Wireless Centripetal Force Accessory

ME-8094

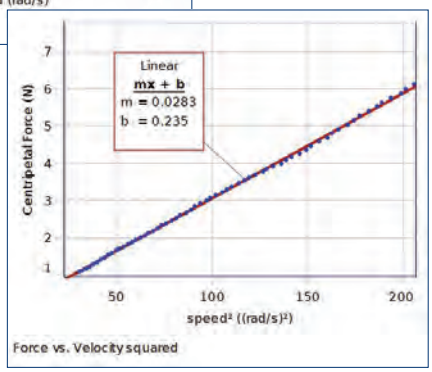
- Transmitting data wirelessly eliminates friction
- Uses Wireless Force Acceleration Sensor
- Vary speed, radius, and mass

The Wireless Centripetal Force Accessory is a low-friction, sliding mass holder that connects to a Wireless Force Acceleration Sensor (PS-3202). When installed on a Rotating Platform (ME-8951), it provides a simple and direct measurement of centripetal force and acceleration. Vary the mass using the holed masses in the Mass and Hanger Set (ME-8979). The string length is easily adjusted to vary the radius.



This PASCO Capstone graph shows the Centripetal Force (measured directly by the Wireless Force Acceleration Sensor) versus Angular Speed as the platform slows down.

In this PASCO Capstone graph, a "QuickCalc" of speed squared has been chosen on the horizontal axis, resulting in a straight line.



Includes:

- Low-friction sliding mass holder
- Mounting post for force sensor

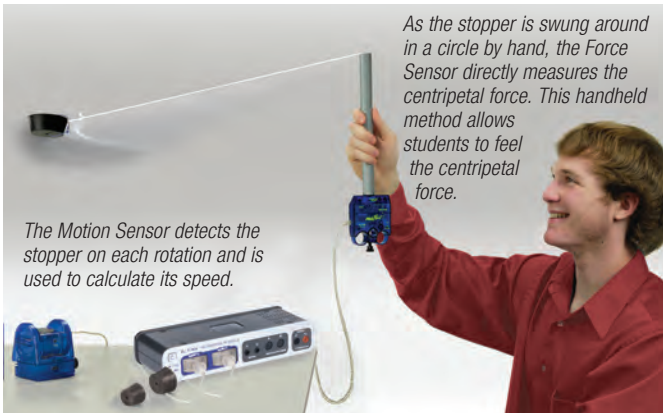
Order Information

Wireless Centripetal Force Accessory	ME-8094	
Recommended:		
Wireless Force Acceleration Sensor	PS-3202	p. 65
Mass and Hanger Set	ME-8979	p. 207
Rotating Platform	ME-8951	p. 180
PASCO Capstone		pp. 68-71

Handheld Centripetal Force

Discover Centripetal Force Kit

ME-9837A



Use this kit traditionally with hanging masses, or use it with a Force Sensor to continuously measure the centripetal force. Adding sensors to this classic experiment creates a dynamic, quantitative lab that your students will never forget.

Includes:

- Rubber Stoppers (sizes 6, 8, 10)
- Plastic Ties (10)
- Yellow String (73 meters)
- Hollow Tube

Order Information

Discover Centripetal Force Kit	ME-9837A	
Shown in use with:		
PASPORT High Resolution Force Sensor	PS-2189	p. 42
PASPORT Motion Sensor	PS-2103A	p. 40
Required for Classic Approach:		
Hooked Mass Set	SE-8759	p. 207
PASCO Stopwatch	ME-1234	p. 129

Flying Plane

SE-6673

An alternative to the Flying Pig, the Flying Plane is a great way to do experiments in uniform circular motion. The Flying Plane sweeps a conic section allowing students to measure the angle from the point of attachment and analyze the motion using force vector diagrams.

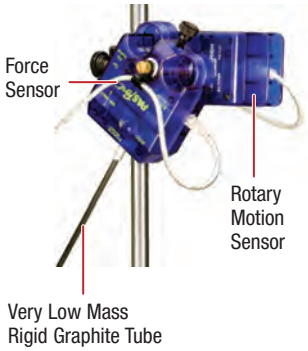
Order Information

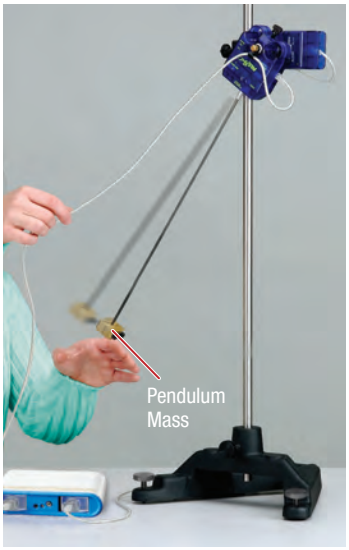
Flying Plane	SE-6673	

Centripetal Force Pendulum

ME-9821

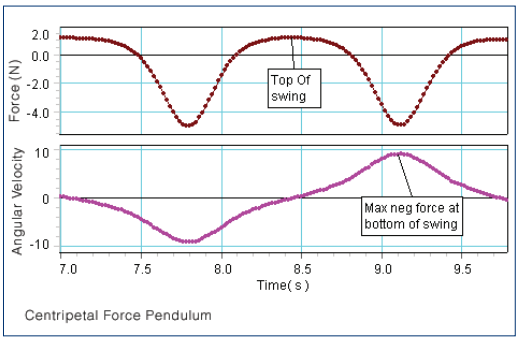
- Quantitative force vs. velocity data
- Repeatable results
- Vary pendulum length and mass





When used with Force and Rotary Motion Sensors, the Centripetal Force Pendulum allows students to collect accurate circular motion data.

The Centripetal Force Pendulum attaches to a Force Sensor and allows students to directly measure the forces involved in circular motion. By attaching the Force Sensor/pendulum combination to the Rotary Motion Sensor, the relationship between force, mass, and velocity in a circular path can be investigated.



The Centripetal Force Pendulum is used to produce graphs of force and angular velocity vs. time. Note that the force changes direction at the top of the swing for large amplitudes.

Includes:

- Graphite Pendulum Rod with Threaded Connector
- Sliding Mass (100 g)
- Mount with Cord Clip

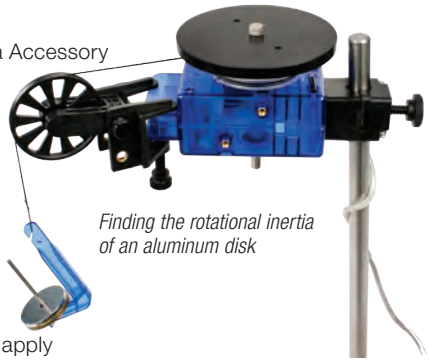
Order Information

Centripetal Force Pendulum	ME-9821	
Required:		
Large Rod Base	ME-8735	p. 196
45 cm Stainless Steel Rod	ME-8736	p. 196
90 cm Stainless Steel Rod	ME-8738	p. 196
Multi-Clamp	ME-9507	p. 198
PASPORT Rotary Motion Sensor	PS-2120A	p. 41
PASPORT Force Sensor	PS-2104	p. 42

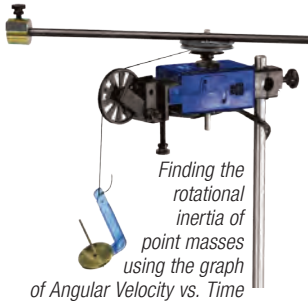
Rotational Inertia Accessory

ME-3420

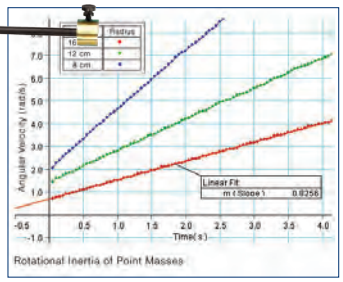
Add the Rotational Inertia Accessory to any PASCO Rotary Motion Sensor to study the oscillations of a pendulum, the rotational inertia of a disk, a steel ring and a metal rod, as well as the conservation of momentum during a rotational collision. The clamp-on Super Pulley allows students to apply a torque by hanging a mass over the pulley.



Finding the rotational inertia of an aluminum disk



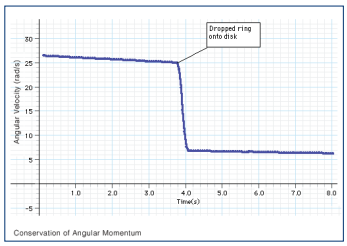
Finding the rotational inertia of point masses using the graph of Angular Velocity vs. Time



Conservation of Angular Momentum

See page 344 for complete experiment.

To demonstrate conservation of angular momentum, a non-rotating ring is dropped onto a rotating disk. The angular velocity of the disk is recorded in real time, and students can easily determine the angular velocities of the disk just before and after the ring is dropped. Combining these velocities with the rotational inertia of the disk and ring, students can confirm that angular momentum is conserved.



The angular speed of the disk decreases when the ring is dropped onto the spinning disk.

Includes:

- Disks: 8.9 cm diameter, 100 g
- Thin Ring: 8.9 cm o.d., 7.9 cm i.d., 100 g
- 38 cm Pendulum Rod (27 g)
- 75 g Mass (2)
- Clamp-on Super Pulley
- Alignment Guides: 3.9 cm radius, 1.7 g

Order Information

Rotational Inertia Accessory	ME-3420	
Also available:		
Ring And Disk Set	ME-3419	
(Includes ring, 2 disks, and 3 alignment guides)		

Pivot

ME-7034

The Pivot is a general purpose rotation device that can be mounted on a rod stand to perform rotation experiments in the horizontal or vertical planes.

Perform These Experiments:

- Meter Stick Torque
- Rotational Inertia
- Physical Pendulum
- Centripetal Acceleration

A Smart Gate with a Pulley measures the rotational velocity of the apparatus mounted on the Pivot.

Specifications:

Slotted Shaft Diameter: 1/4-inch (6.35 mm)

Slotted Shaft Length: 16 mm (both sides)

Slotted Shaft: Both ends are threaded for the included 6-32 screw

Shielded Ball Bearings: 2

Case Dimensions: 4.0 x 4.1 x 7.3 cm

Built-in Rod Clamp: Fits up to 1/2-inch (12.7 mm) diameter rod

Includes:

- Pivot
- 3-step Pulley

Order Information

Pivot	ME-7034	
Recommended:		
Ring And Disk Set	ME-3419	p. 151
Super Pulley with Mounting Rod	ME-9499	p. 64
Wireless Smart Gate	PS-3225	

Pendulum Accessory

ME-8969

The pendulum rod and masses can be purchased separately.

Includes:

- 38 cm Pendulum Rod (27 g)
- 75 g Mass (2)

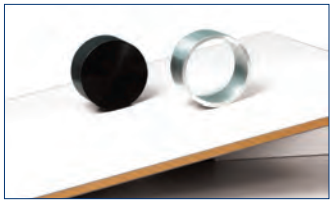
Order Information

Pendulum Accessory	ME-8969

Rotational Inertia Set

ME-9774

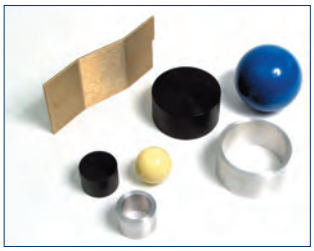
Release two different sized objects simultaneously.



Compare rotational inertias of objects with different shapes and sizes. Students learn that the speed of an object rolling down the ramp is not affected by its mass or radius. The shape or distribution of the mass determines the outcome. The sphere will reach the bottom first, followed by the disk. The ring will be last.

Includes:

- 10 cm outer diameter set
  - Solid Sphere (810 g)
  - Ring (Aluminum, 230 g)
  - Disk (Plastic, 370 g)
- 5 cm outer diameter set
  - Solid Sphere (110 g)
  - Ring (Aluminum, 90 g)
  - Disk (Plastic, 70 g)
- Release Mechanism



Order Information

Rotational Inertia Set..... ME-9774

Spherical Mass Set

ME-8968

This set includes four balls, each of which has a diameter of 2.5 cm and a different mass than the others. Includes a hollow steel ball, solid steel ball, plastic ball and aluminum ball.

Applications:

- Race the hollow steel and solid aluminum balls down an incline. They have about the same mass, but the solid aluminum ball has a much larger acceleration down the ramp.
- Fire the yellow plastic, solid steel, and hollow steel balls from a PASCO Projectile Launcher.

Includes:

- Solid Yellow Nylon Ball (10 grams)
- Solid Steel Ball (66 grams)
- Hollow Steel Ball (21 grams)
- Solid Aluminum Ball (24 grams)

(release mechanism not included)

Order Information

Spherical Mass Set..... ME-8968

Rotational Inertia Wands

ME-9847

The red and blue wands have the same mass, but the red wand is easier to rotate because it has less rotational inertia.

These two wands have the same mass and the same dimensions and yet the red wand is easier to rotate. This is because the red wand has two metal slugs near its center, while the blue wand has two similar metal slugs at its ends. This demonstrates that rotational inertia depends on the distribution of the mass.

These sturdy plastic wands have small holes near the center and at the ends to enable students to see where the metal is located in each wand. What initially seems a mystery can be explained to the students by allowing them to examine the wands more closely.

To demonstrate the difference in rotational inertia of the two rods, ask two students to grab the center of a wand and instruct them to rotate the wand back and forth as rapidly as they can. No matter how strong the student with the blue wand is, he or she is not able to rotate it as fast as the student with the red wand.

Specifications:

Length: 1 m
Diameter: 4 cm
Ratio of Blue Rotational Inertia to Red: Approx. 6

Includes:

- Red Wand (1)
- Blue Wand (1)

Order Information

Rotational Inertia Wands ME-9847

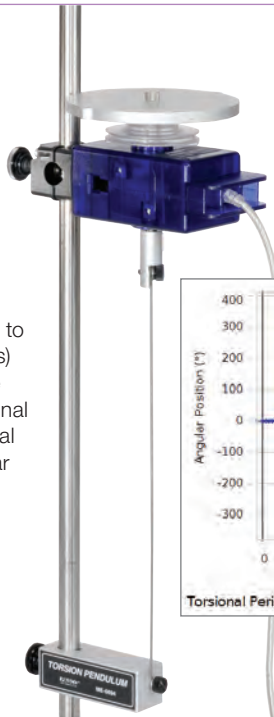
Torsional Pendulum

ME-6694

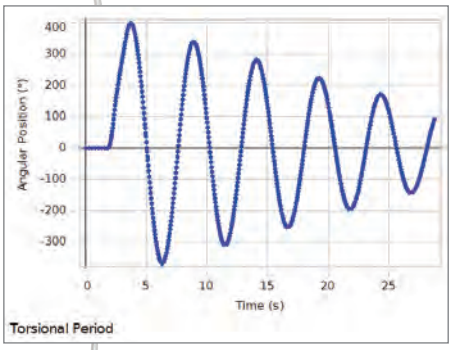
Concepts:

- Period of a torsional pendulum
- Rotational inertias of a disk, ring, and point masses
- Torque
- Torsional spring constant

The period of a Torsional Pendulum is measured and compared to the theoretical value. The torsional pendulum consists of a torsion wire attached to a Rotary Motion Sensor with an object (a disk, ring, or rod with point masses) mounted on top of it. The period of oscillation is measured from a plot of the angular displacement versus time. To calculate theoretical period, the rotational inertia is determined by measuring the dimensions of the object. The torsional spring constant is determined from the slope of a plot of force versus angular displacement.

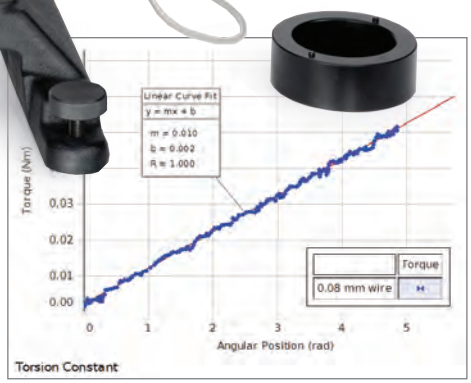


The Torsional Pendulum uses a Rotary Motion Sensor to record the oscillations.

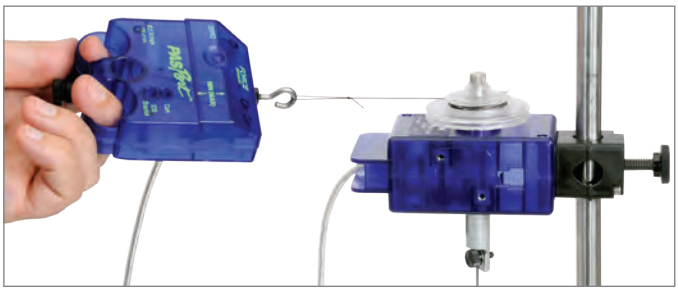


The period of the Torsional Pendulum is determined from a plot of angular displacement versus time.

To determine the torsional spring constant, a torque is applied by pulling with a Force Sensor.



The torsional spring constant is determined from a plot of torque versus angular displacement.



Includes:

- Torsional Wires
  (3 each of 3 different spring constants)
- Wire Clamps (2)

PASCO Advantage

To determine the torsional spring constant, the Force versus Angular Displacement graph is quickly and easily obtained by pulling with a Force Sensor on a string wrapped around the Rotary Motion Sensor pulley.

Order Information

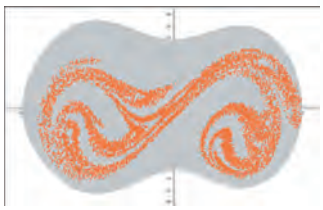
Torsional Pendulum	ME-6694	
Required:		
Large Rod Base	ME-8735	p. 196
Stainless Steel Rod, 60 cm Threaded	ME-8977	p. 196
Rotational Inertia Accessory	ME-3420	p. 184
PASPORT Rotary Motion Sensor	PS-2120A	p. 41
PASPORT Force Sensor	PS-2104	p. 42
550 or 850 Universal Interface*		pp. 26-29
PASCO Capstone Software		pp. 84-87

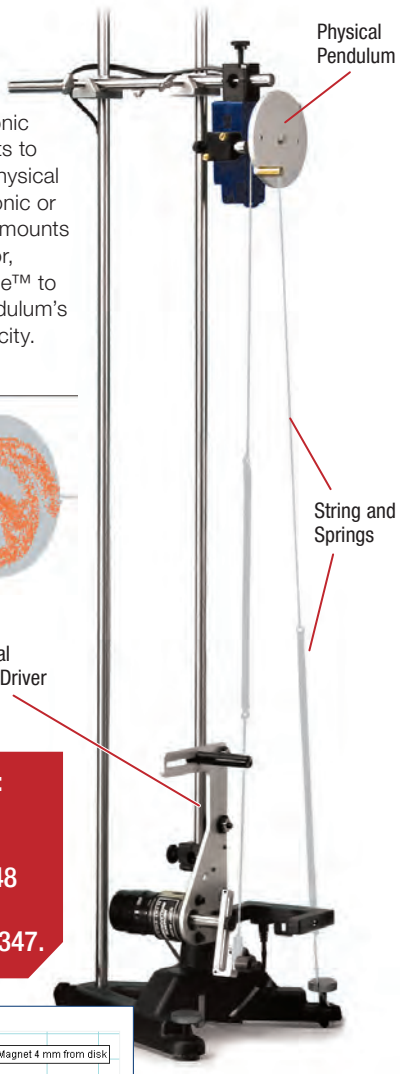
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Chaos/Driven Harmonic Accessory

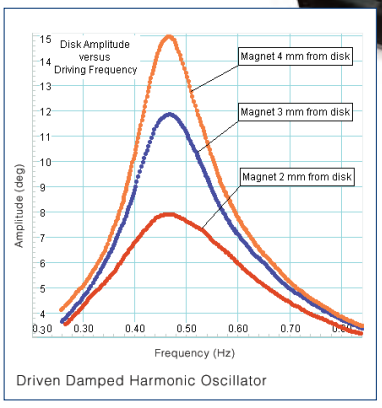
CI-6689A

The Chaos/Driven Harmonic Accessory allows students to study the behavior of a physical pendulum in either harmonic or chaotic motion. The disk mounts to a Rotary Motion Sensor, allowing PASCO Capstone™ to monitor and plot the pendulum's angular position and velocity.





See full experiments: EX-5522A Driven Damped Harmonic Oscillator on page 348 and EX-5523A Chaos Experiment on page 347.



Driven Damped Harmonic Oscillator

Angular Velocity vs. Frequency graph shows effects of magnetic damping on amplitude of resonance peak.

Includes:
- Rotating Disk (9.5 cm diameter, 120 g)
- Eccentric Mass (15 g)
- Springs
- Adjustable Magnet for Damping

Order Information

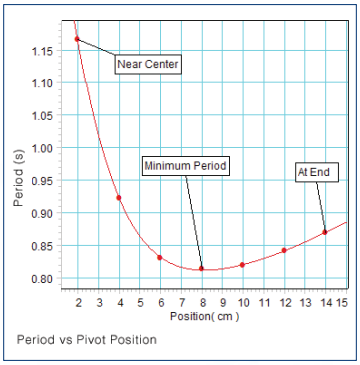
Chaos/Driven Harmonic Accessory..... CI-6689A

Physical Pendulum Set

ME-9833

This set of six objects is perfect for studying Physical Pendulums, Moments of Inertia, and the Parallel Axis Theorem. Each piece fastens directly to a Rotary Motion Sensor to measure the object's acceleration due to an applied torque, or the period when the pendulum freely oscillates.

Each piece is made from 1/4 inch-thick aluminum plate.

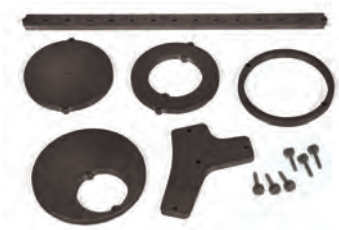


Period vs Pivot Position

The Pendulum Bar has holes spaced at 2 cm intervals. A graph of Oscillation Period vs. Pivot Hole Position shows that there is a unique placement that gives a minimum period. This location can be verified using calculus.

Unique design allows pivot exactly at the edge. Measure the period of the thick ring oscillating at either the inner or outer radius.

Includes:
- Solid Disk
- Thick Ring
- Thin Ring
- Offset Hole
- Pendulum Bar
- Irregular Shape
- Mounting Screws (6)



Order Information

Physical Pendulum Set..... ME-9833

Gyroscopic Motion

Demonstration Gyroscope (3-Axis)

ME-8960

- All components accessible
- Excellent demonstration tool
- Precision angle indicator

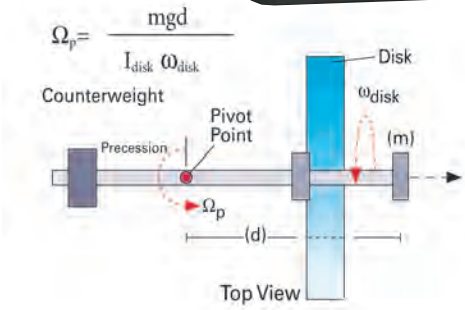
The low friction, open design of PASCO's Gyroscope enables rotational motion studies that were previously impossible with commercial units. The completely open design lets students stop precession by grabbing the vertical shaft, causing the Gyroscope to dip. Rotational mathematics can predict the dipping motion, but with PASCO's Gyroscope it can finally be confirmed.

How It Works:

The disk is spun by wrapping a string around the pulley and pulling. Or the disks can be spun by hand. Add mass to either end of the gyroscope and it responds with a predictable precession. Many features make this an exceptional demonstration tool for rotational motion concepts.

Features:

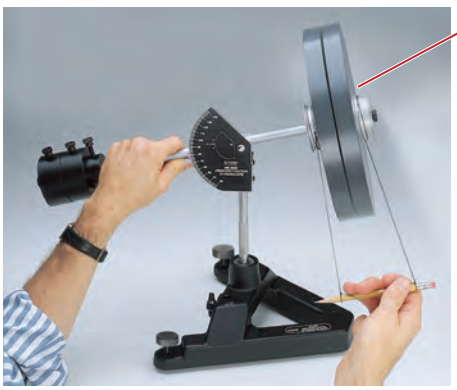
- **Low Friction:** The disk takes almost 6 minutes to slow to half of its original speed due to low-friction bearings in the gyroscope axle and vertical shaft.
- **Accurate Angle Indicator:** Measures from 30° to 140° and is easily read to the nearest degree. A retractable stop acts as a marker during experiments.
- **Easy Timing:** Low rotation speeds allow measurement of angular speed by counting revolutions and using a stopwatch.
- **Easy Balancing:** Two counterweights allow coarse and fine balance adjustment.
- **Large Inertia Disk:** With the large rotational inertia of the disk, PASCO's gyroscope generates precession rates similar to smaller, enclosed gyroscopes. The slow rotation speed of PASCO's disk lets students study fast as well as slow precession and use a stopwatch to make measurements.



Students can determine the rotational inertia of the rotating disk. They can then check the measured precession rate when a mass (m) is added a distance (d) from the pivot point.

Order Information

Demonstration Gyroscope (3-Axis)..... ME-8960
Recommended:
Gyroscope Disk and Mass..... ME-8961



A Unique Experiment: Rotate two disks in opposite directions at the same speed. The angular momenta cancel and the total angular momentum of the gyroscope is zero. The result is no precession.

Gyroscope Disk and Mass

ME-8961

Includes:

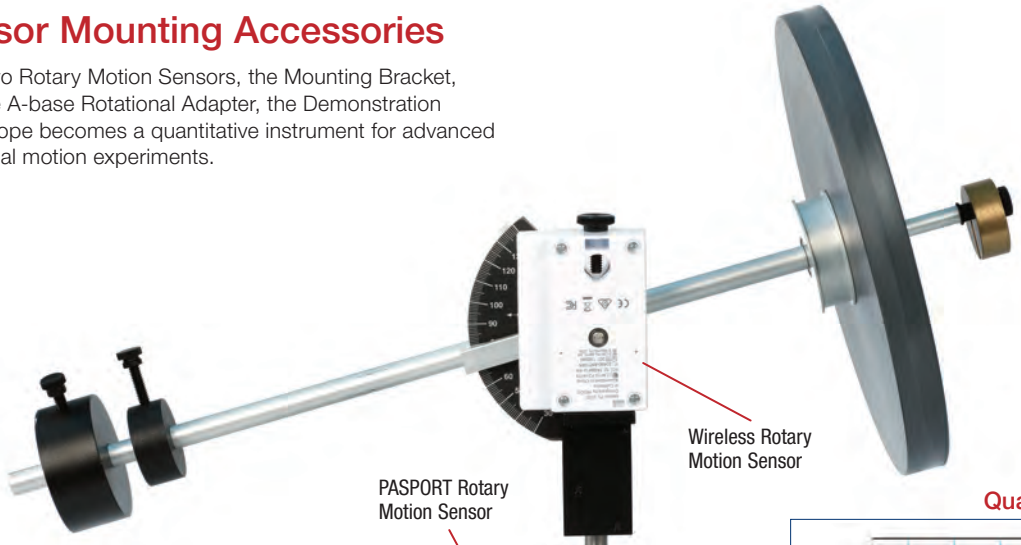
- Accessory Disk
- Extra Counter Mass

Order Information

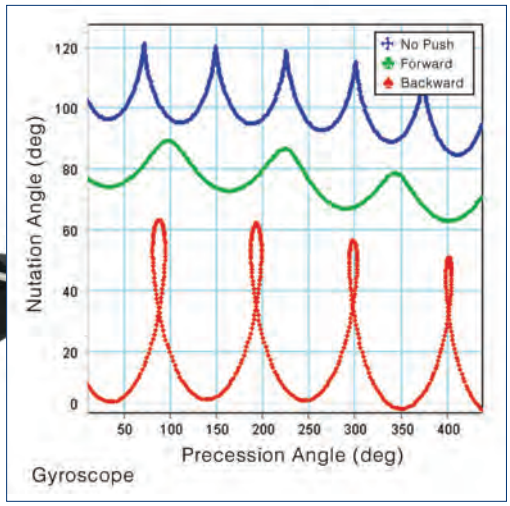
Gyroscope Disk and Mass.....ME-8961

Sensor Mounting Accessories

With two Rotary Motion Sensors, the Mounting Bracket, and the A-base Rotational Adapter, the Demonstration Gyroscope becomes a quantitative instrument for advanced rotational motion experiments.



Quantitative Measurements



Graph shows nutation pattern for three cases: The blue trace results when the Gyroscope is released from rest, with no initial push forward or backward.

Gyroscope Mounting Bracket for Rotary Motion Sensor

ME-8963

With the Mounting Bracket and the A-base Rotational Adapter (CI-6690), the Demonstration Gyroscope becomes a quantitative instrument for advanced rotational motion experiments. With two Rotary Motion Sensors, students obtain a graphical picture of the Gyroscope's nutation and precession motions.

Order Information

For Recording Nutation Data:
Gyroscope Mounting Bracket
for Rotary Motion Sensor ME-8963
Required:
PASPORT Rotary Motion Sensor ..... PS-2120A p. 41
Interface ..... pp. 24-25
OR
Wireless Rotary Motion Sensor ..... PS-3220 p. 63

A-Base Rotational Adapter

CI-6690

The A-base Adapter allows students to mount a Rotary Motion Sensor for high resolution data collection. One revolution of the vertical shaft corresponds to one revolution of the Rotary Motion Sensor, generating up to 4000 data points per revolution.

Includes:

- Rotary Motion Sensor Mounting Post
- O-Ring Drive Belt
- Three-Step Pulley
- Pulley Mounting Screw

This accessory is not compatible with PS-3220 Wireless Rotary Motion Sensor.

Order Information

For Recording Precession Data:
A-Base Rotational Adapter CI-6690
Required:
PASPORT Rotary Motion Sensor ..... PS-2120A p. 41
Interface ..... pp. 24-25

Bicycle Gyroscope

ME-6837

- Solid 1/2” steel shaft
- Cushioned hand-grips
- Precision ball bearings for low friction
- Non-marking rubber tire

The newly redesigned Bicycle Gyroscope is perfect for getting your students engaged in understanding rotational motion. Unlike other bicycle gyroscopes, the PASCO model is extremely rugged for years of use, but also lightweight at just 6 lbs. Cushioned hand-grips, a pull-cord with handle, and an included suspension cord (to demonstrate precession) make it simple and easy to use.

Precision ball bearings result in extremely low friction for both the Bicycle Gyroscope and the Rotating Chair.

The Bicycle Gyroscope with the Rotating Chair gives you a perfect demonstration of the conservation of angular momentum.

Use the included pull-cord with handle to spin up the wheel.

This 2.8 kg (6 lb.) Bicycle Gyroscope has a solid 2.7 mm (1/2”) steel shaft with cushioned hand-grips.

Attach cord (included) to hole in handle to demonstrate precession.

Includes:

- Bicycle Gyroscope
- Cords with Handles (2)

Order Information

Bicycle Gyroscope..... ME-6837
Shown in use with:
Rotating Chair..... ME-6856

Bicycle Wheel Mass Set

ME-6972

Adding all four of the masses adds 1.6 kg to the wheel’s approximate 2.8 kg mass and increases its rotational inertia by over 60%.

Mass securely clamps to the wheel rim using included screws.

Includes:

- Four 400 g masses

Order Information

Bicycle Wheel Mass Set ME-6972
Shown in use with:
Bicycle Gyroscope..... ME-6837

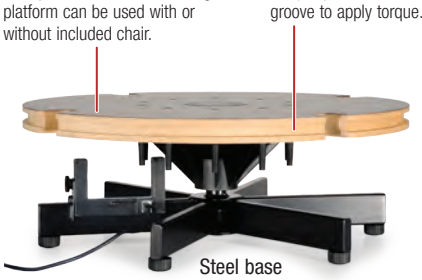
Rotating Chair

ME-6856

Rugged design and incredibly low friction make this far superior to any office chair.

Sturdy 45 cm diameter rotating platform can be used with or without included chair.

Wrap rope around groove to apply torque.



Includes:

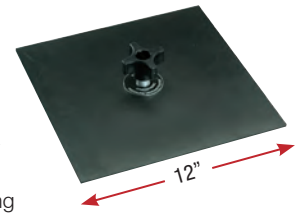
- Chair
- Rotating Platform with Leveling Feet

Order Information

Rotating Chair..... ME-6856
Shown in use with:
Photogate Head ME-9498A

Atmospheric Pressure Demonstrator

ME-8966A



Demonstrate the effect of a pressure differential. Easily lift a box or stool by simply placing the rubber sheet on a smooth surface of the object and lifting up on the handle.

As you pull up on the handle, a low-pressure region is created.

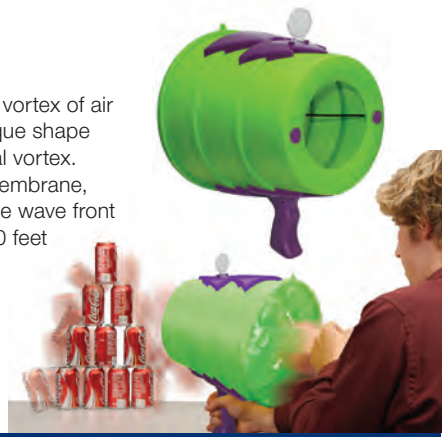
Order Information

Atmospheric Pressure Demonstrator ME-8966A

Air Cannon

SE-7370

The Air Cannon uses a vortex of air for ammunition. Its unique shape creates a stable toroidal vortex. Pull back the flexible membrane, release, and the invisible wave front of air can hit a target 20 feet away. Here is a great demonstration of the energy that can be stored in waves.



Order Information

Air Cannon SE-7370

Student Bell Jar

SE-9790

This bell jar provides a vacuum chamber for students to perform many experiments including:

- Watching a balloon expand or warm water boiling as air is pumped from the chamber
- Observing that a suction cup no longer sticks when the jar is evacuated

Water boils as air is evacuated from the Bell Jar.

Includes:

- 8 cm x 6 cm dia. clear plastic bell jar with base
- Plastic vial, balloons and suction cup
- 60 cc syringe and valves for evacuating the jar

Order Information

Student Bell Jar SE-9790

PhiTOP

SE-7594

The PhiTOP is an egg-shaped top (a prolate ellipsoid) that can be spun by hand to stand up on end. This is a fascinating demonstration used by Nikoli Tesla in 1893.

When spun with a magnetic stirrer, the PhiTOP replicates Tesla's famous Egg of Columbus demonstration. An alternating magnetic field will spin the PhiTOP from rest along its minor axis due to Lenz's law of electromagnetic induction. As the angular speed increases, the center of mass will rise, and the PhiTOP will spin along its major axis.

Includes:

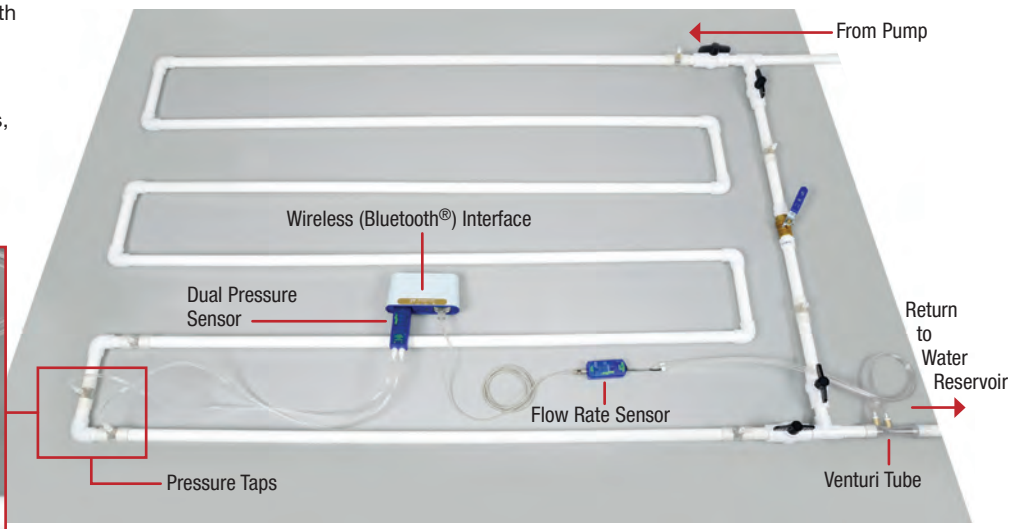
- PhiTOP
- Mirror Stand

Order Information

PhiTOP SE-7594
Recommended:
Magnetic Stirrer SE-7700

Pipe Network: Build it your way and instrument it inexpensively.

- Instrument your pipe network with pressure and flow sensors
- Transparent Venturi Tube and pressure taps
- Study head loss in pipes, fittings, and valves
- Find the relationship between pump head and flow rate



Pressure Taps are installed before and after elbow joints to measure the pressure loss. The Venturi Tube measures the velocity.

Measure Pressure

When constructing a pipe network, it is useful to know the pressure in the fluid at numerous places along the pipe. The transparent Pressure Taps can be glued into a 3/4" PVC pipe network at any place, using a slip joint. Each Pressure Tap has a quick-connect for a Dual Pressure Sensor (PS-2181). Since the quick-connect closes when disconnected, it is possible to move the pressure sensor around the network to determine the pressures at different positions, rather than having a separate pressure sensor for each position.

Measure Flow Rate

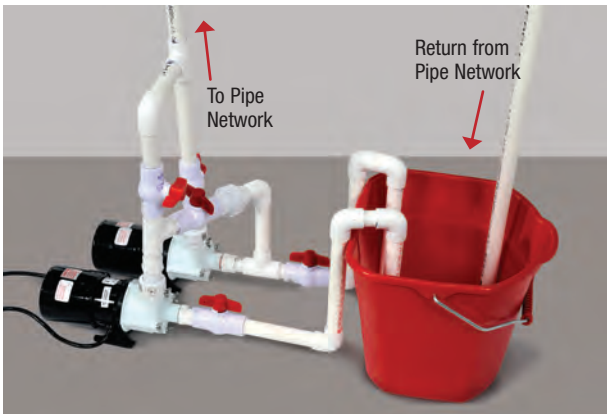
The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas, and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network. The Venturi Tube is made of clear PVC so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor (PS-2225) by the matching couplers.

Create Pump Curves

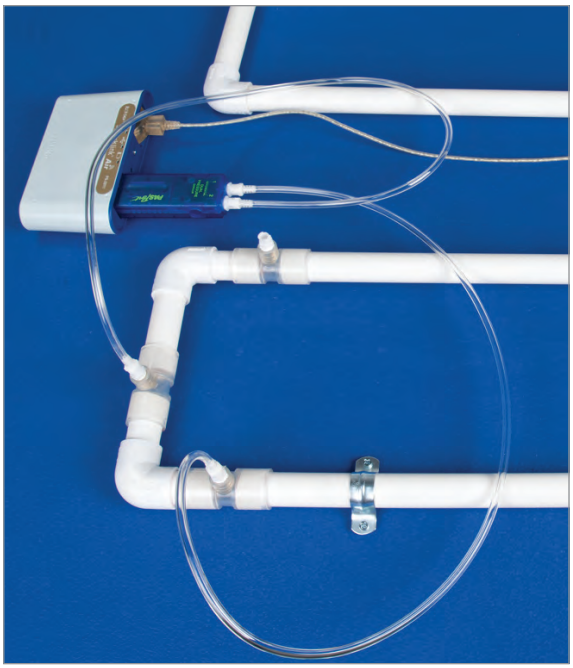
Create a plot of pressure vs. flow rate for a pump and determine the maximum head and flow rate. Study how these change when two pumps are connected in series or parallel.

Portable Interface

Use the SPARKlink Air (PS-2011) with a Dual Pressure Sensor (PS-2181) as a great portable pressure measurement system. The SPARKlink Air has two PASPORT sensor ports and can accommodate a General Flow Sensor to measure the volume flow rate and a Dual Pressure Sensor to measure the pressures along the pipe.



Study one pump or two pumps in series and parallel.



General Flow Sensor

PS-2222

The General Flow Sensor determines the fluid velocity of air or water by measuring the difference in pressure between the two input tubes. The Venturi Tube or Pitot Tube must be connected to the General Flow Sensor to collect data. The type of fluid (air or water) being used is selected using PASCO software.

Order Information

General Flow Sensor PS-2222

PASPORT Dual Pressure Sensor

PS-2181

- Measure pressure at two pipe pressure taps at once

The Dual Pressure Sensor is capable of reading two absolute pressures, one gauge pressure, or one differential pressure. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.

Specifications:

Maximum Sample Rate: 1000 Hz

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Differential Pressure: ±100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m^2, and psi)

Order Information

PASPORT Dual Pressure Sensor PS-2181

Order Information

Required for all above:
PASPORT Interface ..... pp. 24-25
PASCO Capstone Software ..... pp. 84-87
PVC Pipe and Fittings (supplied by user)
Pumps (2) (supplied by user)

Venturi Tube

ME-2220

The Venturi Tube is made of clear PVC, so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor by the matching couplers.
The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network.

Order Information

Venturi Tube ME-2220

Pressure Taps (set of 5)

ME-2224A

The transparent Pressure Taps can be glued into a 3/4" PVC pipe network at any place, using a slip joint.

Each Pressure Tap has a quick-connect for a Dual Pressure Sensor (PS-2181). Since the quick-connect closes when disconnected, it is possible to move the pressure sensor around the network to determine the pressures at different positions, rather than having a separate pressure sensor for each position.

Includes:

- Pressure Taps (5)
- 1/8" ID Tubing (4.5 m)
- Couplings (10)

Order Information

Pressure Taps (set of 5) ME-2224A

Wireless Interface

The SPARKlink Air (PS-2011) is a Bluetooth® interface that allows the computer to be away from water spills. See page 60 for more information.

Order Information

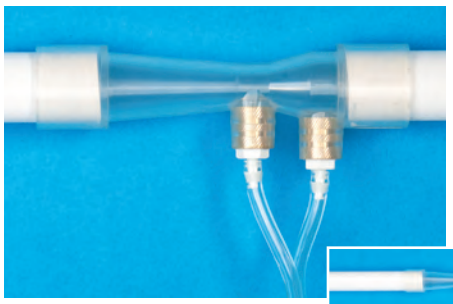
Shown in use with:
SPARKlink Air Interface ..... PS-2011 p. 60
Pitot Tube ..... ME-2221 p. 55

Explore the Equations for Fluid Flow Using Sensors

General Flow Sensor with Venturi Tube

PS-2225

- Measure fluid velocities and confirm the Continuity Equation
- Use Bernoulli's Equation to determine pressure difference
- Show faster moving fluids have lower pressures



The Venturi Tube has pressure taps at the narrow diameter and the larger diameter.

The General Flow Sensor connects to the Venturi Tube to measure the pressures.

In this apparatus, the Venturi Tube has pressure taps at the narrow diameter and the larger diameter. The General Flow Sensor connects to the Venturi Tube to measure the different pressures due to different fluid velocities. You supply the 3/4 inch PVC pipe and the water. It is suggested that you connect the pipe to a faucet with flexible tubing and, at the other end, let the water flow into a bucket resting on a Force Platform (PS-2141). As the water flows, the velocity can be determined by the changing weight of the bucket as measured by the Force Platform.

The recommended interface is the SPARKlink Air because two ports are required and it is convenient to have a wireless interface so your laptop can be away from the water. However, two AirLinks (PS-3200) or a 550 or 850 Universal Interface will do as well.

Continuity Equation: $A_1 v_1 = A_2 v_2$

Bernoulli's Equation: $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

(at constant height)

Order Information

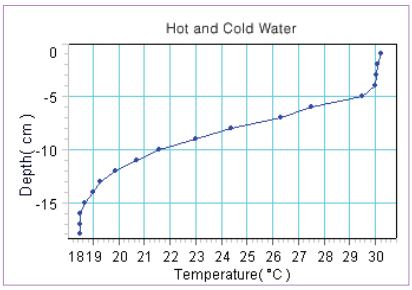
General Flow Sensor with Venturi Tube	PS-2225	
PASPORT Force Platform	PS-2141	p. 43
SPARKlink Air Interface	PS-2011	p. 60
PASCO Capstone Software		See pages 84-87
Supplied by User: PVC Pipe (3/4 inch), water, bucket		
Recommended (for velocity verification): Pitot Tube	ME-2221	p. 55

Density Circulation Model

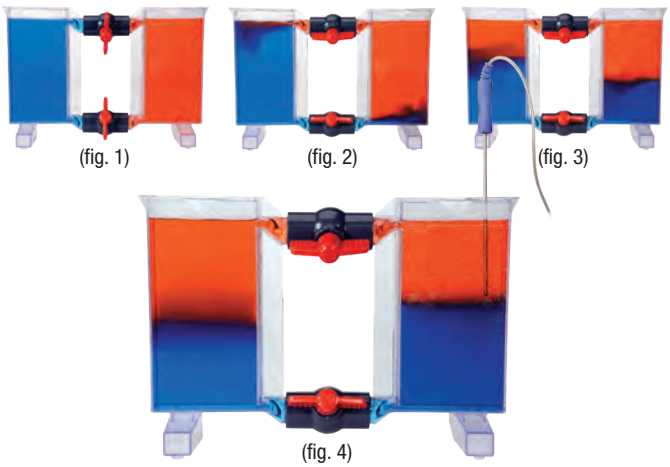
ME-6816

- Model density-driven circulation based on temperature, dissolved substances, or different liquids
- Demonstrate the driving forces of vertical ocean currents
- Measure temperature inversions based on density difference

The PASCO Density Circulation Model allows students to model, measure and understand the complex density-driven circulation associated with heat transfer through convection. Students can recreate vertical ocean currents driven by water bodies with density differences. They can extend this learning by using sensors to collect data and create graphs showing the thermocline, halocline and pycnocline using a Salinity Sensor PS-2195 (page 58).



Here is data showing Temperature vs. Depth. Rapid temperature change occurs in the region where the two water bodies mix.



(fig. 1) (fig. 2) (fig. 3)

(fig. 4)

With the valves closed (fig. 1), two bodies of liquid can be created that differ in temperature, dissolved materials, or other properties. When the valves are opened, a smooth flow of liquid occurs between the chambers (fig. 2 and fig. 3). Minimal mixing occurs and results in clearly defined layers of liquid based on density (fig. 4).

Order Information

Density Circulation Model	ME-6816	
Show in use with: PASPORT Stainless Steel Temperature Probe	PS-2153	p. 46

Density Set

ME-8569A

Use this versatile set of materials with the Overflow Can to investigate Archimedes' Principle of displacement, specific heats, and basic length/volume relationships. Includes pieces that have the same shape, volume, density, and mass, so the variable of interest can readily be isolated. Each piece has a hole, so it can be suspended from a string.

Includes:

- Three cylinders: aluminum, brass, plastic; 2.2 cm dia. x 6.4 cm long (plastic is less dense than water)
- Two blocks: aluminum (1.9 x 3.2 x 4.1 cm) and brass (1.6 x 1.9 x 2.8 cm); The mass of each block equals that of the aluminum cylinder.
- One irregular shape: aluminum
- Instruction manual

Order Information

Density Set ME-8569A

Archimedes' Principle Experiment

EX-9909

See page 341 for complete experiment.

Concepts:

- Archimedes' Principle
- Density
- Buoyant force

Archimedes' Principle states that the buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object.

The buoyant force on several objects is measured by weighing the water displaced by a submerged object. The buoyant force is also determined by measuring the difference between the object's weight in air and its apparent weight in water.

Some of the objects have the same density, some have the same volume, and some have the same mass. The density of each object is measured and the dependence of the buoyant force on density, mass, and volume is explored.

Order Information

Archimedes' Principle Experiment..... EX-9909

Mole Set

SE-7586

The Mole Set contains four element specimens: Copper, Iron, Zinc and Aluminum. Each sample contains approximately one mole, 6.02 x 10^{23} atoms of the element.

Includes:

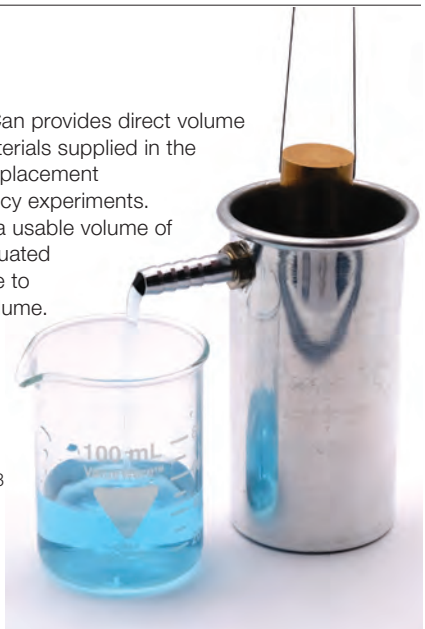
- Mole samples: Zinc, Aluminum, Iron, Copper
- Teaching Suggestions

Order Information

Mole Set SE-7586

Overflow Can

SE-8568A



This aluminum Overflow Can provides direct volume measurements for the materials supplied in the Density Set, as well as displacement measurements for buoyancy experiments. It has a 52 mm diameter, a usable volume of 185 cm^3. Requires a graduated cylinder or a gram balance to measure the displaced volume.

Specifications:

Height: 10.2 cm
Spout Height: 8.7 cm
Inner Diameter: 5.2 cm
Usable Volume: 185 cm^3

Includes:

- Can only

Order Information

Overflow Can SE-8568A

Glassware

Rugged borosilicate glassware for use in the physics lab.

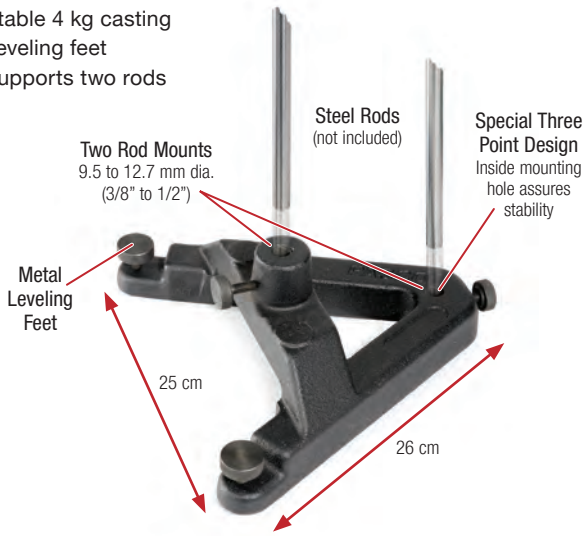
Order Information

Beaker, 100 ml (12 Pack)..... SE-7287
Beaker, 1000 ml (6 Pack)..... SE-7288
50 ml Graduated Cylinder (12 Pack)..... SE-7289

Large Rod Base

ME-8735

- Stable 4 kg casting
- Leveling feet
- Supports two rods



This sturdy 4 kg cast-iron wide base supports one or two rods. Rods from 9.5 to 12.7 mm (3/8 to 1/2 inches) diameter can be supported. Two adjustable feet provide the necessary leveling capabilities.

Order Information

Large Rod Base ME-8735

Metal Knobs and Feet (4 pack)

ME-8954

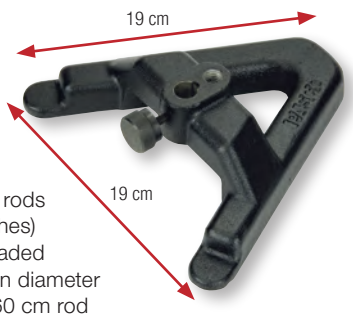
These replacement knobs and feet for the ME-8735 Large Rod Base are made of solid steel with knurled knobs and 5/16"-24 thread.

Order Information

Metal Knobs and Feet ME-8954

Small "A" Base

ME-8976



This 1.7 kg cast iron base is smaller than the Large Rod Base (above) and does not have leveling feet. This base can be used with both threaded and nonthreaded rods. Non-threaded rods from 9.5 to 13 mm (3/8 to 1/2 inches) diameter can be supported. Threaded rods must be 12.7 mm (1/2 inch) in diameter with 1/2"-13 thread, such as the 60 cm rod shown at right.

Order Information

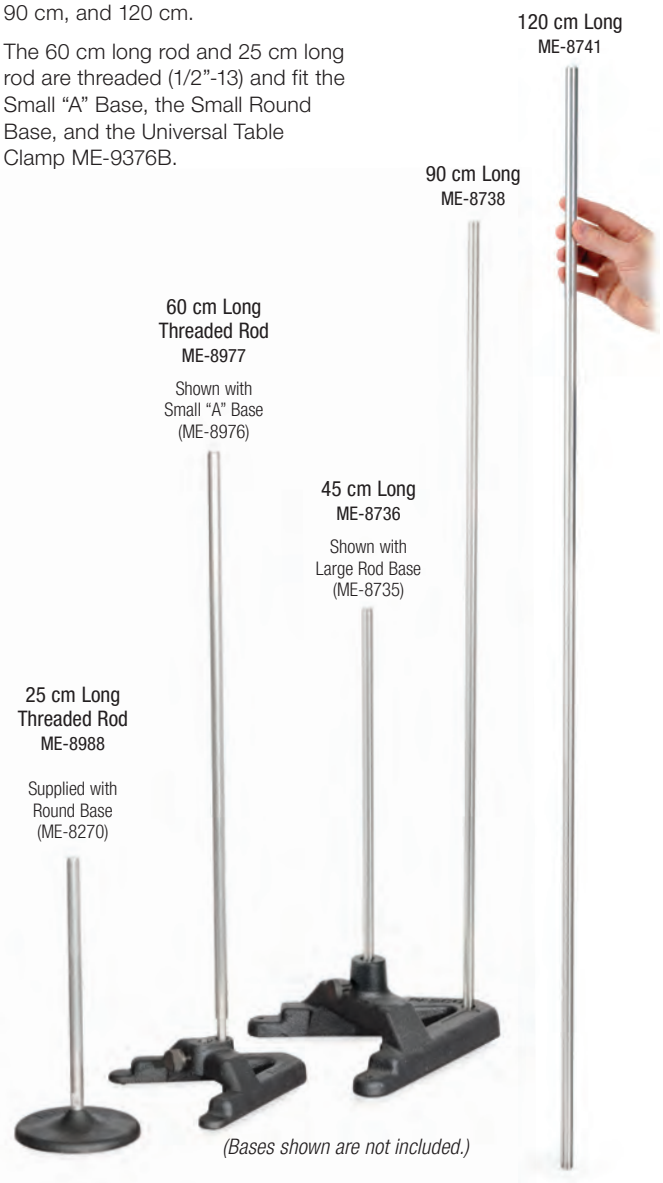
Small "A" Base ME-8976

Stainless Steel Rods

These 12.7 mm (1/2 in.) diameter stainless steel rods do not mar like aluminum rods. They are non-magnetic, very rigid, and durable.

Three different lengths are available in the non-threaded version: 45 cm, 90 cm, and 120 cm.

The 60 cm long rod and 25 cm long rod are threaded (1/2"-13) and fit the Small "A" Base, the Small Round Base, and the Universal Table Clamp ME-9376B.



(Bases shown are not included.)

Order Information

Stainless Steel Rods 12.7 mm (1/2 in.) in diameter:

45 cm Stainless Steel Rod ME-8736
90 cm Stainless Steel Rod ME-8738
120 cm Stainless Steel Rod ME-8741
Round Base with Rod.....ME-8270
Stainless Steel Rod, 60 cm Threaded ME-8977

Flex Rod

ME-8978A

- Flexible rod for holding objects in any orientation

The Flex Rod provides the freedom to place equipment where it's needed. Simply connect the object to the end of the 46 cm long flexible tubing and move it to the desired location. The tubing has enough rigidity to hold many common items in any orientation. In addition, two convenient clamps are included.

Flex Rod holds photogate for Acceleration Due to Gravity experiment using a picket fence (shown with Table Clamp, not included).

The Flex Rod with rod clamp attachment fits sensor handles.

The Flex Rod holds a green laser pointer. Shown with Small "A" Base (not included).

Includes:

- Flex Rod attached to rigid section
- 2 Rod Clamp attachments
- 3-Finger Clamp attachment (Base support not included.)

Order Information

Flex Rod	ME-8978A
Suggested Base Supports:	
Small "A" Base	ME-8976
Aluminum Table Clamp	ME-8995

Base and Support Rod

Large

Large Base and Support Rod with built-in leveling screws and a threaded aluminum rod that is 12.7 mm (1/2 in.) in diameter and 45 cm long.

Round

Round base with rod. The threaded steel rod is 12.7 mm (1/2 in.) in diameter and 25 cm long.

Order Information

Base and Support Rod	ME-9355
Round Base with Rod	ME-8270

How to choose the best mounting rod

Both of these rods are useful for mounting sensors, particularly photogates. They also work well with Smart Pulleys.

The SA-9242 stainless steel rod is the same length as the ME-9483 plastic rod. However, the steel rod has a smaller diameter that may not work with all clamps that require a standard 12.7 mm (1/2 in) diameter. The ME-9483 is made of a hard plastic that clamp screws do not dent and it has a threaded brass stud. The lighter weight of the plastic rod will not damage pulleys when thrown into a bin.

Mounting Rods (10 pack)

ME-9483

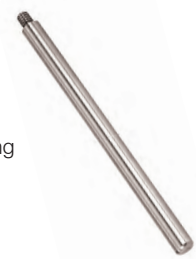
These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) have a 1/4" metal stud that screws into a Super Pulley.

Order Information

Mounting Rods (10 pack)	ME-9483

Pulley Mounting Rod

SA-9242

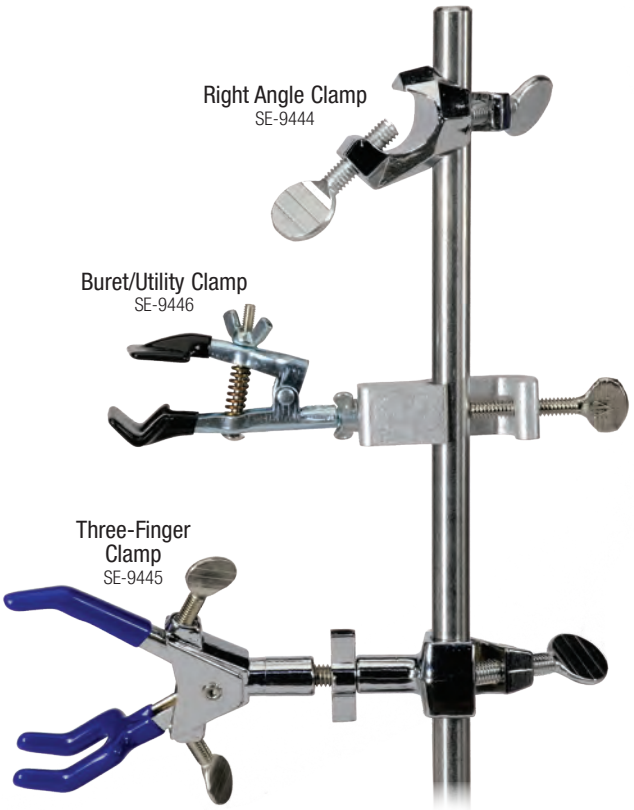


This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Clamp. It has a standard 1/4"-20 thread.

Order Information

Pulley Mounting Rod	SA-9242

Clamps



Right Angle Clamp

SE-9444

This standard right angle clamp fits rods up to 18 mm (11/16 inch) in diameter.

Buret/Utility Clamp

SE-9446

The V-shaped, plastic-coated jaws of this Buret Clamp open from 5 to 35 mm, rotate 360°, and lock in position at any angle. Fits rods up to 16 mm (5/8 inch) in diameter.

Three-Finger Clamp

SE-9445

Clamp tubes, rods, and irregularly shaped objects. The jaws extend 19 mm, open to 57 mm, rotate 360°, and lock securely at any angle. Fits rods up to 19 mm (3/4 inch) in diameter.

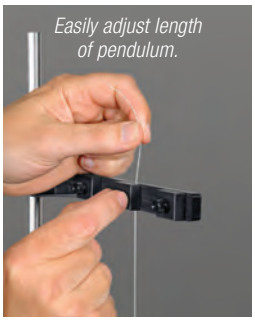
Order Information

Right Angle Clamp	SE-9444
Buret/Utility Clamp	SE-9446
Three-Finger Clamp	SE-9445

Pendulum Clamp

ME-9506

Hang up to three springs or pendulums. Easily adjust the lengths of the pendulum strings.



Order Information

Pendulum Clamp	ME-9506	
Shown in use with:		
Photogate Pendulum Set	ME-8752	p. 177
Small "A" Base	ME-8976	p. 196
45 cm Stainless Steel Rod	ME-8736	p. 196

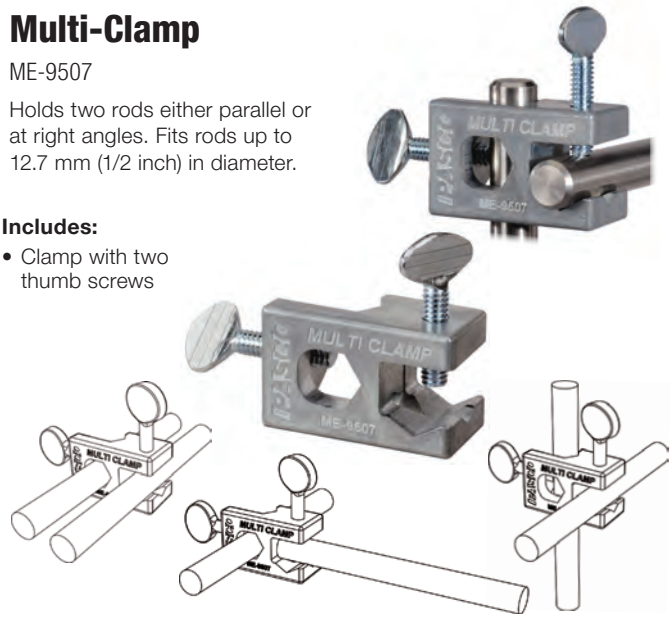
Multi-Clamp

ME-9507

Holds two rods either parallel or at right angles. Fits rods up to 12.7 mm (1/2 inch) in diameter.

Includes:

- Clamp with two thumb screws



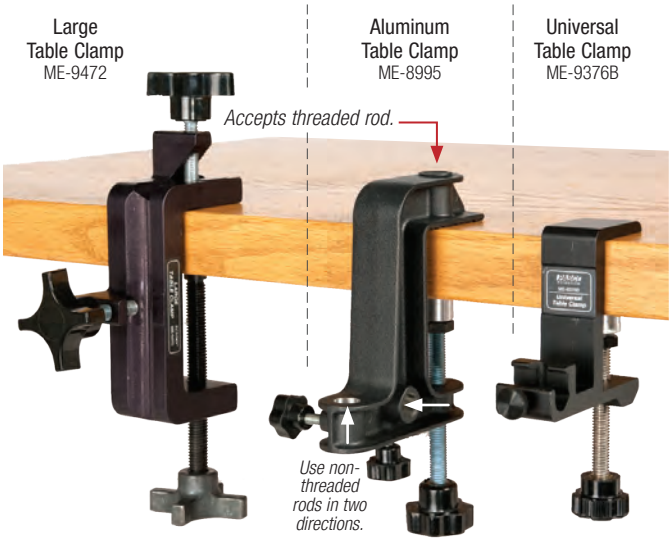
Order Information

Multi-Clamp	ME-9507

Large Table Clamp

ME-9472

These clamps hold up to 12.7 mm (1/2 inch) diameter rods that can be mounted either horizontally or vertically.



Order Information

Large Table Clamp (10 cm grip range) ME-9472

Aluminum Table Clamp (6 1/2 cm grip range) ME-8995

Universal Table Clamp (6 cm grip range) ME-9376B

"C" Clamps

SE-7285

This rugged clamp is perfect for attaching a variety of objects to a table. Available in 10 cm (4 inch) size.

Appearance may vary

Order Information

Large "C" Clamp (6 Pack) SE-7285

Laboratory Jacks

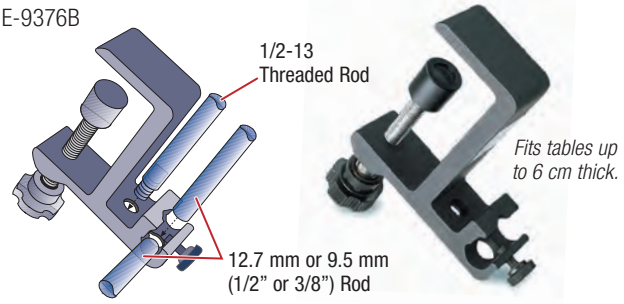
Raise, support and align equipment with these Lab Jacks. They're rugged, stable and ensure precise height adjustment. Two sizes are available.

Order Information

Lab Jack	Model	Platform (cm)	Height (cm)	Load (kg)
Medium	SE-9373	15 x 15	7-25	25
Large	SE-9372	20 x 20	7-25	25

Universal Table Clamp

ME-9376B



Attach this Universal Table Clamp to tables or shelves up to 6.0 cm (2 3/8 inch) thick. Can also be mounted on a ring stand.

Mount rods in the clamp either vertically or horizontally. The rods are held securely by stable three-point contacts. Use standard unthreaded lab rods — 9.5 mm (3/8 inch) to 12.7 mm (1/2 inch) — vertically or horizontally. Use 1/2-13 threaded lab rod vertically.

Order Information

Universal Table Clamp ME-9376B

Double Rod Clamp (3 pack)

ME-9873

Holds any two rods up to 12.7 mm (1/2 inch) in diameter, either parallel or perpendicular to one another.

Order Information

Double Rod Clamp (3 pack) ME-9873

Swivel Clamp (2 pack)

ME-8743

Clamp two rods at any angle or clamp the two rods parallel to each other. Accepts 12.7 mm (1/2 inch) rods.

- Includes Two Clamps

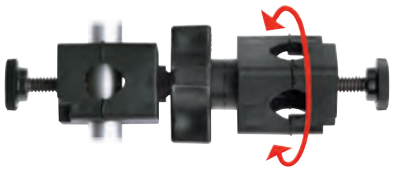
Order Information

Swivel Clamp ME-8743

Adjustable Angle Clamp

ME-8744

This unique clamp fits any rod up to 12.7 mm (1/2 inch) in diameter and can lock the rod in place at any angle.



Order Information

Adjustable Angle Clamp ME-8744

Pulleys

Super Pulley

ME-9450A

- 20 N max load
- Nearly frictionless
- Durable
- Precision dimensions

The PASCO Super Pulley is the standard in physics labs. Its low-friction design produces excellent results. The precision spacing of the 10 spokes makes it ideal for photogate monitoring with PASCO's computer interfaces and photogate systems.

Order Information

Super Pulley ME-9450A

Pulley Mounting Rod

SA-9242

This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Clamp. It has a standard 1/4"-20 thread.

Order Information

Pulley Mounting Rod (rod only) SA-9242

Wireless Smart Pulley

PS-3704

The Wireless Smart Pulley attaches directly to the Wireless Smart Gate, providing a simple, low-friction system to measure position, velocity and acceleration. Remove the pulley to use the photogate in standard photogate experiments.

Includes:

- Wireless Smart Gate (1) PS-3225
- Super Pulley (1) ME-9450A
- Super Pulley Rod (1)

Order Information

Wireless Smart Pulley PS-3704

Super Pulley With Mounting Rod

ME-9499

This Super Pulley mounted on a rigid plastic mounting rod (12.7 mm diameter, 14 cm long) fits most standard laboratory clamps.

Order Information

Super Pulley With Mounting Rod ME-9499

Super Pulley with Clamp

ME-9448B

Upgrade your force table and inclined plane experiments. The Super Pulley with its integral clamp makes setup and alignment easy. The pulley height is fully adjustable, so you can skim the top of a force table for parallax-free readings. Yet you can keep the force parallel to the track on an inclined plane, as shown in the photo below. Fits tables up to 2.0 cm (13/16 in.) thick.

Order Information

Super Pulley with Clamp ME-9448B

Mounting Rods (10 Pack)

ME-9483

These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) screw into a Super Pulley.

Order Information

Mounting Rods (10 Pack) ME-9483

Photogate/ Pulley System

ME-6838A

The Super Pulley attaches directly to a Photogate Head, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.

Order Information

Photogate & Pulley System ME-6838A

Atwood's Machine

SA-9241

Two Super Pulleys mounted on a 6.4 cm long rod produce a classic, low-friction introduction to Newton's Second Law. The instruction sheet fully describes both the experiment and the theory.

Includes:

- Two Pulleys
- Connecting Rod

Order Information

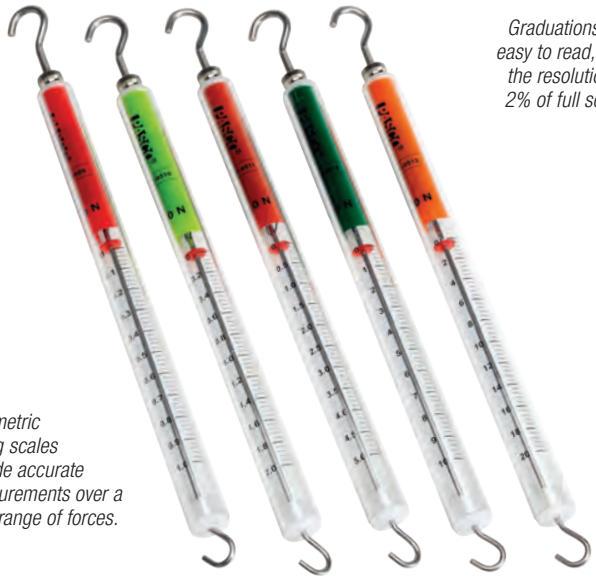
Atwood's Machine SA-9241

Metric Spring Scales

These high-quality metric spring scales are precise, durable, and calibrated in Newtons. Five different scales are available. Students can measure forces from a fraction of a Newton to 20 Newtons with excellent accuracy.

Features:

- **Accurate:** The precision springs provide excellent linearity, and the 10 cm long scales are sharp and clear for superior resolution.
- **Sealed Spring:** Can't get tangled, over-stretched, or lost.
- **Zero Adjust:** Turn the knob to zero the balance.
- **Scales on Inside:** They won't wear off.
- **Five Color-coded Ranges:** Measure almost any force from 0.1 N to 20 N.



Five metric spring scales provide accurate measurements over a wide range of forces.

Graduations are easy to read, and the resolution is 2% of full scale.

Order Information

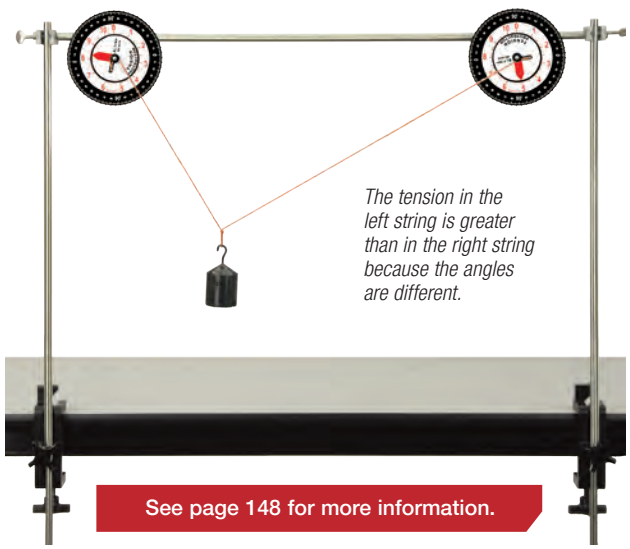
Metric Spring Scales

Model	Range	Resolution	Color
ME-9509	1.0 N	0.02 N	Red
ME-9510	2.0 N	0.04 N	Lt. Green
ME-9511	5.0 N	0.1 N	Brown
ME-9512	10 N	0.2 N	Dk. Green
ME-9513	20 N	0.4 N	Orange

Tension Protractor

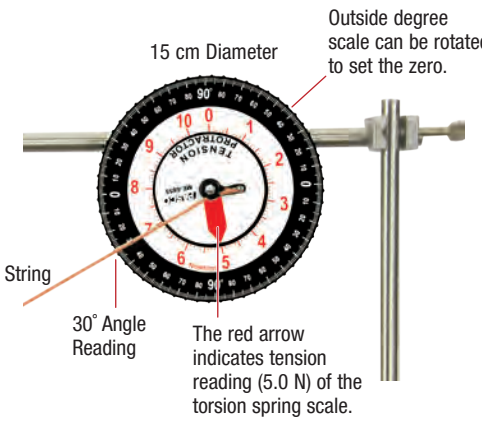
ME-6855

The Tension Protractor is a spring scale and a protractor integrated into one device. Perfect for static equilibrium experiments, the rotary dial indicates the tension in the string and the angle is read where the string passes over the degree scale on the outer ring. Since the Tension Protractor is supported on a rod, it has an advantage over other spring scales that tend to weigh down the string, changing the angle.



The tension in the left string is greater than in the right string because the angles are different.

See page 148 for more information.



- Measure tension and angle with one device
- Large scale for viewing demonstrations
- Zero-adjust for torsion spring scale
- Built-in rod clamp

Order Information

Tension Protractor	ME-6855	
Recommended:		
Large Table Clamp	ME-9472	p. 199
90 cm Stainless Steel Rod	ME-8738	p. 196
Multi-Clamp	ME-9507	p. 198
Hooked Mass Set	SE-8759	p. 207

30 Meter Measuring Tape

SE-8712A

This 30-meter woven fiberglass measuring tape reads metric on one side and imperial on the other.

Order Information

30 Meter Measuring Tape SE-8712A

Digital Calipers

SE-8710

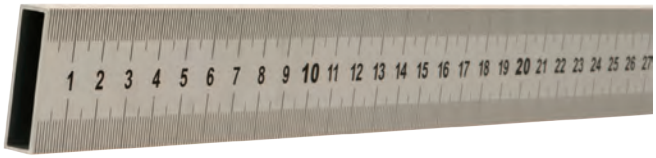
This metric/English (15 cm/6 in.) digital caliper measures to 0.01 mm (0.0005 in.). It has auto power-off and includes a sturdy plastic storage case.

Order Information

Digital Calipers SE-8710

Aluminum Meter Sticks (6 Pack)

ME-7032



These aluminum meter sticks are rigid and straight. Because they are hollow, the aluminum meter stick has about the same mass as a wooden meter stick.

Includes:

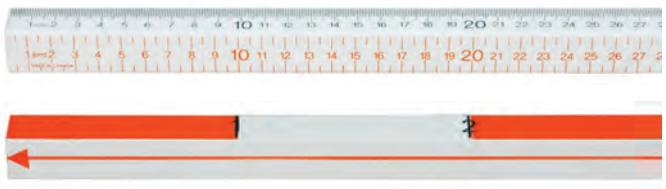
- Aluminum Meter Sticks (6)

Order Information

Aluminum Meter Sticks (6 Pack) ME-7032

Four Scale Meter Stick

SE-8695



The Four-Scale Meter Stick is constructed of plastic square channel. One side has millimeter markings, one has centimeter markings, one has decimeter markings, and the last side has only a one-meter mark.

Order Information

Four Scale Meter Stick.....SE-8695

Micrometer

SE-7337A

This low-cost micrometer provides measurements from 0 to 25 mm with 0.01 mm resolution.

Plastic storage box included.

Specifications:

Measurement Range: 0 to 25 mm

Resolution: 0.01 mm

Measuring Face: Carbide

Order Information

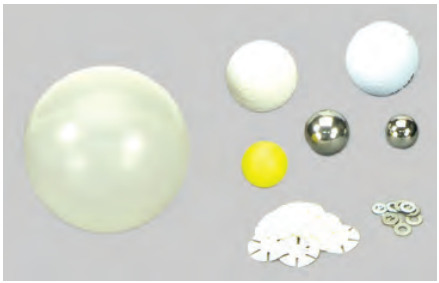
Micrometer.....SE-7337A

Freefall Balls Accessory

ME-9890

This set of balls is used with the Discover Freefall system. The special stickers are used to attach the metal washers to the plastic balls, allowing them to be suspended from a magnet.

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.



Includes:

- Small Nylon Ball (2.5 cm)
- Large Plastic Ball (10 cm)
- Golf Ball (4.4 cm)
- Hollow Golf Ball (4.2 cm)
- Steel Ball (2.5 cm)
- Steel Ball (1.6 cm)
- Release Washers (10)
- Release Stickers (50)

Order Information

Freefall Balls Accessory ME-9890

Steel Balls

ME-9864

Four pack of 2.5 cm diameter balls for use with PASCO Short or Long-Range Projectile Launchers (ME-6800 or ME-6801).

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Order Information

Steel Balls (4 pack) ME-9864

Spherical Mass Set

ME-8968

This set includes four balls with a diameter of 2.5 cm each, but features various masses, including a hollow steel ball, solid steel ball, plastic ball and aluminum ball.

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Includes:

- Solid Yellow Nylon Ball (10 grams)
- Solid Steel Ball (66 grams)
- Hollow Steel Ball (21 grams)
- Solid Aluminum Ball (24 grams)

Applications:

- Race the hollow steel ball and solid aluminum ball down an incline. They have about the same mass, but the solid aluminum ball has a much larger acceleration down the ramp.
- Fire the yellow plastic, solid steel, and hollow steel balls from a PASCO Projectile Launcher.

Order Information

Spherical Mass Set ME-8968

Bounce/No Bounce Ball Set (3 sets)

SE-7571

⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

These two black balls look and feel identical, but drop them side by side and students will notice a big difference in their elasticity. One bounces close to the original drop height, while the other doesn't bounce at all. Includes three sets of the Bounce/No Bounce Balls. Each ball has a diameter of 2.5 cm.

Order Information

Bounce/No Bounce Ball Set (3 pack) SE-7571

Small Steel Balls

ME-9872

These 1.6 cm diameter steel balls are used with the Mini Launcher (ME-6825).

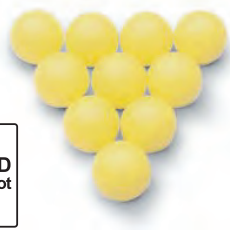
⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Order Information

Small Steel Balls (10 pack) ME-9872

Plastic Balls

ME-6822



⚠ WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Extra brightly colored balls for the Projectile Launcher. Diameter is 2.5 cm (1 in.).

Order Information

Plastic Balls (10 Pack)..... ME-6822

Braided Physics String

SE-8050

▶ 30-lb. Test

This braided Dacron string is tough, resists stretching, and won't unravel. Withstands up to 133 Newtons of force (equivalent to 13.6 kg). Each roll provides 320 meters of string.

Order Information

Braided Physics String SE-8050

Elastic Wave Cord

SE-9409

In addition to the Slinky, this Elastic Wave Cord is great for wave demonstrations. Unlike a Slinky®, the tension can be varied. The cord is 3 mm in diameter. Each roll provides 90 meters of cord.

Order Information

Elastic Wave Cord SE-9409

Yellow String (2 Pack)

ME-9876

Two rolls of highly visible braided yellow cord. Total length of 140 meters.

Order Information

Yellow String (2 pack) ME-9876

Rubber Cord (30 meters)

ME-8986

This rubber cord is used with PASCO's Elastic Bumper. It also fits the Air Track Bumper Set With Holder.

Order Information

Rubber Cord
(Spool of 30 meters) ME-8986

Glow String (2 Pack)

SE-8690

This stretchy "string" glows in the dark after being exposed to light. Use it to demonstrate wave motion, including resonance and standing wave patterns. Two rolls are included, totaling over 15 meters of string.

⚠ WARNING
CHOKING HAZARD
Small parts. Not for children under 3 years.

Order Information

Glow String (2 Pack) SE-8690

Black Thread (3 Pack)

ME-9875

Includes three spools of black Nylon thread

Order Information

Black Thread (3 Pack) ME-9875

Plumb Bobs (10 Pack)

SE-8728

These finished steel plumb bobs are precision-machined to a fine point. Just slide a string through the hole in the top and tie a knot. The plumb bob hangs precisely centered.

Order Information

Plumb Bobs (10 Pack)..... SE-8728

No-Bounce Pad

SE-7347

Color may vary.

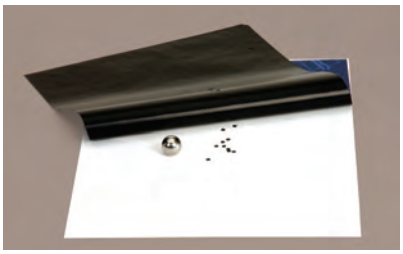
Stop falling objects from bouncing with PASCO's No-Bounce Pad. The 30 cm x 30 cm x 2.5 cm dimensions of the pad provide an ample target for gravity demonstrations. Prevents heavy objects from damaging the floor and prevents falling objects from being damaged on impact.

Order Information

No-Bounce Pad..... SE-7347

Carbon Paper (100 Pack)

SE-8693



Carbon paper is ideal for marking the position of an object as it strikes the floor or other surface.

Order Information

Carbon Paper (100 Sheets) SE-8693

Spirit Levels (10 Pack)

SE-8729

These 23 cm long Spirit Levels have three vials with striped gradations to indicate vertical, horizontal, and 45° alignment. The frame is a durable plastic with tough acrylic vials. A magnetic tape allows hands-free leveling.

Order Information

Spirit Levels (10 Pack) SE-8729

Gratnells® Rolling Carts

EP-3574 (2-column) EP-3575 (3-column)

Gratnells Rolling Carts are the best way to store and transport PASCO sensors and equipment. They can be configured for trays of any size and include large castors with brakes for added stability.

Designed for Gratnells trays, these movable storage rack carts can store up to 8 (2 column) or 12 (3 column) Gratnells F2 trays (sold separately). Each carts comes with either 16 or 24 pairs of runners.

They can be used to store the equipment kits from the Essential Physics or Essential Chemistry curriculum, the storage trays we offer for wireless sensors, or any of the four sizes of empty trays that we offer for everything else you'd like to store.

Assembly is required.
Trays not included.

EP-3575
Stores up to 12 Gratnells F2 trays
24 pairs of runners
107 cm high, 102 cm wide, 43.5 cm deep

EP-3574
Stores up to 8 Gratnells F2 trays
16 pairs of runners
107 cm high, 70 cm wide, 43.5 cm deep

Order Information

Gratnells Rolling Cart (2-column) EP-3574
Gratnells Rolling Cart (3-column) EP-3575

Gratnells® Storage Trays with Lids

Order Information

Storage Tray (F1) Shallow PS-3326
Storage Tray (F2) Deep..... PS-3327
Storage Tray (F25) X-Deep PS-3328
Storage Tray (F3) Jumbo PS-3329

These empty Gratnells storage trays with lids have a length of 427 mm and width of 312 mm.

Depths:
F1: 75 mm
F2: 150 mm
F25: 225 mm
F3: 300 mm

Storage Bins

SE-7560

Stackable plastic bins with lids are useful for storing sensors. 14" L x 9.5" W x 6.9" D

Order Information

Storage Bins (Set of 5) SE-7560

3.8 Liter Plastic Container Set

14 cm x 14 cm x 19.5 cm tall

ME-7559

These containers are great for experiments needing ice water baths. See the Heat Engine Experiment on page 358 for an example.

Order Information

3.8 Liter Plastic
Container Set (set of 2) ME-7559

Glassware

This rugged borosilicate glassware is for use in the physics lab. It it particularly useful for buoyancy labs (shown on page 341).

Order Information

Beaker, 100 mL (12 Pack)..... SE-7287
Beaker, 1000 mL (6 Pack)..... SE-7288
50 mL Graduated
Cylinder (12 Pack)..... SE-7289

Discover Pi Set (10 Pack)

ME-6819A

The Discover Pi Set allows students to derive the meaning of π directly from their measurements. This activity transforms π from a constant with unknown origin to a fundamental characteristic of all circular objects.

Includes:

- 4 Pi Circles: 5.2, 6.4, 8.9, 10.0 cm diameter
- Transparent Measuring Tape

Order Information

Discover Pi Set (10 Pack)..... ME-6819A

Water Reservoir

ME-8594

This calibrated 1000 mL cylinder is useful for experiments (as shown on page 344), requiring either a specific amount of water, a constant flow of water, or water at a constant pressure. The cylinder has three hose connections: one for connection to a source of water, one for overflow, and an outlet near the bottom. Comes with six meters of tubing and two restriction clips.

Order Information

Water Reservoir ME-8594

OHAUS Electronic Balances

SE-8823A (220 g)
SE-8757B (2200 g)
SE-8756B (420 g)
SE-8758B (8200 g)

The Ohaus Scout SKX digital electronic balances combine range, resolution, and low cost, making them ideal for the student physics lab.

Simple two-button operation and visual menu prompts allow students to begin weighing with minimal instruction. The large, crisp display is easily viewed from any angle, so teachers can quickly check student results. A sealed front panel, molded spill ring, and removable stainless steel platform provide protection from spills and make these balances easy to keep clean.

Specifications:

SE-8823A:
Capacity: 0-220 g
Resolution: 0.01 g
Pan Size: 12 cm dia.

SE-8757B:
Capacity: 0-2200 g
Resolution: 0.1 g
Pan Size: 16.5 x 4.2 cm

SE-8758B:
Capacity: 0-8200 g
Resolution: 1.0 g
Pan Size: 16.5 x 14.2 cm

SE-8756B:
Capacity: 0-420 g
Resolution: 0.01 g
Pan Size: 12 cm dia.

Order Information

OHAUS Scout SKX Balances
220g.....SE-8823A
420g.....SE-8756B
2200g.....SE-8757B
8200g.....SE-8758B

Ohaus USB Adapter

SE-8821

Connect any SKX balance directly to a computer (Windows/Mac), Chromebook, or tablet equipped with a USB port.

Note: Requires PASCO Capstone version 1.8.0 or later or SPARKvue version 2.6.0 or later.

Order Information

Ohaus USB Adapter.....SE-8821

Ohaus Triple-Beam Balance

SE-8723 (without tare) / SE-8707 (with tare)

Ohaus Cent-O-Gram Balance

SE-8725

Ohaus mechanical balances have been the standard weighing instruments in student laboratories for decades. They're accurate, easy to use, durable, and inexpensive.

- **Precision-Ground Steel Knives:** for exact measurements and a long balance life
- **Stainless Steel Weighing Pan:** easy to clean, lasts indefinitely
- **Magnetic Damping:** for quick, true measurements
- **Simple Zero-Adjustment:** just zero the masses, then rotate the knob
- **Capacities:** see table below

Specifications:

SE-8723:
Ohaus #: 750-S0
Type: Triple-Beam
Capacity: 610 g
with additional mass set: 2610 g
Readability: 0.1 g
Tare: None

SE-8707:
Ohaus #: 760-00
Type: Triple-Beam
Capacity: 610 g
with additional mass set: 2610 g
Readability: 0.1 g
Tare: 225 g

SE-8725:
Ohaus #: 311-00
Type: Cent-o-Gram
Capacity: 311 g
Readability: 0.01 g
Tare: None

Order Information

Ohaus Triple-Beam Balance (without Tare).....SE-8723
Ohaus Triple-Beam Balance (with Tare).....SE-8707
Ohaus Cent-O-Gram Balance.....SE-8725
Recommended:
Ohaus Additional Mass Set.....SE-8708

Ohaus Additional Mass Set

SE-8708

For Triple-Beam Balances

These additional masses can increase the range of the Ohaus Triple-Beam Balances (SE-8723 and SE-8707) by an additional 2 kg. Included are a 0.5 kg and two 1 kg masses.

Order Information

Ohaus Additional Mass Set.....SE-8708

Slotted Masses

SE-8726A Set (10 g resolution)
SE-8704A Set (1 g resolution)
SE-8703A Hanger (50 g)

This 50 gram mass hanger is the standard hanger for the slotted masses shown.

These slotted masses provide medium to heavy mass (up to 1.110 kg) with 1 g or 10 g resolution.

The SE-8726A Set Includes:

Masses: 1 x 500 g, 2 x 200 g, 1 x 100 g, 1 x 50 g, 2 x 20 g, 1 x 10 g

The SE-8704A Set Includes:

The above masses plus a 5 g, 1 g, and two 2 g masses. Mass hangers available separately.

Order Information

10 g Slotted Mass Set.....SE-8726A
1 g Slotted Mass Set.....SE-8704A
Slotted Mass Hanger.....SE-8703A

Mass and Hanger Set

ME-8979

PASCO's Mass and Hanger Set includes varying units of mass that attach to the 5.0 g mass hangers' steel posts. This set includes 4 hangers and 27 masses ranging from 0.5 g to 100 g. The masses are marked on each unit, and each hanger can hold up to 250 g.

Includes:

- Four Mass hangers (5.0 g each) ±2%
- Brass masses: ±1%
  3 x 100 g 3 x 50 g 6 x 20 g
- Aluminum masses: ±1%
  3 x 10 g 3 x 5 g
- Plastic masses: ±2%
  3 x 2 g 3 x 1 g 3 x 0.5 g
- Molded storage case

Order Information

Mass and Hanger Set..... ME-8979

Recommended:
Mass and Hanger Spares Kit..... ME-8980
(Contains four mass hangers and 10 each of 2 g, 1 g, and 0.5 g plastic masses)

Replacement Mass Sets for ME-8979:
5-gram Mass Set (set of 6) ME-8981
10-gram Mass Set (set of 6) ME-8982
20-gram Mass Set (set of 6) ME-8983
50-gram Mass Set (set of 6) ME-8984
100-gram Mass Set (set of 6) ME-8985

Large Slotted Mass Set

ME-7566

Includes:

- One 0.5 kg mass hanger (36 cm high)
- Nine 0.5 kg slotted masses (8 cm dia.)

Order Information

Large Slotted
Mass Set (5 kg Set)..... ME-7566

Short Slotted Mass Set

ME-7589 (2 kg Set)

Includes:

- One 0.5 kg mass hanger (15 cm high)
- Three 0.5 kg slotted masses (8 cm dia.)

Order Information

Large Slotted Mass
Set (2 kg Set)..... ME-7589
Short Mass Hanger ME-7590

Hooked Mass Set

SE-8759

Includes:

- Masses:
  1 x 1000 g 1 x 500 g 2 x 200 g
  1 x 100 g 1 x 50 g 2 x 20 g
  1 x 10 g
- Molded mass holder

Order Information

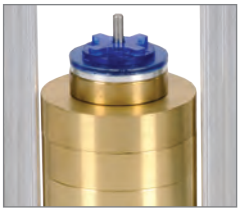
Hooked Mass Set..... SE-8759

1 kg Mass and Hanger Set

ME-9337 (1 kg set)

Set features a 200 g cast aluminum mass hanger with a steel post, and four "holed" 200 g brass masses that will not fall off the hanger. Multiple mass hangers can be used by hooking the top of one into the bottom of another.

The flat bottom on the mass hanger makes it perfect for use with a Motion Sensor when performing Hooke's Law and spring oscillation experiments.



Can be used in conjunction with the entire set of smaller brass and plastic masses in the ME-8979 Mass and Hanger Set.

Includes:

- Mass Hanger ME-9350, Hanger height: 16 cm
- Set of four masses ME-9351, Diameter of masses: 5 cm
- Steel pin, 8 cm height, 3.6 mm diameter

Order Information

1 kg Mass and
Hanger Set..... ME-9337
200 g Mass Hanger ME-9350
200 g Masses
(Set of Four)..... ME-9351

Shown in use with:
Bases and Rods..... pp. 196-197
Equal Length Spring Set..... ME-8970
Pendulum Clamp ME-9506
PASPORT Motion Sensor PS-2103A

PASCO Stopwatch

ME-1234

- No alarm or clock
- Memory for stored event times
- Uses one AA battery
- Durable buttons

Are you tired of annoying stopwatch alarms going off all day? Are your students stuck in the clock mode and can't get their stopwatch back into the timing mode? Does your stopwatch stop working after changing that little watch battery? The PASCO Stopwatch solves all these problems.

This stopwatch was designed specifically for science timing. The modes of operation are intuitive and complete instructions are included. The buttons are built to last and it uses a single long-lasting AA battery, which is less expensive than a watch battery (and easier to install).

The PASCO Stopwatch fits comfortably in your hand.

The EVENT/RECALL button allows you to view the last time, in case you forget to write it down. The EVENT/RECALL button is also used to store and recall up to 9 event times: For example, record a series of events, such as times at which sandbags were dropped along the gym floor.

Two display modes:
MM:SS.SS (00:25.18) or Decimal Seconds (25.18s)

Specifications:

LED Display: Visible indoors and outdoors

Two Display Modes: MM:SS.SS (01:25.34) or Decimal Sec (85.34 s)

Precision: 0.01 sec up to 59:59.99 (MM:SS.SS) or 3599.99 s Then 1 sec to 99:59:59 (HH:MM:SS) or 359999 s

Max Number of Event Times: Nine

Auto-off: After one hour idle

Includes: One AA battery and instruction sheet

Order Information

PASCO Stopwatch..... ME-1234

PASCO Stopwatch, 10-pack

ME-1235

- Includes fitted foam storage box

Order Information

PASCO Stopwatch, 10-pack.....ME-1235

Student Timer

SE-8768

- Inexpensive
- 0.01 Second Resolution
- Easy Operation – start/stop, reset and lap

Appearance may vary

Order Information

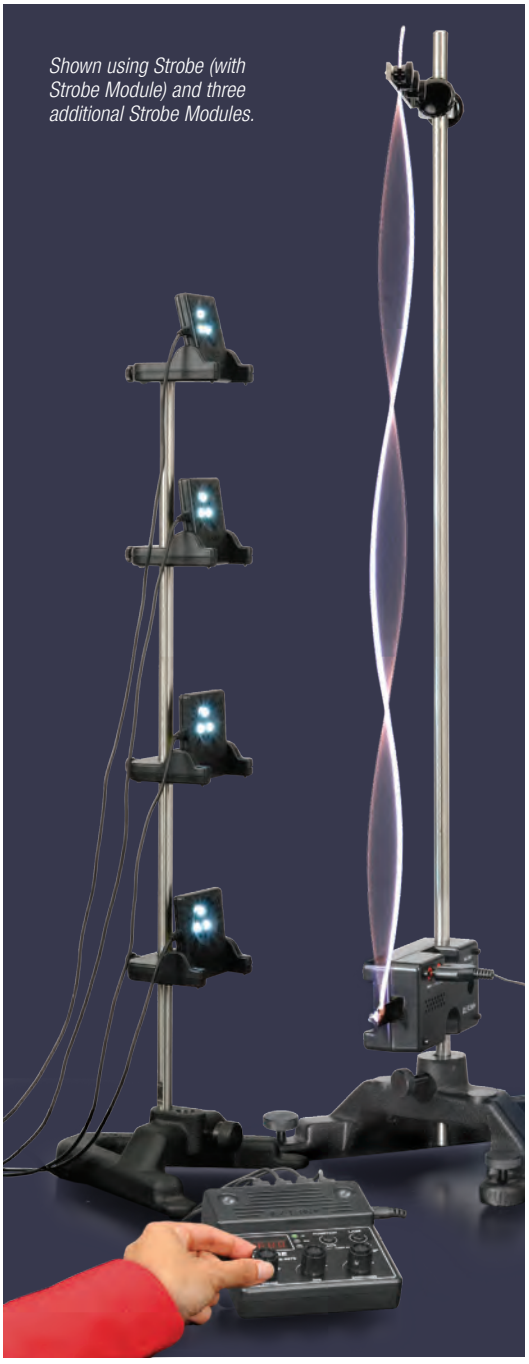
Student Timer SE-8768

Strobe System

ME-6978

- 1 Hz to 500 Hz
- Variable intensity
- Low cost
- External trigger

This unique modular design makes it easy to light any geometry. The Strobe includes the Strobe Control Box and one Strobe Module. Additional Strobe Modules can be purchased separately (see below) to connect up to a total of four lamp modules per controller. Multiple control boxes can be connected together using the External Trigger. The Strobe Modules have a tilting lamp head on a sturdy base that sits on the table or fastens to a rod stand.



Shown using Strobe (with Strobe Module) and three additional Strobe Modules.

Specifications:

Accuracy: 0.1%
Frequency Range: 1 Hz to 500 Hz
Resolution: 0.1 Hz
Lamp Life: 50,000 hours
Brightness: 230 lumens (peak) per module

Features:

- Display frequency in Hz or RPM
- Adjustable light intensity
- Add additional Strobe Lamps (ME-6982), up to four modules per controller
- External Trigger to daisy-chain multiple controllers together
- Trigger strobe using external input such as the ME-9498A photogate.

Learn more at **pasco.com/strobe**

Order Information

Strobe System	ME-6978	
(Includes Control Box and one Strobe Module)		
Strobe Lamp Module	ME-6982	
Shown in use with:		
String Vibrator	WA-9857A	p. 270
Sine Wave Generator	WA-9867	p. 271

Thermal Expansion Apparatus

TD-8856

- Use with Multimeter or Temperature Sensor
- Brass, copper, and aluminum tubes included

With PASCO's Thermal Expansion Apparatus, students can accurately and easily investigate the expansion of metals with increasing temperature.

Base
Provides storage for all three tubes

Steam Generator
(sold separately)

Built-in Digital Gauge
Simple and very accurate measurements with 0.01 mm resolution

Built-in 10 kΩ Thermistor
Together with a digital ohmmeter, or Temperature Sensor directly measures the temperature of the tube

Digital Multimeter
Measures thermistor resistance
(sold separately)

Features:

- **Built-in Digital Gauge:** Measure the rod expansion with 0.01 mm resolution
- **Built-in Thermistor:** A 10 kΩ thermistor is connected directly to each tube and the temperature can be determined using a digital ohmmeter or Temperature Sensor.
- **Heat with Steam or Water:** The fluid used may be steam or water at any temperature.
- **Three Drop-in Metal Tubes:** Each tube connects securely onto the rigid base. The other two can be simultaneously mounted on the base for convenient storage.

Thermistor cable connects directly to the Temperature Sensor.

Includes:

- Base with built-in dial gauge and thermistor
- Expansion tubes brass, copper and aluminum; 16 mm dia. (80 cm length)

Order Information

Thermal Expansion Apparatus	TD-8856	
Required:		
Steam Generator	TD-8556A	p. 211
Recommended:		
Basic Digital Multimeter	SE-9786A	p. 240
OR		
PASPORT Quad Temperature Sensor	PS-2143	p. 46

Steam Generator

TD-8556A

- Variable steam output
- Rapid heating
- Automatic safety shut-off

The Steam Generator is an inexpensive heat reservoir with constant temperature. It can boil 3/4 of a liter of water in ten minutes and provides continuous steam at up to 10 g/min. The included baster can be used to remove hot water during experiments. This product also includes additional features for safety and convenience.

See page 212 for additional Steam Generator applications.

Order Information

Steam Generator TD-8556A

Heater Stirrer

PS-3401

- Removable rod for suspending sensors.

This compact hot plate and stirrer has a white ceramic top that is ideal for heating and for seeing color changes when mixing solutions. It has been designed to withstand spills. Its safety features include warning labels and indicator LEDs. And the included rod makes it easy to support sensors.

When used as a heater:
This compact Heater-Stirrer can boil water in minutes. The ceramic top provides an even heating surface and the indicator LEDs let you know when the top is hot.

When used as a stirrer:
This apparatus is great for mixing solutions. The white top makes color changes during titrations easy to see.

Specifications:

Speed Range: 50-1500 rpm
Plate Diameter: 135 mm
Max Temperature: 310°C

Includes:

- Support Rod

Order Information

Heater Stirrer PS-3401

Ball and Ring

SE-7597

- Demonstrates thermal expansion

When the Ball and Ring are at room temperature, the ball easily fits through the ring. Heat the ball in a Bunsen burner flame and it expands and no longer fits through the ring. If the ring is also heated, the ball will fit through it once again.

Specifications:

Length: 23 cm
Ball Diameter at Room Temperature: 2.36 cm
Ring Inner Diameter at Room Temperature: 2.39 cm

Order Information

Ball and Ring SE-7597

Bimetallic Strip

SE-7598

- Demonstrates differential thermal expansion
- Demonstrates how thermostats work

When heated in a Bunsen burner flame, this bi-metallic strip bends. The strip is steel on one side and brass on the other side. Since brass expands more than steel, the strip becomes longer on the brass side. As it cools, it becomes straight again.

Specifications:

Blade Length: 12.5 cm

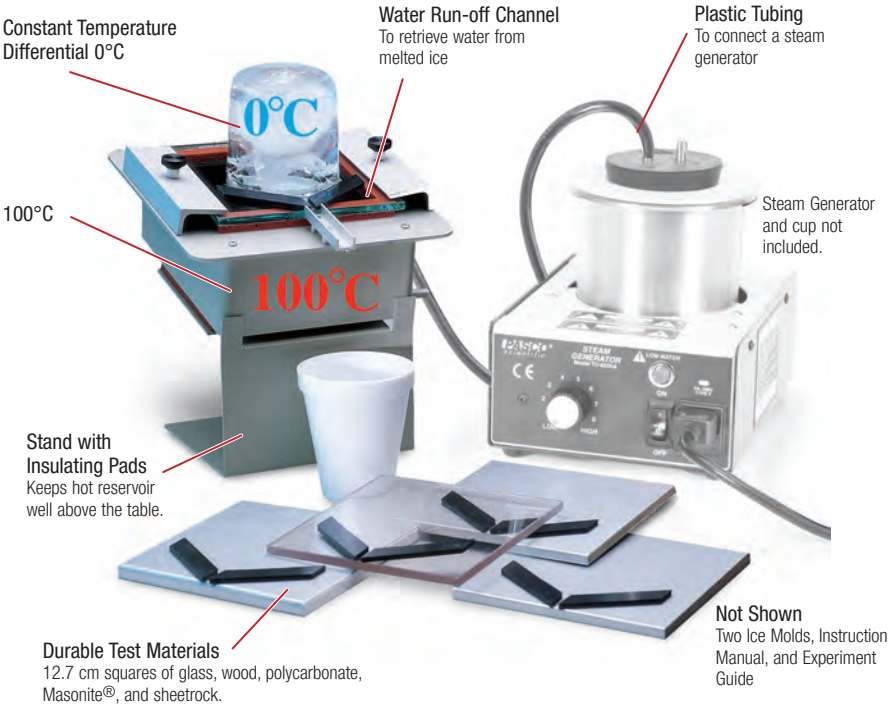
Order Information

Bimetallic Strip SE-7598

Thermal Conductivity Apparatus

TD-8561

- Measure heat flow through five different materials
- Constant temperature differential makes calculations easy
- Easy to use, no mess



One of the most important considerations for buildings in the modern world is their ability to provide good thermal insulation. This apparatus gives students a way to observe and quantify heat flow across a constant temperature differential. Students use five common materials as test samples: glass, wood, polycarbonate, Masonite and sheetrock.

Features:

- **No Mess:** The water from the melting ice runs off into the measuring cup — not on the lab table.
- **Durable Test Materials:** The wood, Masonite and sheetrock are covered with a thin aluminum sheet for waterproofing and to ensure good thermal contact.
- **Elevated Steam Reservoir:** The hot reservoir is well above the lab table to eliminate heat damage.

How It Works:

A block of ice is placed against one side of the test material. The other side is clamped against a steam chamber, establishing a constant 100°C temperature differential. The rate at which the ice is converted to water is a measure of the rate at which heat passes from the steam, through the test material, and into the ice.

Includes:

- Stand with insulating pads
- Ice molds (2)
- Materials: 12.7 cm squares of glass, wood, polycarbonate, Masonite, and sheetrock
- Plastic tubing to connect steam generator
- Instruction manual and experiment guide

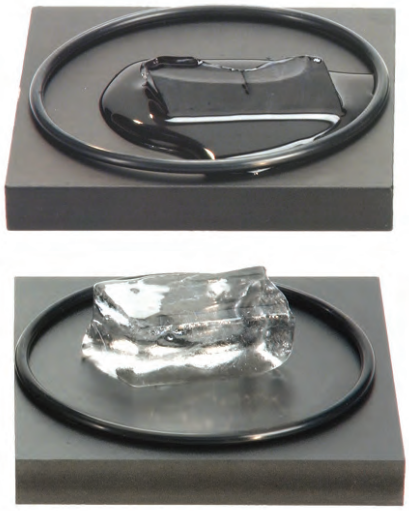
Order Information

Thermal Conductivity Apparatus	TD-8561	
Required:		
Steam Generator	TD-8556A	p. 211
Graduated Cylinder		

Ice Melting Blocks

SE-7317

- Great thermal conductivity and heat capacity demonstration



The two Ice Melting Blocks look similar but are composed of different materials. One block feels cold to the touch, while the other block feels slightly warm. Both blocks are at room temperature but have very different thermal conductivities and heat capacities.

After allowing students to hold the blocks, ask them which block would melt ice more quickly. Place an ice cube on each block and watch their amazement as the “cold” block melts the ice cube within two minutes. Melting the ice cube is barely noticeable on the “warm” block. The “cold” block is aluminum and has a much greater ability to transfer heat to the ice cube or the hand.

The “warm” block is plastic, which does not conduct heat as well.

Includes:

- Aluminum Block
- Plastic Block
- O-rings (2)

Order Information

Ice Melting Blocks	SE-7317

Basic Calorimetry Set

TD-8557B

- An affordable introduction to thermodynamics

This Styrofoam™ calorimeter cup (7.5 cm inside diameter, 10 cm deep) has 1.3 cm thick walls for excellent thermal properties. Includes five different metal samples, a thermometer, plastic tubing, and a water trap that prevents unwanted condensation of steam.

Applications:

- Define the calorie
- Determine thermal capacity and specific heat of aluminum, copper, brass, stainless steel, and zinc
- Latent heat of vaporization
- Latent heat of fusion

Includes:

- Calorimeter cup with lid
- Alcohol thermometer 20°C to 110°C in 1° increments
- Samples of aluminum, copper, brass, zinc, and stainless steel (80 g each)
- Water trap and plastic tubing
- Instruction manual and experiment guide

Order Information

Basic Calorimetry Set	TD-8557B	
Required:		
Steam Generator	TD-8556A	p. 211
Ohaus Triple-Beam Balance (without Tare)	SE-8723	p. 206
Replacement Supplies:		
Calorimetry Cups (6)	TD-8825A	

Specific Heat Set

SE-6849

This specific heat set has five different materials, all with the same mass (80 g). Each has a hole to tie a loop of string to hang the samples in water.

Includes:

- Aluminum 1.25” d x 1.5” h
- Brass 3/4” d x 1.5” h
- Stainless Steel 3/4” d x 1.44” h
- Zinc 3/4” d x 1.58” h
- Copper 0.625” d x 1.8” h

Order Information

Specific Heat Set	SE-6849	
Recommended:		
Calorimetry Cups (6)	TD-8825A	

Density Set

ME-8569A

Use this versatile set of materials with the Overflow Can to investigate Archimedes' Principle of displacement, specific heats, and basic length/volume relationships.

Includes pieces that have the same shape, volume, density, and mass, so the variable of interest can readily be isolated. Each piece has a hole, so it can be suspended from a string.

Includes:

- Three cylinders: aluminum, brass, plastic; 2.2 cm dia. x 6.4 cm long (plastic is less dense than water)
- Two blocks: aluminum (1.9 x 3.2 x 4.1 cm) and brass (1.6 x 1.9 x 2.8 cm).
  The mass of each block equals that of the aluminum cylinder.
- Irregular shape: aluminum
- Instruction manual

Order Information

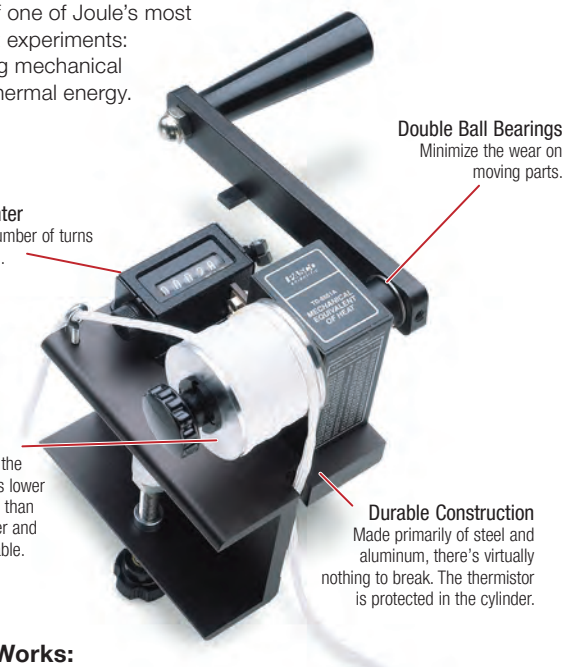
Density Set	ME-8569A

Mechanical Equivalent of Heat Apparatus

TD-8551A

- Accurate to 5%
- Rugged ball-bearing construction
- Thermistor—no thermometer to break

This Mechanical Equivalent of Heat Apparatus provides an updated version of one of Joule's most important experiments: converting mechanical work to thermal energy.



How It Works:

Turn the crank to perform a measurable amount of work. The crank turns an aluminum cylinder. A flat nylon rope is wrapped several times around the cylinder. As the crank is turned, the friction between the rope and the cylinder is just enough to support a mass hanging from the other end of the rope. This ensures that the torque acting on the cylinder is constant and measurable. A counter keeps track of the number of turns of the crank. The thermal energy is measured by monitoring the temperature of the cylinder using the embedded thermistor.

With this apparatus, the equivalence of work and heat is easily established to within 5%.

Includes:

- Base, cylinder, crank, and counter with a built-in table clamp
- 1-gallon can that can be filled with a measured mass of sand or water (if 10 kg of laboratory masses are not available)
- 3.7 m of flat nylon rope
- Laboratory manual including theory, step-by-step instructions, and data tables

Order Information

Mechanical Equivalent of Heat Apparatus	TD-8551A	
Required:		
Basic Digital Multimeter	SE-9786A	p. 240
Ohaus Triple-Beam Balance (with Tare)	SE-8707	p. 206

A refrigerator (or ice) for cooling the cylinder below room temperature; calipers and a thermometer for measuring room temperature are helpful, but not necessary.

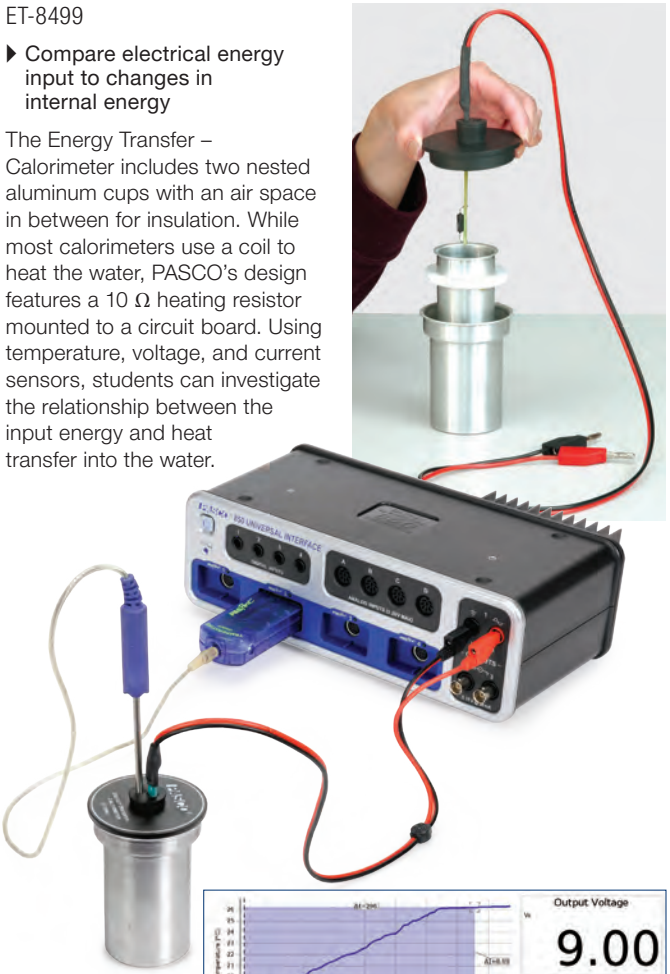
Replacement Supplies:		
Replacement Brush	TD-8583	
Replacement Cylinder	TD-8582	

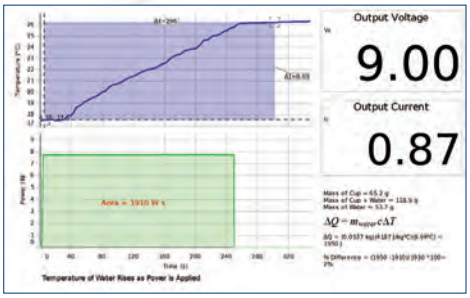
Energy Transfer - Calorimeter

ET-8499

- Compare electrical energy input to changes in internal energy

The Energy Transfer – Calorimeter includes two nested aluminum cups with an air space in between for insulation. While most calorimeters use a coil to heat the water, PASCO's design features a 10 Ω heating resistor mounted to a circuit board. Using temperature, voltage, and current sensors, students can investigate the relationship between the input energy and heat transfer into the water.





The bottom graph displays the power output from the generator, and the top graph shows the increase in temperature. The amount of electrical energy used to heat the water is determined by finding the area under the Power vs. Time curve.

Includes:

- Outer Aluminum Cup (8.9 cm tall, 4.7 cm dia)
- Inner Aluminum Cup (7.5 cm tall, 3.8 cm dia)
- Plastic Lid
- Two-Hole Rubber Stopper
- Heating Resistor with Input Cables

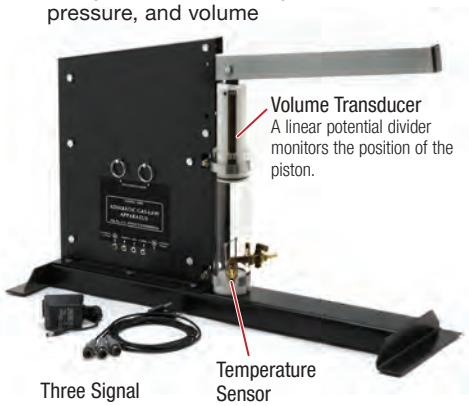
Order Information

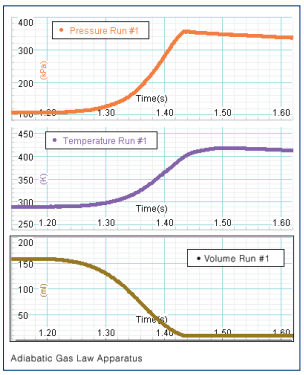
Energy Transfer - Calorimeter	ET-8499	
Recommended for use with ScienceWorkshop:		
Temperature Sensor	CI-6605A	p. 34
Voltage Sensor (unshrouded)	UI-5100	p. 35
Current Sensor	CI-6556	p. 35
Recommended for use with PASPORT:		
PASPORT Temperature Sensor	PS-2125	p. 46
PASPORT Voltage/Current Sensor	PS-2115	p. 49

Adiabatic Gas Law Apparatus

TD-8565

- Investigate the compression of gases
- Computer monitors temperature, pressure, and volume





Students monitor pressure, temperature, and volume as a gas is compressed rapidly.

Experiments

PASCO's Adiabatic Gas Law Apparatus can be used with our 850 Universal Interface. The computer functions as a 3-channel storage oscilloscope, generating graphs for pressure, temperature, and volume, as well as integrating the area under a Pressure vs. Volume curve to determine the work done on the gas.

Includes:

- Adiabatic Gas Law Apparatus
- Instruction Manual, Experiment Guide
- Signal Cables 3.5 mm plug to 5-pin DIN
- Power Adapter 9 V DC @ 1 A

Order Information

Adiabatic Gas Law Apparatus..... TD-8565
Required:
PASCO Capstone Software..... pp. 84-87
A computer with an interface that will accept three analog signals simultaneously via 5 or 8-pin DIN connectors such as PASCO's 550 and 850 Interfaces.

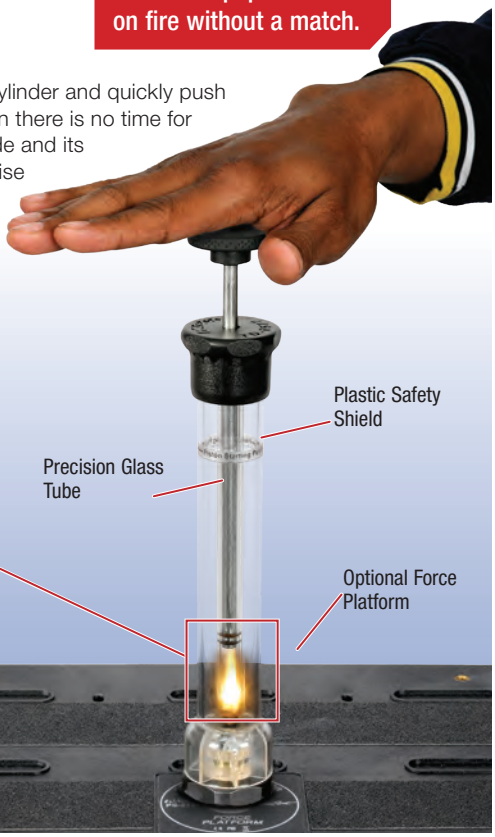
Compression Igniter

TD-8577

- Adiabatic compression ignites paper!
- Works every time
- Durable and cleanable

Students will be amazed to see the paper catch on fire without a match.

Put a small piece of tissue paper into the cylinder and quickly push down on the piston. In a quick compression there is no time for heat to be exchanged between the air inside and its surroundings, causing the temperature to rise well above the combustion temperature of paper.

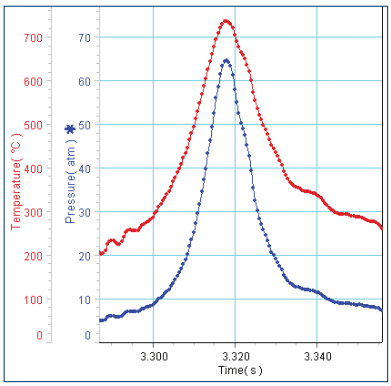


This Compression Igniter has been specially designed to be cleanable. The bottom screws off to clean out the soot and to load the paper. The large piston handle decreases the pressure on your hand and makes it easier to hit the piston quickly.

The glass tube is surrounded by plastic for safety. In the event that the glass tube breaks, the glass tube can be replaced.

Includes:

- Compression Igniter
- Spare Glass Tube with O-rings
- Cleaning Wire
- Complete Instructions with Theory



Pressure data is calculated using the force measured by the Force Platform. Assuming Adiabatic, the data shown gives a compression ratio of nearly 20:1 and a peak temperature of over 700°C.

Order Information

Compression Igniter.....TD-8577
Replacement Glass Tubes TD-8498A
Shown in use with:
PASPORT Force Platform .....PS-2141 p. 43

Ideal Gas Law Apparatus

TD-8596A

- Experimentally determine the Ideal Gas Law
- Large syringe for accurate volume measurements
- Built-in fast response thermistor

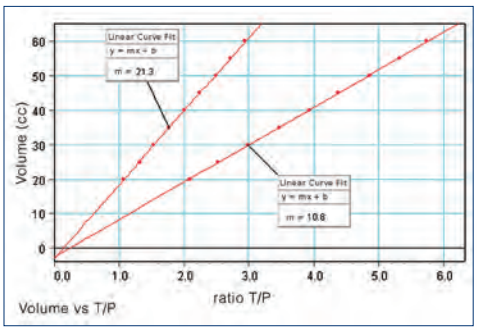
Investigating the Ideal Gas Law is simple using PASCO's Ideal Gas Law Apparatus. By connecting a Pressure Sensor and a Temperature Sensor to the syringe, students can quantitatively look at the relationships between pressure, temperature, and volume.

How It Works:

A low thermal mass thermistor is mounted within the syringe for real-time measurement of temperature changes inside the syringe. Tubing and a quick-connect port allow a Pressure Sensor to be directly connected to the syringe. As the plunger of the syringe is depressed, the volume decreases while pressure and temperature increase. The data will help students better understand the Ideal Gas Law.

$$PV = nRT$$

A mechanical stop is included on the syringe plunger to prevent damaging of the thermistor within the syringe and to allow quick (adiabatic) volume changes.



Slope of the Volume vs. $\frac{T}{P}$ graph equals nR.

Includes:

- Ideal Gas Law Syringe
- Built-in Fast Response Thermistor
- Quick-Connect Pressure Port
- Male Luer connectors to attach Wireless Pressure Sensor

Order Information

Ideal Gas Law Apparatus	TD-8596A	
Shown in use with:		
PASPORT Absolute Pressure/ Temperature Sensor	PS-2146	p. 45
AirLink Interface	PS-3200	p. 24, 60
PASCO Capstone Software	pp. 84-87	

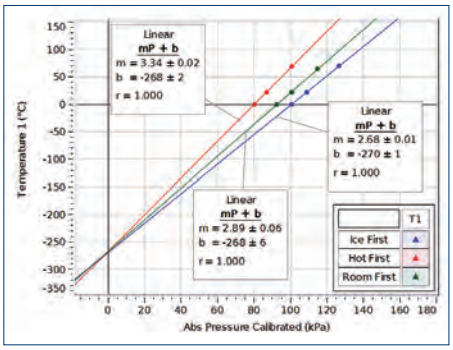
Absolute Zero Sphere

TD-8595

- Constant volume sphere
- Measure pressure and temperature directly using PASCO sensors
- Empirically determine the absolute zero temperature

The Absolute Zero Sphere is an effective tool for determining absolute zero temperature. Students connect Pressure and Temperature Sensors before immersing the sphere in water baths of varying temperatures. As the pressure and temperature change, a live graph is generated in PASCO Capstone™. Once the data is collected, students can use a linear fit to extrapolate the value of absolute zero.

Absolute Zero Apparatus being used with PASPORT Absolute Pressure Sensor



Temperature and pressure data is taken for three temperature water baths. The experiment is repeated with a different amount of gas initially in the sphere. The slopes of the two graphs reflect the change in the number of moles of gas, and both graphs extrapolate to about the same value for absolute zero.

Includes:

- Absolute Zero Sphere
- Built-in Fast Response Thermistor Probe
- Quick Connect Pressure Port
- Male Luer connector to attach wireless pressure sensor

Order Information

Absolute Zero Sphere	TD-8595	
Shown in use with:		
PASPORT Absolute Pressure/ Temperature Sensor	PS-2146	p. 45
AirLink Interface	PS-3200	p. 24, 60
PASCO Capstone Software	pp. 84-87	

Heat Engine and Gas Law Apparatus

TD-8572A

- Measure the actual efficiency of a real heat engine.
- Bring P-V diagrams to life.
- Low-friction graphite piston in glass cylinder
- See the complete experiment (EX-5530B) on page 358.

The Heat Engine and Gas Law Apparatus enables students to perform quantitative Ideal Gas Law experiments, while exploring a functional heat engine. A Rotary Motion Sensor and Pressure Sensor can be added to graph heat engine cycles, determine actual efficiency, and more!

How It Works:

When the air chamber is moved from the cold water bath to the hot bath, the piston rises, lifting the 200 g mass to demonstrate work. The mass is removed, and the air chamber is returned to the cold bath, closing the isobaric/isothermal cycle.

The heat engine cycle is plotted in real time using a Pressure vs. Volume graph.

Pressure in the cylinder is measured by a pressure sensor. Volume is measured by tracking the piston's position with a rotary motion or motion sensor. Temperatures of the hot and cold baths are recorded using temperature sensors.

Students compare the area inside the P-V cycle to the actual work done while lifting the weight to determine how the efficiency of their heat engine compares to the theoretical maximum.

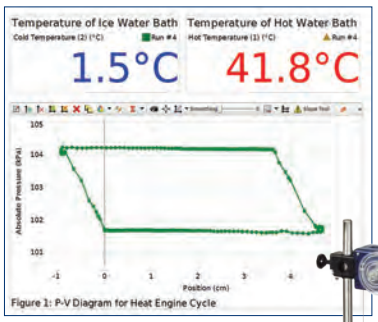
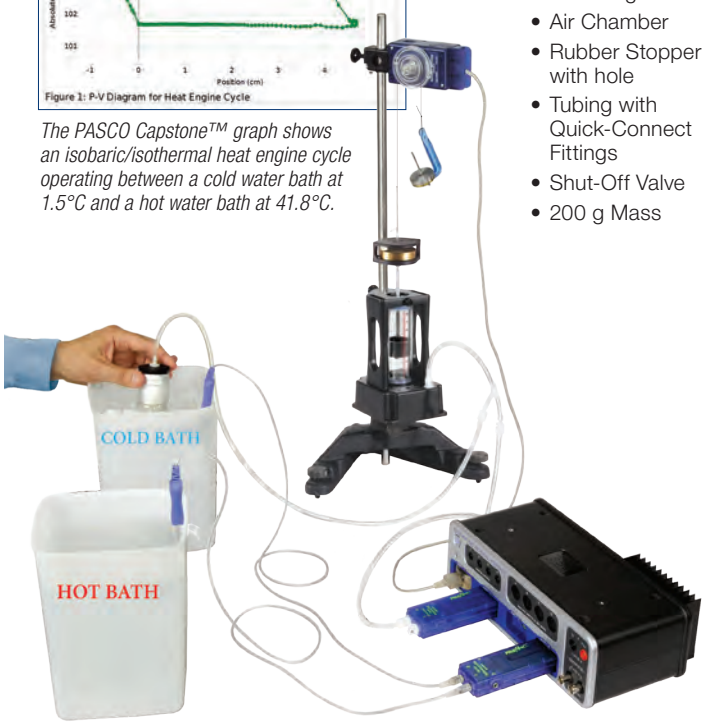
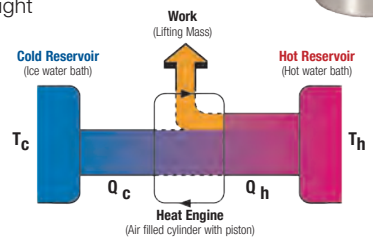


Figure 1: P-V Diagram for Heat Engine Cycle

The PASCO Capstone™ graph shows an isobaric/isothermal heat engine cycle operating between a cold water bath at 1.5°C and a hot water bath at 41.8°C.





Includes:

- Heat Engine
- Air Chamber
- Rubber Stopper with hole
- Tubing with Quick-Connect Fittings
- Shut-Off Valve
- 200 g Mass

Specifications:

Piston diameter: 32.5 mm
Maximum piston displacement: ≈10 cm

Order Information

Heat Engine and Gas Law Apparatus	TD-8572A	
Shown in use with:		
850 Universal Interface	UI-5000	p. 26
PASPORT Quad Temperature Sensor	PS-2143	p. 46
PASPORT Dual Pressure Sensor	PS-2181	p. 45
PASPORT Rotary Motion Sensor	PS-2120A	p. 41
3-Liter Plastic Tub (2-Pack)	ME-7559	p. 205
Small "A" Base	ME-8976	p. 196
Stainless Steel Rod, 60 cm Threaded	ME-8977	p. 196

Heat Engine Accessory

Included in TD-8572A

TD-8581A

This replacement kit includes a set of parts for the Heat Engine (suitable for both versions TD-8572 and TD-8572A) that are most likely to need replacement after extensive use. These parts connect the air chamber and the Pressure Sensor to the Heat Engine.

Includes:

- Air Chamber
- Rubber Stopper #10 with hole
- Male Luer Lock Barbs (2)
- Female Luer Lock Barbs (2)
- Tube Connector 3/16 x 1/8"
- Plastic Tee for 1/8" Tubing
- One-way Stopcock
- Female In-line 1/8" CPLG (2)
- Polyurethane Tubing 1/8" ID 80 cm

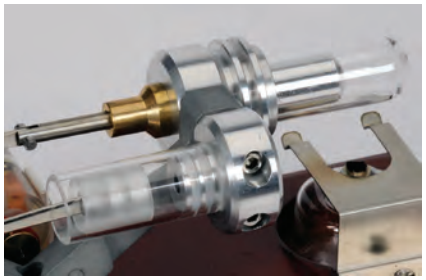
Order Information

Heat Engine Accessory	TD-8581A

Glass Stirling Engine

SE-8636A

This functional Stirling Engine provides a close-up look at the Stirling Cycle Principle with its active pistons and glass cylinders. This highly engaging apparatus connects to a generator which lights LEDs and includes a burner for denatured alcohol, as well as a platform for solid fuel.



Features:

- Completely assembled and ready to run
- Solid hardwood platform
- Replaceable Pyrex® power cylinder
- Replaceable, adjustable Pyrex® heat cap
- Generator with LEDs
- Clear cylinders for viewing pistons

Specifications:

Dimensions: 18 cm length x 9 cm width x 8 cm height

Order Information

Glass Stirling Engine SE-8636A

Colliding Spheres

SE-7303

- Demonstrates transformation of kinetic energy into heat
- Colliding spheres leave burn mark on paper

Hit these two steel balls together with a piece of paper in between. The kinetic energy is converted to heat and leaves a burn mark on the paper.

Specifications:

Diameter: 2 in (5 cm)

Order Information

Colliding Spheres SE-7303

Thermoelectric Converter

TD-8550A

- Demonstrate the First Law of Thermodynamics
- Reversible

Features:

- Demonstrates that a temperature differential is essential for extracting usable energy
- Produces electrical energy from a temperature differential
- Produces a temperature differential with electrical energy
- 15 cm tall with 6 cm diameter fan

How It Works:

The Thermoelectric Converter uses a series of semiconductor thermoelectric cells to convert thermal energy into electrical energy. The output from the cells drives a small electric motor.

Heat to Electrical Energy

Place one leg of the Thermoelectric Converter into cold water, the other into hot. The fan turns as the converter draws energy from the hot source (typically a 50°C temperature differential is required).

Electrical Energy to Heat

Pass a current (3 A DC at 5 V) through the Thermoelectric Converter. It acts as a heat pump. One leg becomes warmer while the other becomes cooler.

When a temperature differential is established between the two legs, the fan turns.

Order Information

Thermoelectric Converter TD-8550A
Required:
Containers for holding hot water, cold water, etc.
Triple Output Power Supply ..... SE-8587 p. 262
Partial Immersion Thermometer SE-9084B

PASPORT Non-Contact Temperature Sensor

PS-2197

- Non-contact
- -70°C to 380°C

The Non-Contact Temperature Sensor measures surface temperature by detecting the emitted infrared light. Record the temperature of objects without touching them!

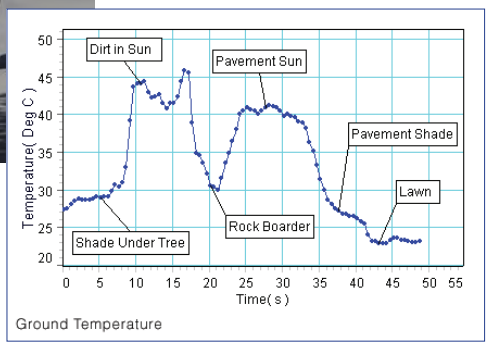
Applications:

- Compare temperature of hands, skin, face, and clothes
- Measure the temperature of different outdoor ground surfaces
- Map the temperature profile of an exterior wall

Specifications:

Range: -70°C to 380°C
Accuracy: ±0.5°C
Response Time: Less than 0.1 s
Maximum Sample Rate: 200 Hz
Field of View: ±35°

The student measures the late-morning ground temperature over four distinct surfaces. Starting in the shade under the distant tree, she then crosses bare dirt (in sun), a rock border, pavement, and lawn.



Ground Temperature

Order Information

PASPORT Non-Contact Temperature Sensor PS-2197
Shown in use with:
PASCO Capstone Software ..... pp. 84-87

PASPORT Temperature Type K Sensor

PS-2134

- Extra-long probe

The PS-2134 is a single channel sensor that uses a Type K thermocouple probe to measure temperatures ranging from -200°C to +1000°C. Includes one Type K Thermocouple.

Applications:

- Measure temperatures down to -200°C
- Measure temperatures in hard-to-reach places
- Use in high temperature applications where the narrow tip of the probe can be applied without burning the insulation cover (such as a candle flame)

Specifications:

Temperature Range: -200°C to +1000°C
Maximum Sample Rate: 10 Hz
Accuracy: ±3ºC or 3%, whichever is greater

The Type K Temperature Sensor can be used to measure the temperature of a flame. Works with any industry standard Type K thermocouple.

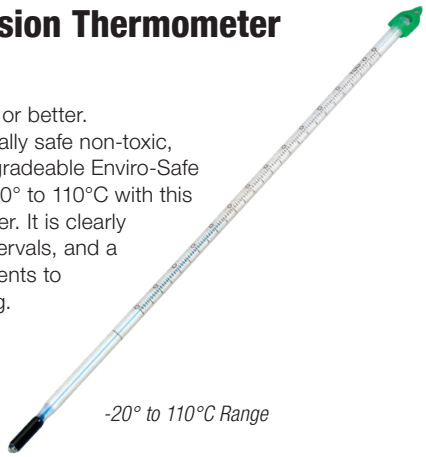
Order Information

PASPORT Temperature Type K Sensor PS-2134
Recommended:
Type K Thermocouple PS-2155

Partial Immersion Thermometer

SE-9084B

Features 1°C accuracy or better. Filled with environmentally safe non-toxic, non-hazardous, biodegradeable Enviro-Safe liquid. Measure from -20° to 110°C with this 30 cm long thermometer. It is clearly marked at 1 degree intervals, and a ring on top allows students to suspend it from a string.



-20° to 110°C Range

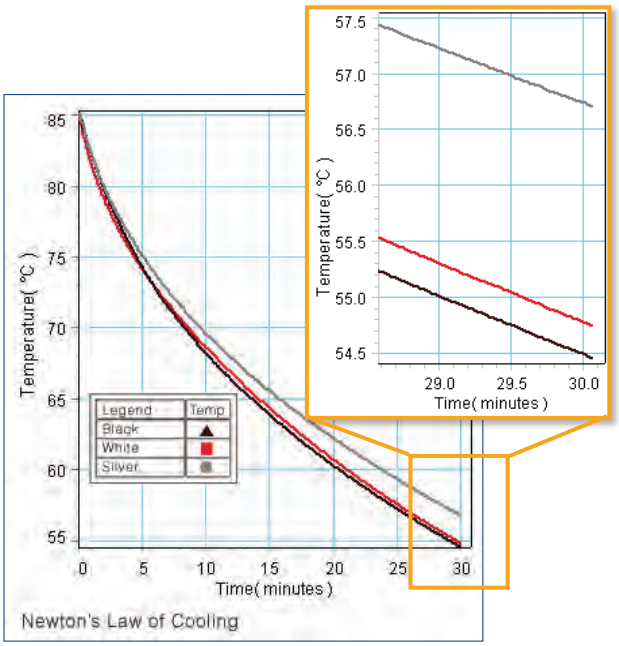
Order Information

Partial Immersion Thermometer SE-9084B

Radiation Cans

TD-8570A

These three aluminum cans have different surface finishes: silver (unpainted), white, and flat black. They are 15 cm high and hold about 350 ml of water. Their large thermal mass ensures good results with both temperature probes and standard glass thermometers. Fill them with cool water and place them outside in the sunlight to investigate the effect of the surface finish on solar heating. Or place them inside filled with hot water to discover Newton's Law of Cooling.



The black, white, and silver Radiation Cans are filled with hot water and allowed to cool. Graphs made in PASCO Capstone.

Order Information

Radiation Cans	TD-8570A	
Required to measure temperature:		
Wireless Temperature Sensor	PS-3201	p. 68
OR		
Partial Immersion Thermometer	SE-9084B	p. 219

Thermal Radiation Cube (Leslie's Cube)

TD-8554A

- Low-temperature radiation source

Features:

- **Electrically Heated:** The 100-watt bulb inside eliminates the danger of an open flame and the inconvenience of water-heated cubes. Temperature is conveniently controlled with the power control knob.
- **Thick Aluminum Walls**
- **Thermistor:** A 100 kΩ thermistor embedded in one wall of the cube provides accurate temperature measurement with no thermometer to break.

Order Information

Thermal Radiation Cube (Leslie's Cube)	TD-8554A	
Required:		
Radiation Sensor	TD-8553	
Basic Digital Multimeter	SE-9786A	p. 240

Radiation Sensor

TD-8553

- Radiation detector
- Thermopile

Point the Radiation Sensor toward any object – open the shutter and read the digital voltmeter to measure the relative intensity of the thermal radiation emitted.

Flat Spectral Response:
0.6 to 30 µm

Order Information

Radiation Sensor	TD-8553	
Required:		
Basic Digital Multimeter	SE-9786A	p. 240

Stefan-Boltzmann Lamp

TD-8555

- High-temperature radiation source

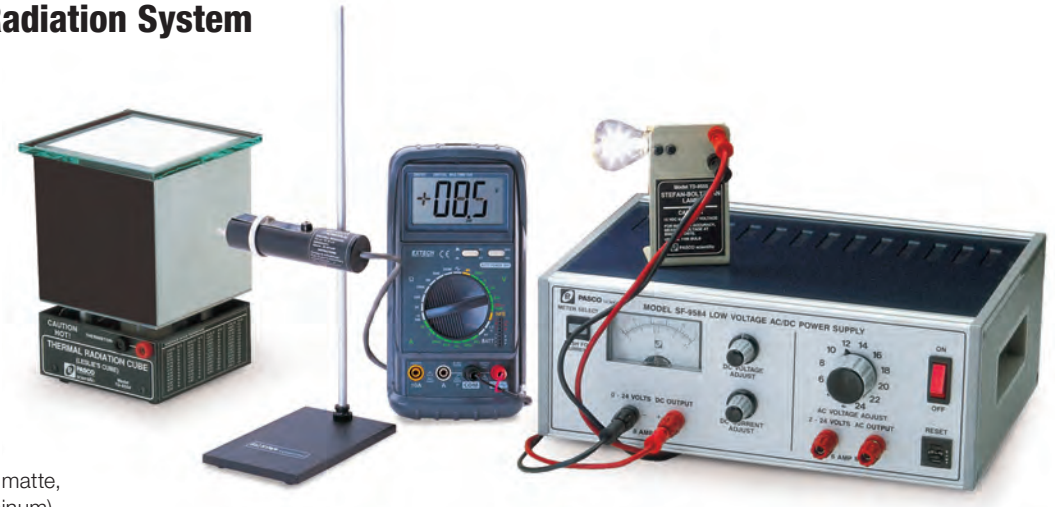
The temperature of this 12 V incandescent lamp filament can be accurately determined by measuring the voltage and current that students supply to the lamp (a graph of Temperature vs. Resistivity is provided).

Order Information

Stefan-Boltzmann Lamp	TD-8555	
Required:		
12 V DC Power Supply – see page 264		

Complete Thermal Radiation System

TD-8855



With the Radiation Sensor, a versatile Radiation Cube, and the Stefan-Boltzmann Lamp, four key experiments in thermal radiation can be performed.

Students begin with a study of thermal radiation from different types of surfaces at the same temperature. The Thermal Radiation Cube has four different surfaces that can be monitored (black matte, white matte, polished aluminum, and dull aluminum). The cube is heated electrically with a 100-watt bulb (its output can be varied). The thick aluminum walls assure the same temperature on all four walls to within a fraction of a degree. The Radiation Sensor provides an accurate measure of thermal radiation throughout the infrared region. Its output is a voltage that is proportional to the intensity of radiation.

Another important introductory experiment is the Inverse Square Law. The Stefan-Boltzmann Lamp uses a special bulb to provide a near-perfect point source, providing accurate results.

Finally, students can verify the Stefan-Boltzmann Law for both low and high temperatures by using the Radiation Cube for the low temperatures and the Stefan-Boltzmann Lamp for the high temperatures.

Includes:

- Thermal Radiation Cube
- Stefan-Boltzmann Lamp
- Radiation Sensor

See opposite page for component details.

Typical Experiments

With Teacher's Guide and Sample Data

- Introduction to Thermal Radiation
- Stefan-Boltzmann Law at Low Temperatures (Rrad = σT^4)
- Inverse Square Law
- Stefan-Boltzmann Law at High Temperatures

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Crooke's Radiometer

SE-7283

- Demonstrates that black surfaces are better radiators

This product consists of a set of vanes, each with one shiny side and one black side, mounted on a spindle in a partially evacuated glass bulb. When exposed to the sun or other intense light, the vanes begin to rotate with the black side trailing. The black side heats the air next to it more than the shiny side, so the air pushes harder on the black side.

Specifications:

Dimensions: Diameter 8 cm; height 13 cm

Order Information

Crooke's Radiometer	SE-7283

Order Information

Complete Thermal Radiation System	TD-8855	
Required:		
Basic Digital Multimeter	SE-9786A	p. 240
Low Voltage AC/DC Power Supply	SF-9584B	p. 264
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 238

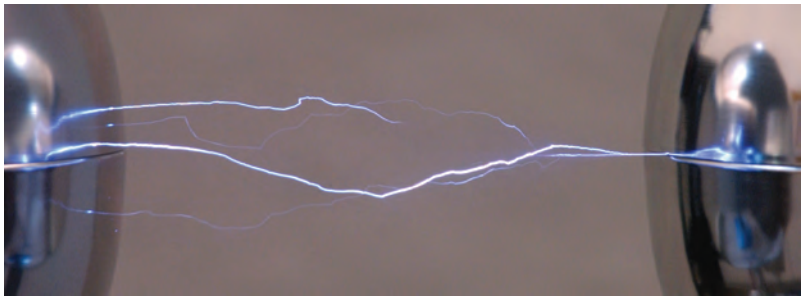
Van de Graaff Generator, High Voltage

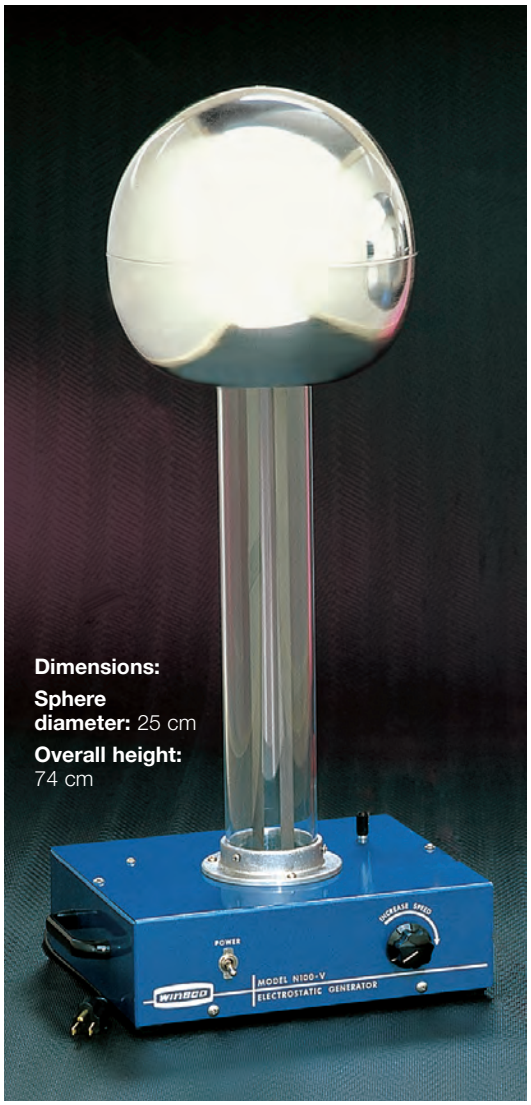
SE-8691

- Large sphere creates higher voltage
- Sparks up to 35 cm in length
- Large size ideal for demonstrations

The High Voltage Van de Graaff Generator features a 25 cm diameter sphere that can generate approximately 400,000 volts. The size of the sphere, its rounded edges, and its height from the demonstration table contribute to the high voltages generated.

Its large size, long sparks, and high voltages make it ideal for use in larger rooms or lecture halls. An extra belt is included.

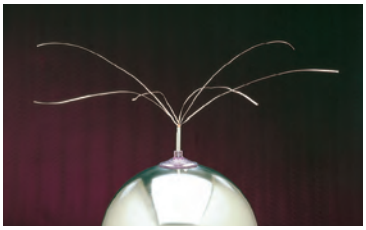




Electrostatic Plume

SE-7232

The lightweight ribbons are connected to a stand that rests on top of the Van de Graaff Generator. As the generator operates, the ribbons stand on end, due to the repulsive force between their like charges.

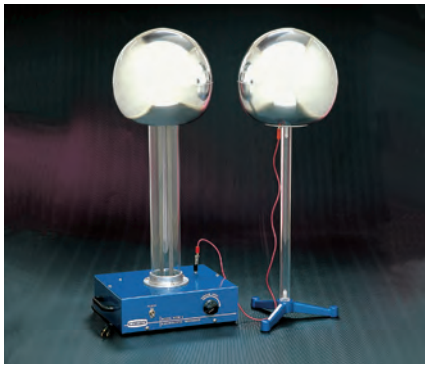


Order Information

Electrostatic Plume SE-7232

Discharge Sphere

SE-7231



This 25 cm sphere is supported on a Lucite column with a cast iron base. Includes cabling for connection to the Van de Graaff Generator or to a ground.

Order Information

Discharge Sphere SE-7231

Electrostatic Whirl

SE-7233

When held near the sphere of the generator, the spokes are propelled by charge leaving the points.

Order Information

Electrostatic Whirl SE-7233

Order Information

Van de Graaff Generator, High Voltage SE-8691
Replacement Supplies:
Replacement Belt SE-7355

Replacement Belt, Van de Graaff Generator

SE-7355

Order Information

Replacement Belt, Van de Graaff Generator..... SE-7355

Electroscope

SE-7247

Show the amount of charge and the sign of the charge relative to a standard. Includes charging ball plus a set of condenser plates with insulated rod.

Ring diameter: 150 mm

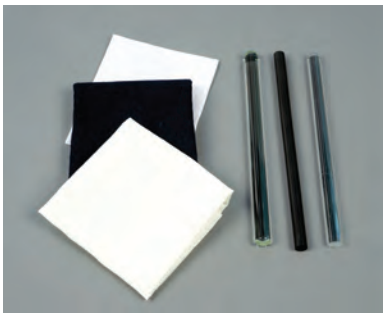
Order Information

Electroscope SE-7247

Electrostatics Materials

SE-6658

This electrostatics kit provides the necessary tools to separate positive and negative charges. Students can experiment with different combinations of cloth and rod materials to explore how each becomes charged.



Includes:

- 3 fabric cloths (wool, cotton, silk)
- 3 rods (glass, ebonite, acrylic)

Order Information

Electrostatics Materials SE-6658

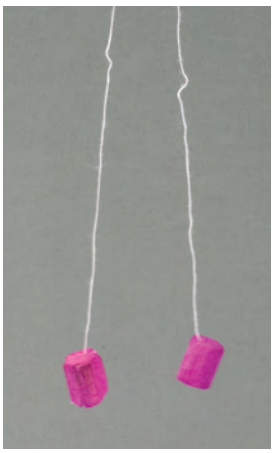
Coated Pith Balls (Set of 10)

SE-7719

These threaded pith balls are coated with a conductive material. Suspend two pith balls from a rod and charge with the Electrostatic Materials SE-6658.

Includes:

- Threaded Coated Pith Balls (10)



Order Information

Coated Pith Balls (Set of 10) SE-7719

Dissectible Leyden Jar

SE-7718

▶ Acts as a capacitor

This Leyden Jar is designed for classroom demonstrations and comes with a durable inner and outer plate, a plastic dielectric, and instructions. The inner plate has a hook and ball attached, which makes it easy to charge with a Van de Graaff Generator or a charged rod.

Leyden Jar is 3" in diameter and 8" tall.

Order Information

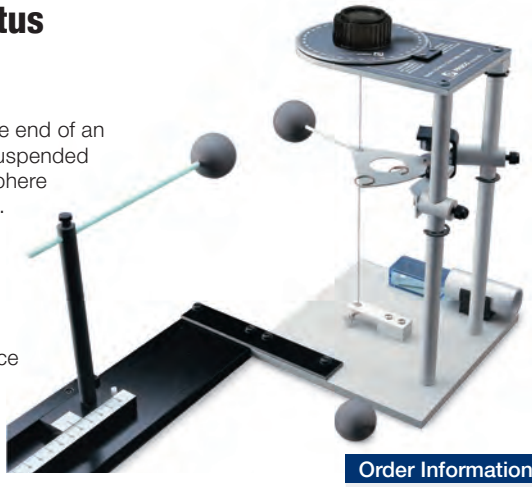
Dissectible Leyden Jar SE-7718

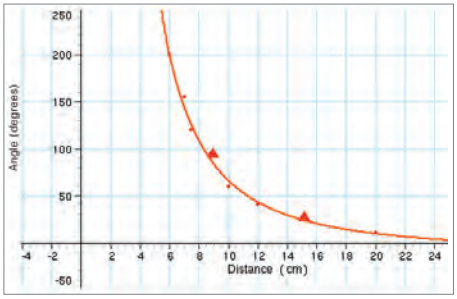
Coulomb's Law Apparatus

ES-9070

How It Works:

A conductive sphere is mounted on the end of an insulating, counterbalanced rod and suspended from a thin torsion wire. An identical sphere is mounted on a calibrated linear track. This second sphere can be positioned at various distances from the first. When the conductive spheres are charged, the force between them is proportional to the twist of the torsion wire that is required to bring the balance back to its equilibrium position. Beginning students can determine the Inverse Square Law in a simple experiment. Advanced students can perform a more sophisticated investigation into all the variables of electrostatic repulsion.





Actual data of the Angle (force) vs. Distance

More information on page 323.

Order Information

Coulomb's Law Apparatus ES-9070

Basic Electrostatics System

ES-9080B

- Quantitative electrostatics
- Comprehensive experiment manual included
- Individual or demonstration use

The PASCO Basic Electrostatics System includes all the components necessary for a quantitative investigation into the basics of electrostatics.

Topics Covered:

- Production of charges, equal and opposite
- Charge by induction
- Principle of the Faraday Ice Pail
- Charge transfer
- Charge distribution in electric fields
- Capacitors and the Q=CV relationship
- Moving charges and current

Order Information

Basic Electrostatics System ES-9080B

Includes:

- Basic Electrometer: ES-9078A
- Charge Producers and Proof Plane: ES-9057C
- Faraday Ice Pail: ES-9042A
- Conductive Spheres: ES-9059C
- Conductive Shapes: ES-9061
- Basic Variable Capacitor: ES-9079
- Electrostatics Voltage Source: ES-9077
- Experiment Manual

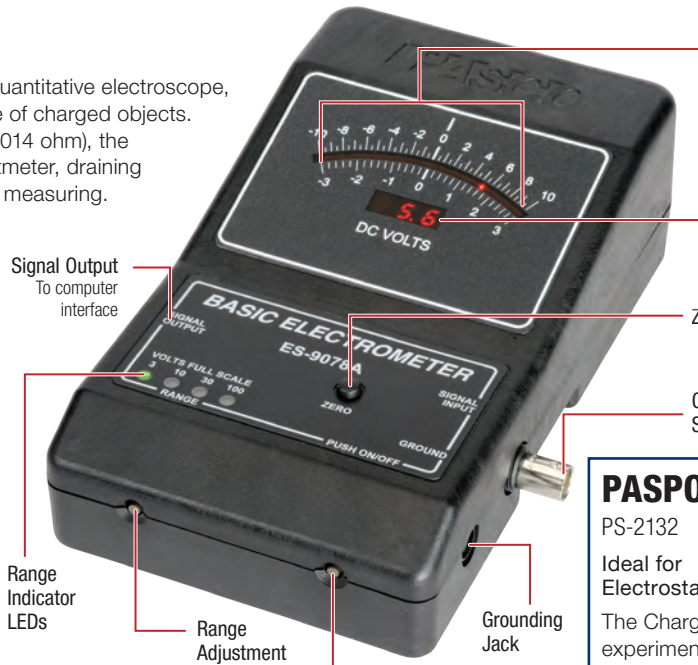
Basic Electrometer

ES-9078A

The PASCO Basic Electrometer is a quantitative electroscope, measuring the polarity and magnitude of charged objects. With almost infinite input resistance (1014 ohm), the Electrometer is a high-impedance voltmeter, draining almost no charge from the object it is measuring.

Features:

- **Center-Zero Meter:** Polarity is indicated directly.
- **Switch-Selectable Ranges:** 3, 10, 30 and 100 VDC. LED lights indicate the range in use.
- **Zeroing Switch:** Removes all charge from the input and brings the meter to zero.
- **Automatic Shutoff:** Turns off about 3 hours after turned on (or used in any way).
- **Output Compatible with PASCO Interfaces:** The interface cable included with the electrometer connects directly to an analog channel on a ScienceWorkshop interface, and connects to a PASPORT interface through an Analog Adapter. This enables the output signal from the electrometer to be recorded, displayed, and analyzed by the data acquisition software.
- **Battery Operation:** 4 “AA” cells included. Range indicator lights flash when batteries need to be replaced.



Includes:

- Shielded input cable to connect the Electrometer to the Faraday Ice Pail or other source of charge
- Grounding cable with clip
- Interface cable
- Instruction and experiment manual

Order Information

Basic Electrometer.....ES-9078A

PASPORT Charge Sensor

PS-2132

Ideal for Electrostatics

The Charge Sensor is designed for experiments in electrostatics such as inductive charging, charge production/distribution, and charge on a capacitor. When used with the Faraday Ice Pail, the Charge Sensor can measure the total charge on an object by the induction method.

The Charge Sensor can also be used as a high impedance voltmeter (10^{12} Ω). It includes a 0.9 m shielded cable with alligator clips to eliminate stray fields.

Order Information

PASPORT Charge Sensor PS-2132

Electrostatics Voltage Source

ES-9077

This compact unit is ideal for performing experiments in electrostatics. It may be used as a source of charge or to maintain an object at a constant potential.

Output voltages are 1000, 2000, and 3000 VDC for charging spheres, capacitor plates, etc. A 30 VDC source is also provided for experiments with capacitors.

Specifications:

Output: 30, 1000, 2000, 3000 VDC ±3%, line regulated

Resistance in Series with Output: 120 MΩ/kV

Operating Voltage: 115/220, 50/60 Hz

AC Adapter: 9 VDC

Order Information

Electrostatics Voltage Source..... ES-9077

Basic Variable Capacitor

ES-9079

Two 18 cm diameter plates allow the capacitance to be varied from 225 pF to zero by sliding the movable plate in its 28 cm long track. The sliding plate has adjustment screws to make the plates parallel to each other. Electrical connection studs are located on each plate.

A BNC connector cable is provided for connection to an Electrometer.

Order Information

Basic Variable Capacitor..... ES-9079

Conductive Spheres

ES-9059C

These Conductive Spheres (two per set) can be used to store charge or to investigate the charge distribution on one or two spherical conductors. A terminal on the bottom of each sphere provides a connection point for the power supply. Each sphere is attached to a heavy base (for stability) with an insulating rod. The spheres are 13 cm in diameter and 30 cm high.

Order Information

Conductive Spheres..... ES-9059C

Charge Producers and Proof Plane

ES-9057C

The Charge Producers create equal positive and negative charges when rubbed together. The Proof Plane samples the charge density from a charged object. The charge can then be measured using the Electrometer and Faraday Ice Pail.


Use the ball end to sample inside the hollow sphere.

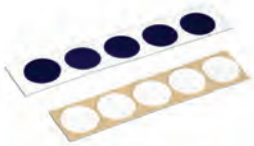
Order Information

Charge Producers and Proof Plane..... ES-9057C

Replacement Pad Set

ES-9056

(for ES-9057C)



Includes:

- Artificial leather pads (5)
- Blue vinyl pads (5)

Order Information

Replacement Pad Set..... ES-9056

Conductive Shapes

ES-9061

This set includes a conductive sphere with a hole in it. Demonstrate that static charge resides outside the surface of a conductive sphere by sampling the inside surface with the ball end of the proof plane. Also included is an oblong shape for demonstrating the difference in charge densities on a large-radius surface vs. a small-radius surface. The whole surface is at the same potential, and students seem surprised to find that the charge density is greater on the smaller end.

Order Information

Conductive Shapes..... ES-9061

Faraday Ice Pail

ES-9042A

With the Faraday Ice Pail, students can use the Electrometer to measure charge as well as potential.

Touch the Proof Plane to the point of interest on the charged body, then place the Proof Plane inside the Ice Pail. The Electrometer reading will be directly proportional to the charge on the Proof Plane.

The Faraday Ice Pail is 10 cm in diameter and 15 cm deep. It is made of wire mesh, so it is easy to see what is going on inside. The outside shield has a diameter of 15 cm.

Order Information

Faraday Ice Pail..... ES-9042A

Charge, Equipotential and Field Mapper

ES-9060

The Charge, Equipotential, and Field Mapper is an excellent addition to the Basic Electrostatics System.

Draw any set of two-dimensional conductors with the conductive ink. Investigate the electric field and the equipotential field lines between and around the conductive paper. Charge it and investigate the distribution of charge on its surface.

Similar to the Field Mapper Kit, except it includes electrometer probes, a "point charge" holder, and larger sheets of conductive paper for investigating charge distributions on conductive surfaces.

Includes:

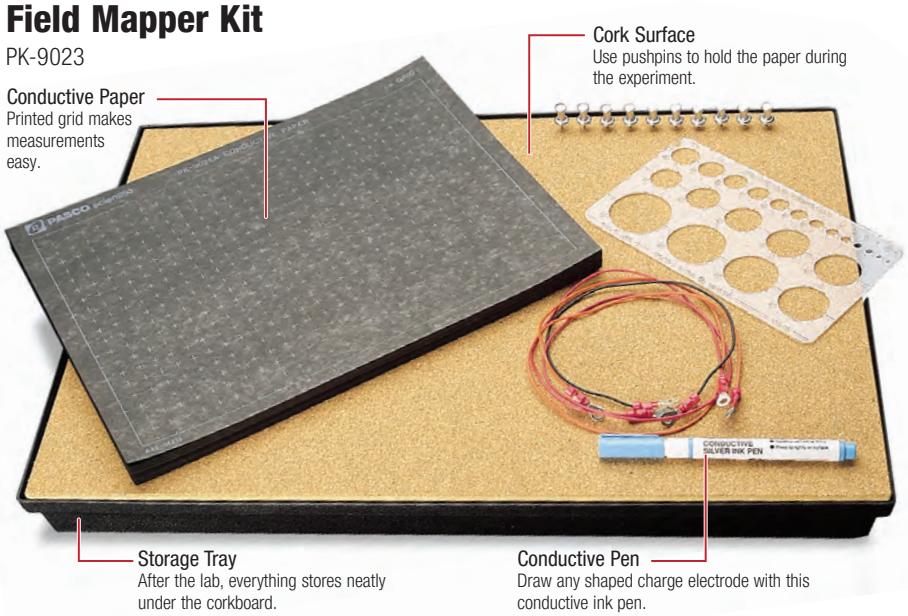
- Conductive paper for mapping charge distributions: 30 x 45 cm (50 sheets)
- Conductive paper with cm grid for mapping equipotentials and field gradients: 23 x 30 cm (100 sheets)
- Pushpins, connecting wire and electrometer probes
- Conductive ink pen and a circular template for drawing conductors
- "Point charge" holder
- Plastic tray with corkboard top: 32 x 48 cm
- Manual with 13 experiments

Order Information

Charge, Equipotential and Field Mapper.....ES-9060
Replacement Supplies:
Special Conductive Ink Pen PK-9031B
(limited shelf life of six months; not refillable)
Conductive Paper with Grid.....PK-9025B
Conductive Paper (no Grid).....PK-9026

Field Mapper Kit

PK-9023



Start by investigating standard electrostatic configurations, such as point sources, dipoles, and capacitors. Then go further. You might, for example, investigate whether a person is safe in a car, under a tree, or on top of a flag pole in a thunder storm. Or you might create an electrostatic model of fluid flow to show that water flows fastest in the narrowest portion of a hose.

How It Works

With this kit students can map both the potentials and the electric fields around any conceivable system of two-dimensional charged conductors.

The procedure is simple:

1. Draw any electrode
2. Plot the equipotentials
3. Plot the electric field

Features:

- Complete kit
- Complete manual
- Measure electric fields directly
- Measure potentials directly
- No mess
- Inexpensive
- Easy storage

Typical Experiments

- Dipoles of Like Charges
- Dipoles of Opposite Charges
- Parallel Plate Capacitor
- Point Source and Guard Ring (cylindrical capacitor)
- Floating Electrode

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Includes:

- Conductive paper with cm grid: 23 x 30 cm (50 sheets)
- Pushpins (10) and Wires (3)
- Conductive Ink Pen and circular template
- Plastic tray with corkboard top: 32 x 48 cm
- Instruction manual with 10 experiments

Order Information

Field Mapper Kit.....PK-9023
Required:
Basic Digital Multimeter.....SE-9786A p. 240
(or any voltmeter with at least a 10 MΩ input impedance)
Triple Output Power Supply.....SE-8587 p. 262
(or another low voltage DC power supply or battery)
Replacement Supplies:
Special Conductive Ink Pen PK-9031B
(limited shelf life of six months; not refillable)
Conductive Paper with Grid.....PK-9025B
Conductive Paper (no Grid).....PK-9026

Special Conductive Ink Pen

PK-9031B

The PASCO Conductive Silver Ink Pen makes it easy to study field patterns. Draw over 60 meters of patterns with a single pen. Pen shelf life is six months. Not refillable.

Order Information

Special Conductive Ink Pen PK-9031B
*Price may fluctuate with the price of silver.

Resistivity Apparatus

EM-8812

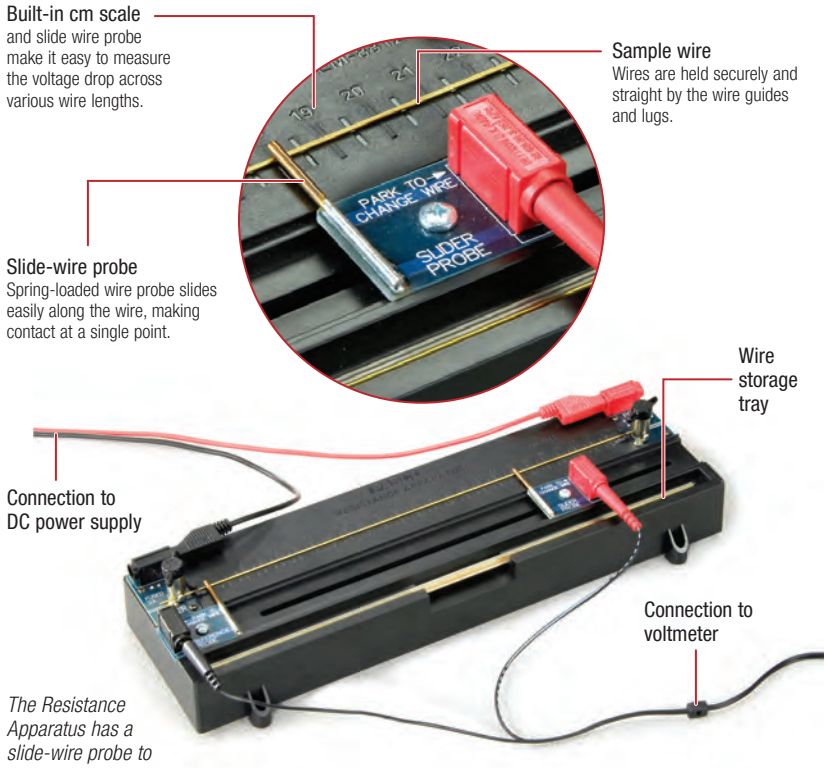
- Slide-wire potentiometer
- Measure resistance and resistivity
- Four wire diameters, five wire materials

A current is established in a wire of known diameter, and the voltage drop across a section of the wire is measured. Students can calculate the resistance of the wire and the resistivity of the material.

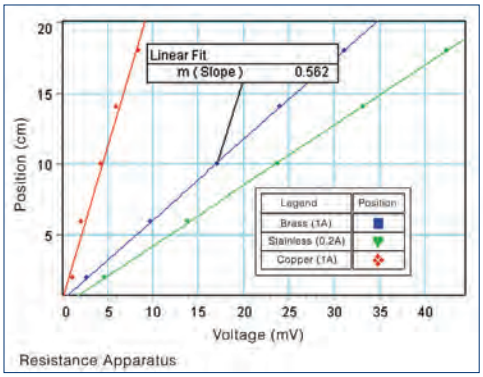
$$R = \frac{\rho L}{A}$$

Features:

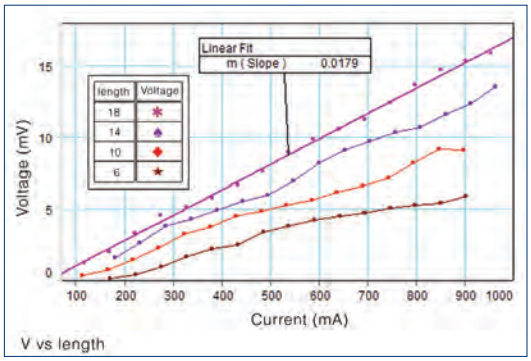
- **Vary Wire Length:** Slide-wire potentiometer pick-up makes it easy. Use the built-in scale to measure the length of the wire.
- **Vary Wire Diameter:** Four different diameters of brass wire are included. Investigate the difference between resistance and resistivity. Interchange wires quickly and easily.
- **Vary Wire Material:** Five different material wires are included. Investigate how resistivity depends on the wire material.
- **Storage:** Built-in storage tray to hold wires.
- **Sample Wire:** Wires are held securely and straight by the wire guides and lugs.
- **Slide Wire Probe:** Spring-loaded wire probe slides easily along the wire, making contact at a single point.
- **Built-in cm Scale** and slide wire probe make it easy to measure the voltage drop across various wire lengths.

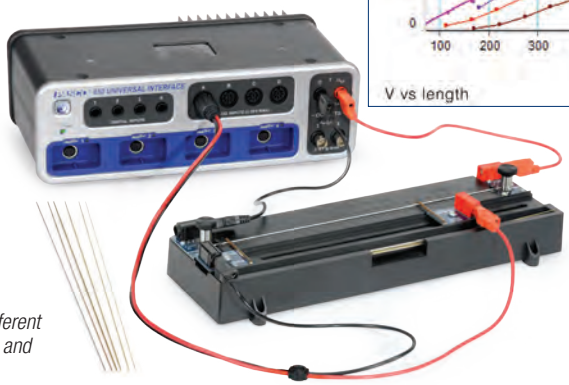


The Resistance Apparatus has a slide-wire probe to easily change the measured length of the wire and utilizes a four wire hook-up to accurately measure the voltage drop. It comes with four different brass wire diameters and four other wire materials.



Graph shows voltage drop across various lengths for three different material wires. The slope of the line (along with wire diameter and current) is used to calculate the resistivity of the material.





For this experiment, the 850 Universal Interface produces a 10 sec voltage ramp to apply a varying current through a brass wire. A graph of Voltage Drop vs. Current is created, and the slope of this line is the resistance of that length of wire.

Includes:

- 30 cm long wires (2 of each):
  - Copper (1.0 mm diameter)
  - Aluminum (1.0 mm diameter)
  - Stainless Steel (1.0 mm diameter)
  - Nichrome (1.0 mm diameter)
  - Brass (0.5 mm, 0.8 mm, 1.0 mm, 1.3 mm diameter)

Order Information

Resistivity Apparatus	EM-8812	
Shown in use with:		
850 Universal Interface	UI-5000	p. 26
Voltage Sensor (unshrouded)	UI-5100	p. 35
2 Meter Patch Cord Set	SE-9415A	p. 238
Recommended:		
PASPORT Galvanometer	PS-2160	p. 50
Replacement Wires, Resistivity Apparatus	EM-8813	

PASCO Modular Circuits

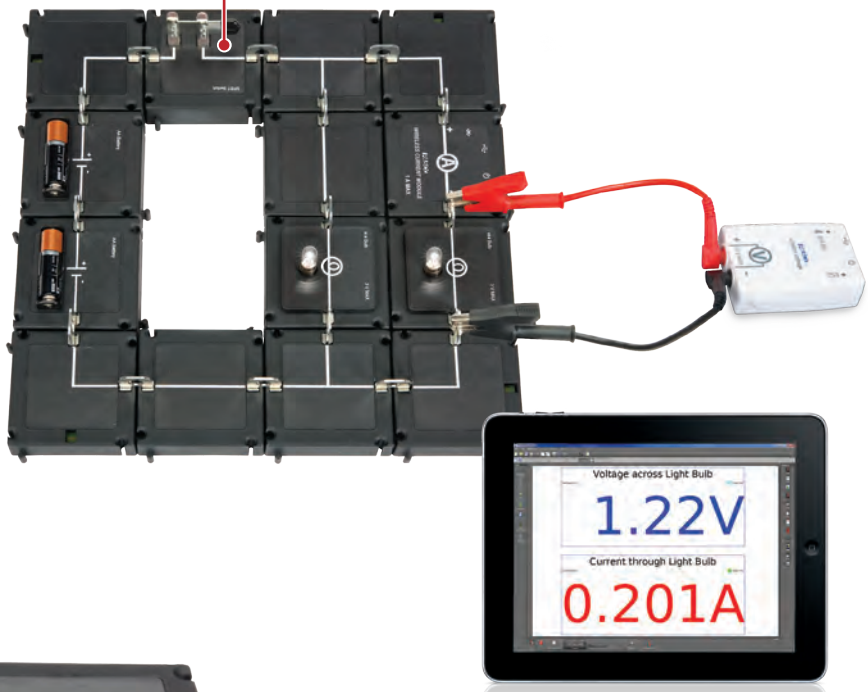
- Puts learning first
- Eliminates confusing wires
- Easy-to-connect modules

These circuit modules are designed specifically for introductory circuits classes. For students who have never wired a circuit, this modular system makes it easy for them to see the layout because it ends up looking like a circuit diagram.

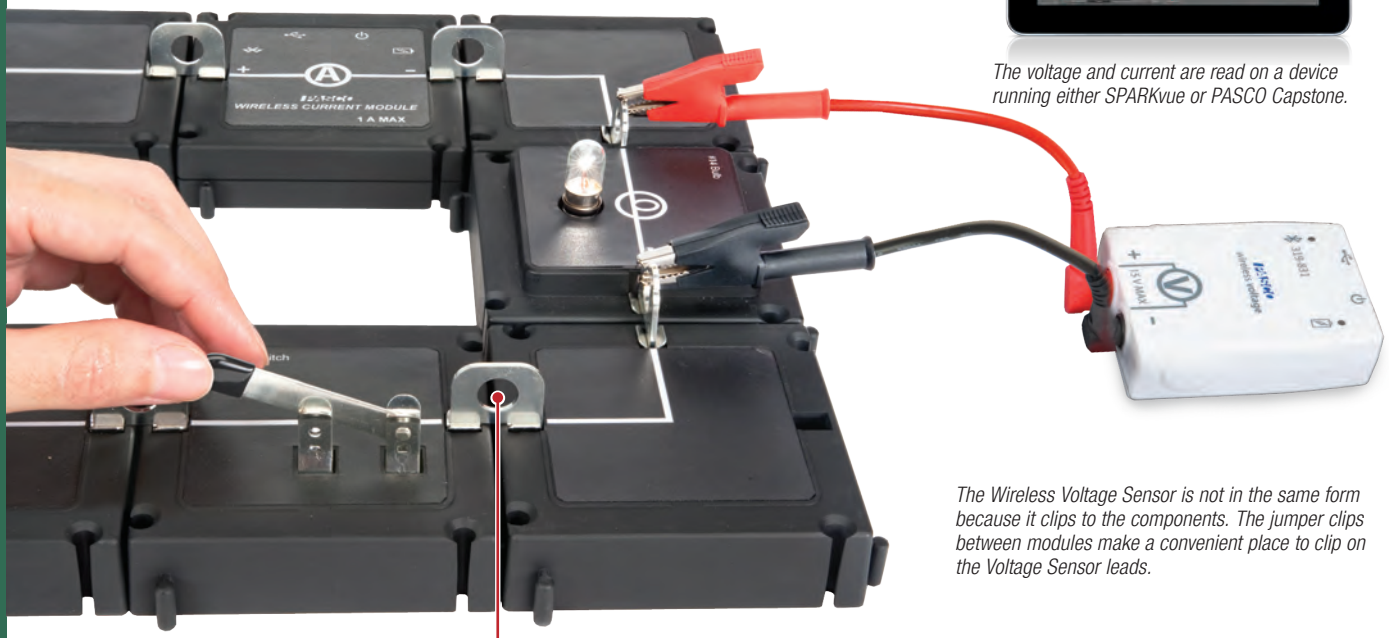
Each module connects mechanically to another by sliding the tabs into each other. It works on any tabletop. No special surface is required. To electrically connect two modules, students insert a jumper clip, which emphasizes that an electrical connection has been made. The large size of the modules (8 cm x 8 cm) enables all the students around the table to see and understand the completed circuit.

Students learn the correct way to insert an ammeter into a circuit: First they remove one of the straight wire modules from their circuit and then they replace it with the Wireless Current Sensor Module. Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components. The fact that the Current Sensor is wireless helps the pedagogy: There is only one way in and one way out of the Current Sensor. There are no extra wires coming out of it to confuse students.

Believe it or not, these two circuits are the same. Which would be easier for your students to understand?



The voltage and current are read on a device running either SPARKvue or PASCO Capstone.

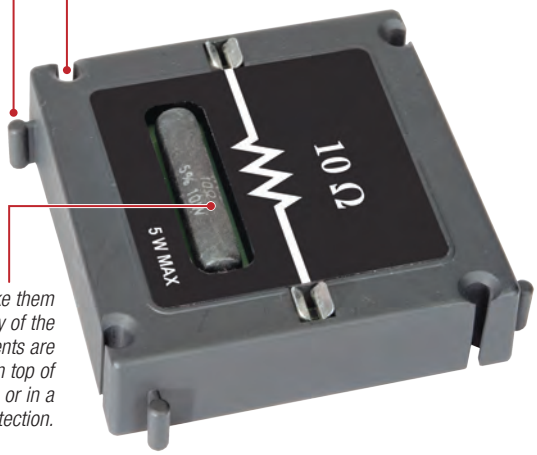


The Wireless Voltage Sensor is not in the same form because it clips to the components. The jumper clips between modules make a convenient place to clip on the Voltage Sensor leads.

To electrically connect two modules, students insert a jumper clip, which emphasizes that an electrical connection has been made.

Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components.

Each module connects mechanically to another by sliding the tabs into each other.



To make them visible, many of the components are mounted on top of the module or in a well for protection.

Wireless Current Sensor Module EM-3534 (included in EM-3536) Specifications:

- **Two ranges:** ±1A, ±0.1A
- **Resolution:** 0.2mA (±1A range); 0.02mA (±0.1A range)
- **Bluetooth® sampling rate of 1 kHz**
- **Higher speed sampling via USB**
- **Includes remote logging**

See more Modular Circuits Kits and the AC/DC Module on pages 230-231.

Basic Modular Circuits Kit

EM-3535

The Basic Kit has enough modules to do the five basic experiments listed below.

- Ohm's Law
- Series/Parallel Circuits
- Batteries and Bulbs Circuits
- Switches/Open/Closed Circuits
- Electric Power and Energy

Essential Physics Modular Circuits Kit

EM-3536

The Essential Kit has more modules, includes the Wireless Current Sensor Module and Wireless Voltage Sensor, and has 12 experiments.

- Ohm's Law
- Series/Parallel Circuits
- Kirchhoff's Laws
- Batteries and Bulbs Circuits
- Switches/Open/Closed Circuits
- Electric Power and Energy
- Electromagnets
- Electromagnetic Induction
- RC and RL Circuits
- Variable Resistance
- LED Circuits
- Electric Motors

Includes Module	Basic EM-3535	Essential EM-3536
Straight	4	5
Corner	4	4
Resistor	2	3
Light Bulb	2	3
Tee	2	2
Battery Holder (batteries not included)	2	2
SPST	1	1
Capacitor	1	1
Spring Clips	1	1
Inductor	0	1
Motor	0	1
LED	0	1
Potentiometer	0	1
SPDT Switch	0	1
Bar Magnet	0	1
Wireless Voltage Sensor	0	1
Wireless Current Sensor Module	0	1
Extra Jumpers	15	15
Loose Components for Spring Clips	5	5
Gratnells® Case	1	1
Experiments (download)	5	12

Each kit comes in a Gratnells® case with trays that organize the modules.

Order Information

Basic Modular Circuits Kit EM-3535
Essential Physics Modular Circuits Kit EM-3536
Required:
2 AA Batteries
Required for EM-3536:
PASCO Capstone Software ..... see pages 84-87
OR SPARKvue Software ..... see pages 88-89
Also available separately:
Wireless Current Sensor Module ..... EM-3534 p. 70
Wireless Voltage Sensor ..... PS-3211 p. 70

Wireless AC/DC Module

EM-3533

The Wireless AC/DC Module is a Bluetooth Low Energy wireless signal generator designed for use with PASCO's Modular Circuits. The AC/DC Module can act as a DC power supply, as well as generate Sine, Triangle, and Square AC signals. A built-in rechargeable battery provides long-lasting power for your basic circuits, and is rechargeable using the included USB cable. An internal voltage sensor monitors the output voltage at all times. Controllable in either PASCO Capstone or SPARKvue software, this latest circuit module expands the number and type of experiments you can perform with Modular Circuits to include Ohm's Law, RC Circuit Time Constant, and LRC labs.

Programmable using Blockly programming in PASCO Capstone 2 software.

The Wireless AC/DC Module is the perfect power supply for these experiments:

- Series and Parallel Circuits
- Capacitor Charge and Discharge
- RC and LRC Circuits
- Ohm's Law

Features:

- Compatible with Modular Circuits
- ±3V Output; 0.3 A Max
- DC, Sine, Triangle, Square
- Bluetooth Low Energy
- Rechargeable Battery
- Controllable with PASCO Capstone or SPARKvue Software

Waveforms:

- DC
- Sine
- Triangle
- Square

Wireless AC/DC Module with Modular Circuits

Specifications:

Output Types: DC, Sine, Triangle, Square
Output: ±3 V
Maximum Current: 300 mA
Output Resolution: 10 mV
Output Frequency: 0.1 Hz to 10 kHz
Output Frequency Resolution: 10 mHz
Battery: Rechargeable Lithium-Polymer 1000 mA
Protection: Overcurrent, Overtemperature and Back EMF
Connectivity: USB or Bluetooth® Low Energy
Max Wireless Range: 30 m (unobstructed)
Max Sample Rate for Output Voltage: 100 kHz

Includes:

- Micro USB Cable (PS-3584)

Order Information

Wireless AC/DC Module	EM-3533	
Requires:		
PASCO Capstone Single User License	UI-5401	pp. 84-87
OR		
SPARKvue Single User License	PS-2401	pp. 88-89

Modular Circuits Advanced Expansion Kit

EM-3556

This expansion pack supplies additional modules for constructing more complex and advanced circuits. The modules in the Modular Circuits Advanced Expansion Kit are intended to be used with (and as an addition to) the circuit modules found in either the Basic or Essential Physics Modular Circuits Kits (EM-3535 and EM-3536). This kit includes a storage case with a custom foam insert.

Includes:

- Speaker Module
- DC Buzzer Module
- Diode Module
- Solar Cell Module
- MOSFET Module
- Bipolar Junction Transistor Module
- Two-Terminal Module
- Jumper Clips (15)
- N-Channel MOSFET Transistor (2)
- P-Channel MOSFET Transistor (2)
- NPN Bipolar Junction Transistor (2)
- PNP Bipolar Junction Transistor (2)
- Gratnells® case with foam, tray, and lid

Order Information

Modular Circuits Advanced Expansion Kit..... EM-3556

Modular Circuits Expansion Kit

EM-3540

This expansion pack supplies extra modules found in both the Basic and Essential Physics Modular Circuits Kits (EM-3535 and EM-3536). It also includes a Banana Jack Terminals module for powering your circuits with an external power supply or signal generator. It also includes a storage case with a custom foam insert.

Includes:

- Spring Clips
- Straight (2)
- Tee (2)
- Corner (2)
- Light Bulb
- Battery Holder (battery not included)
- Jumper Clips (15)
- Banana Jack Terminals
- Gratnells® Storage Case

Order Information

Modular Circuits Expansion Kit	EM-3540	
Recommended:		
Basic Modular Circuits Kit	EM-3535	p. 229
Essential Physics Modular Circuits Kit	EM-3536	p. 229
Replacements		
Replacement Bulbs for Modular Circuits	EM-3541	
Replacement Jumper Clips	EM-3542	

AC/DC Expansion Kit

EM-3555

This kit includes the AC/DC Module (EM-3533) and the Modular Circuits Advanced Expansion Kit (EM-3556). This expansion pack supplies additional modules for constructing more complex and advanced circuits. The modules in the Modular Circuits Advanced Expansion Kit are intended to be used with (and as an addition to) the circuit modules found in either the Basic or Essential Physics Modular Circuits Kits (EM-3535 and EM-3536). This kit includes a storage case with a custom foam insert.

The kit includes the wireless AC/DC Module to power the circuits. Also included are:

- Speaker Module
- DC Buzzer Module
- Diode Module
- Solar Cell Module
- MOSFET Transistor Module
- Bipolar Junction Transistor Module
- Two-Terminal Module
- Jumper Clips (15)

Includes:

- Modular Circuits Advanced Expansion Kit (EM-3556) (shown above)
- Wireless AC/DC Module (EM-3533)

Order Information

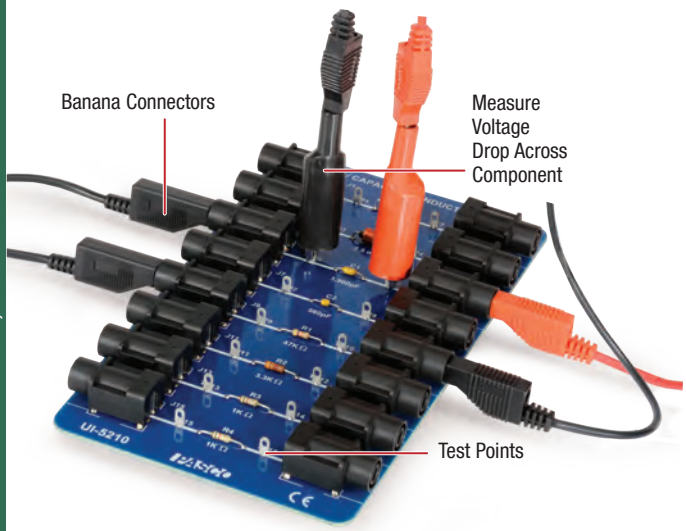
AC/DC Expansion Kit..... EM-3555

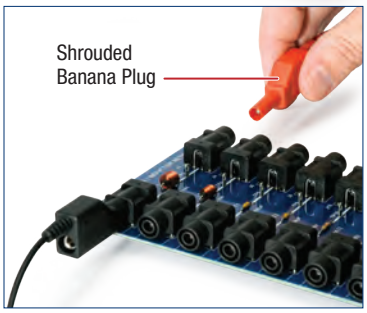
(The AC/DC Expansion Kit includes everything in the Advanced Expansion Kit, plus the AC/DC Module.)

Resistor Capacitor Inductor Network

UI-5210

Pair this circuit board with the 850 Universal Interface to study and test RC circuits, circuit laws and theories. The board components can be used to investigate Kirchhoff's Circuit Laws, Ohms' Law, RC Circuits, and A.C. LRC circuit theory with resonant frequencies between 55 kHz and 135 kHz, depending on values used. Designed for use with the 850 Universal Interface.





The circuit board accepts patch cords with shrouded banana terminals.

Shown in use with the 850 Universal Interface power amplifier. Both the applied voltage and the resulting current are measured directly by the 850.

Includes:

- Inductor: 6.8 mH, 2.5 mH (2)
- Capacitor: 3900 pF, 560 pF (2)
- Resistor: 47 kΩ, 3.3 kΩ, and two 1.0 kΩ (4)

Order Information

Resistor Capacitor Inductor Network UI-5210

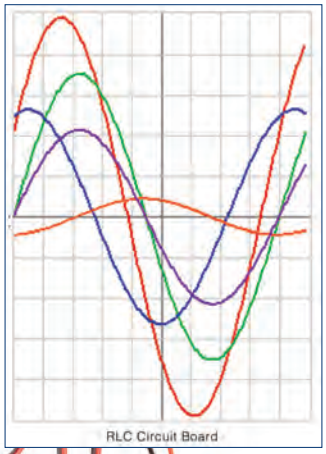
RLC Circuit

CI-6512

Designed to be used with an 850 Universal Interface to study the behavior of resistors, inductors, and capacitors in an AC circuit.

This board offers a unique set of components for demonstrating:

- Voltage/Current Phase Relationships
- RLC Resonance
- Non-Ohmic Characteristics; components include resistors, capacitors, and an inductor coil.



Phase relationships can be studied between voltage across the capacitor, resistor, and inductor.

The 550 or 850 Interface can measure current and voltage as well as provide power to the RLC Circuit.

Specifications:

Resistors: 100 Ω, 1 W; 33 Ω, 5 W; 10 Ω, 10 W
Capacitors: 100 µF, 16 V and 330 µF, 16 V (capacitance values may vary by ±20%)
Lamp: 7.5 V, 0.22 A, # 50 miniature screw style
Red LED: 655 nm
Green LED: 565 nm
LED: Typical forward voltage = 1.7 V to 2.1 V
LED: Average brightness at 20 mA = 1.5 mcd
Inductor: 8.2 mH @ 1 kHz
Inductor: 6.5 Ω maximum DC resistance
Inductor: 0.8 A current rating RMS
Inductor: 3/4" I.D. x 1-3/4"

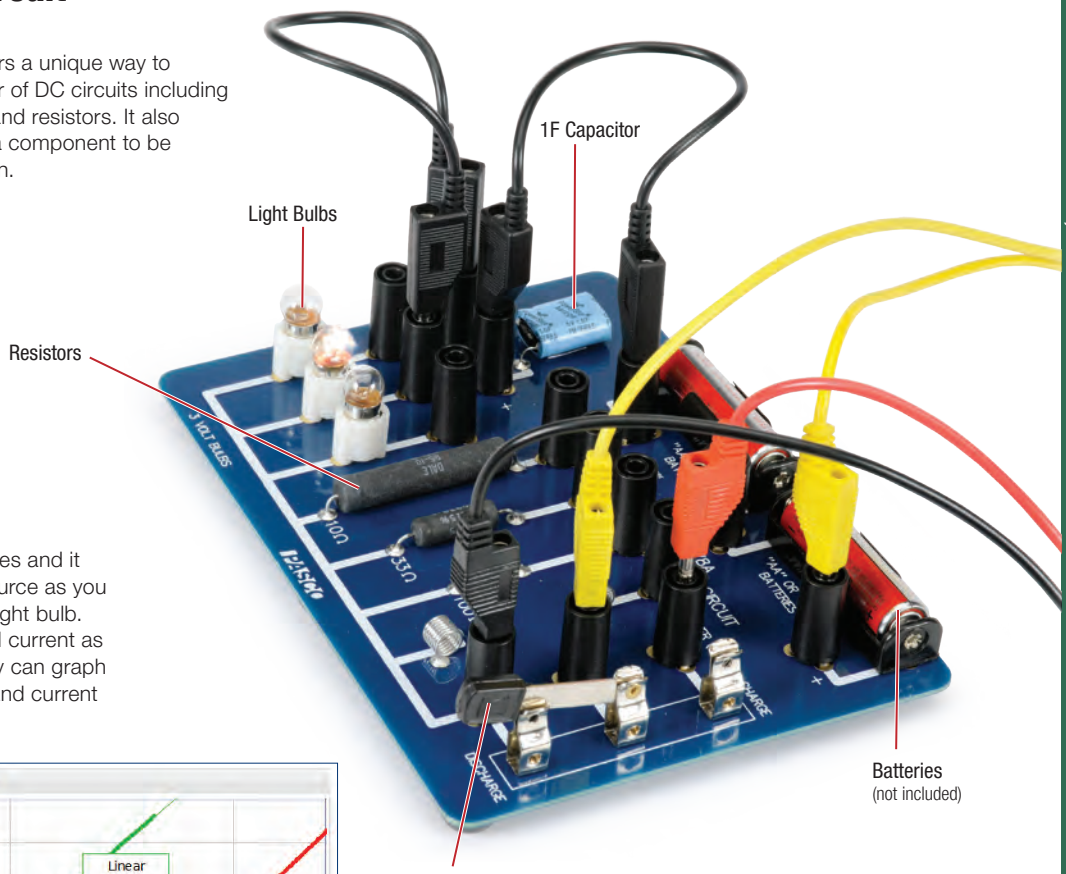
Order Information

RLC Circuit CI-6512

Charge/Discharge Circuit

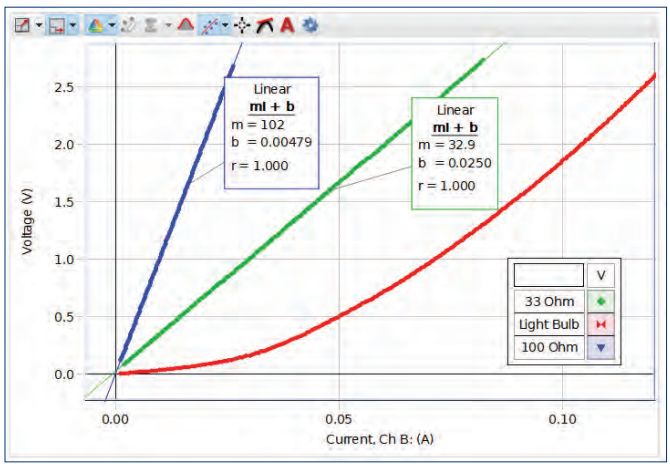
EM-8678A

The Charge/Discharge Circuit offers a unique way to observe and measure the behavior of DC circuits including batteries, capacitors, light bulbs, and resistors. It also includes an open slot that allows a component to be inserted for further experimentation.

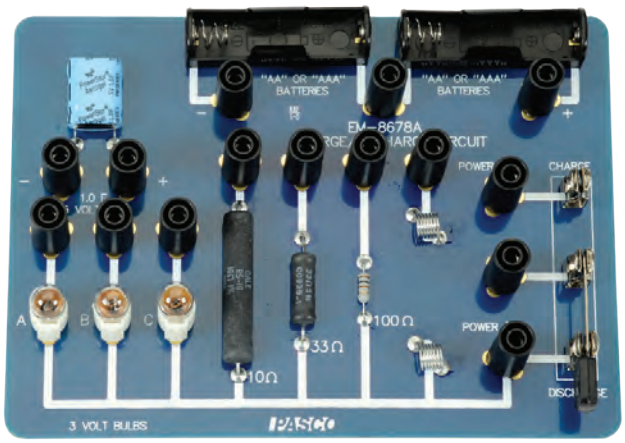


Works Like a Variable DC Power Supply

Charge the capacitor using batteries and it will act as a variable DC power source as you discharge it through a resistor or light bulb. Students measure the voltage and current as the capacitor discharges, and they can graph the relationship between voltage and current for various components.



Voltage vs. Current for a 33 Ω resistor, a 10 Ω resistor, and a light bulb. Note the non-linearity for the bulb. Data was recorded in PASCO Capstone using a 550 Universal Interface, Voltage Sensor (UI-5100) and a Wireless Current Sensor (PS-3212).



Includes:

- Farad Capacitor
- #14 Light Bulbs (3)
- 10 Ω Resistor
- 33 Ω Resistor
- 100 Ω Resistor
- Battery Holders
  (uses AA or AAA; batteries not included)
- Double-Throw Knife Switch
- Instruction Manual

Order Information

Charge/Discharge Circuit	EM-8678A	
Recommended:		
Light Bulbs (#14, 25 Pack)	EM-8627	p. 237
4-pack "AA" Batteries (not included)		
Wireless Current Sensor	PS-3212	p. 70
Wireless Voltage Sensor	PS-3211	p. 70
PASCO Capstone Software		pp. 84-87

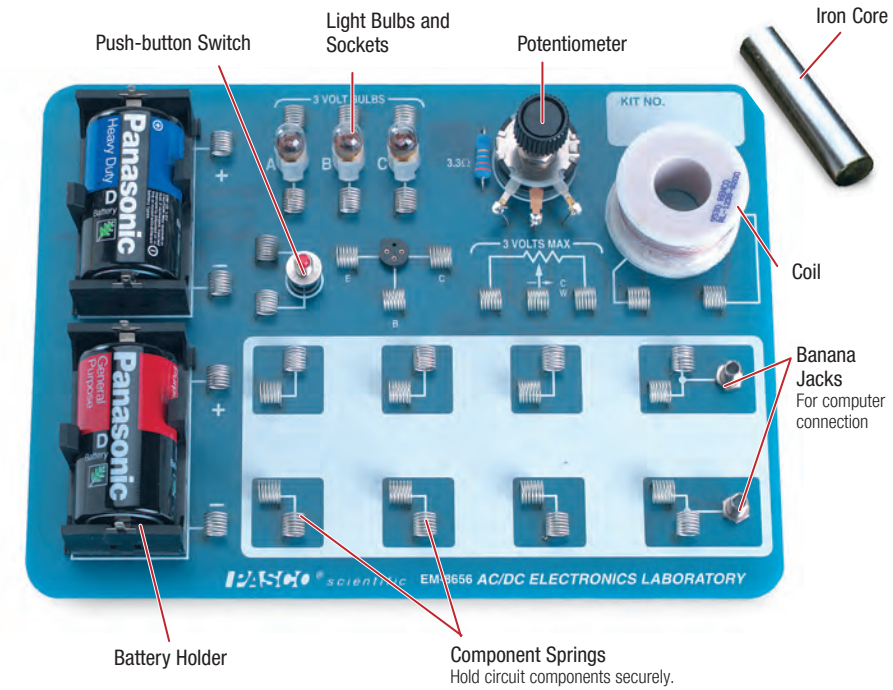
AC/DC Electronics Laboratory

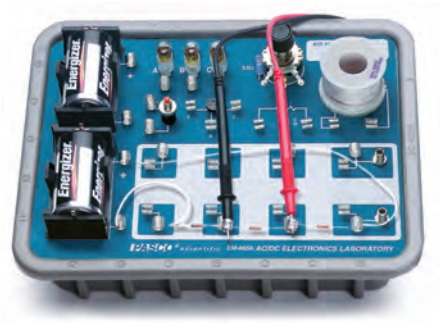
EM-8656

- Standalone operation
- Computer compatible
- Includes coil and iron core

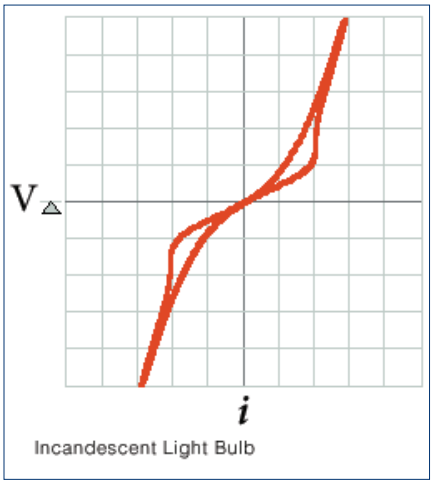
The AC/DC Electronics Laboratory dynamically teaches the basics of AC/DC circuits. It features banana jacks for computer connection, component springs that secure circuit components, a push button switch, light bulbs and sockets, as well as a potentiometer, coil, battery holder, storage tray, and an iron core.

The AC/DC Electronics Laboratory can be used with an 850 or 550 Interface or as a standalone unit with D batteries.

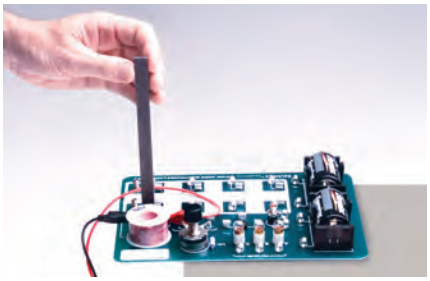




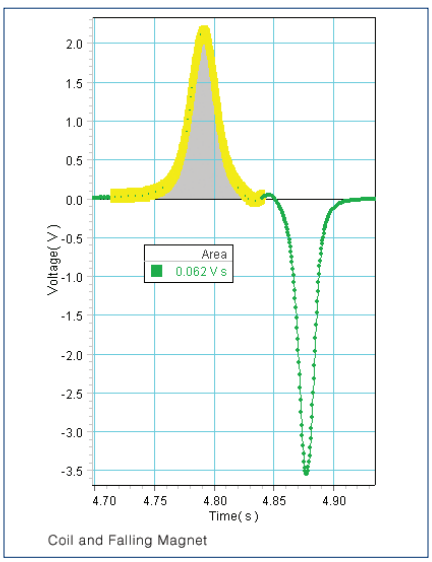
Students study how the resistance of a light bulb filament changes as it heats up. The graph below displays Voltage vs. Current for an incandescent light bulb. It is clear that the resistance is not linear but changes as the bulb begins to glow.



Incandescent Light Bulb



With PASCO Capstone and a Voltage Sensor, students can measure the electromotive force (EMF) created when a magnet is dropped through a coil, as well as the changes in magnetic flux caused by the magnet.



Coil and Falling Magnet

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Includes:

- 18 cm x 25 cm circuit board
- Resistors (24) (4.7 Ω – 220 kΩ, 5%, 0.25 - 5 W)
- Capacitors (7) (1 µF – 330 µF)
- Diodes, Transistors, and LEDs
- Wire leads (22 gauge)
- Push-button switch
- Storage tray and laboratory manual
- Battery holders (2)
- Light sockets and lamps (3)
- 25 Ω, 2 W potentiometer
- Component connectors (36)
- Transistor socket
- 8.2 to 19 mH coil and iron core

Order Information

AC/DC Electronics Laboratory EM-8656

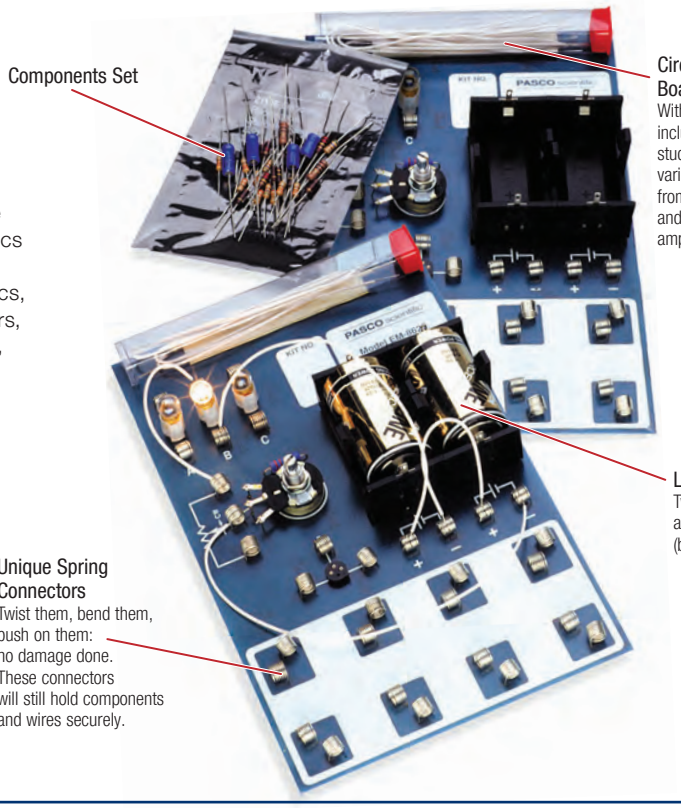
Electronic Components – AC/DC Lab EM-8668

Basic Electricity Lab

EM-8622

- Durable, easy-to-use kits
- Explore basic electronics
- Complete lab manual

These simple kits provide a strong foundation for future studies in electronics. They take students from the basics of Ohm's Law through simple series and parallel circuit analysis and into some elementary aspects of electronics, where they will build circuits using capacitors, transistors, and diodes. One kit per two students is recommended, giving each student his or her own circuit board.



Includes:

Two Circuit Boards with the following features:

- Battery holders (2)
- Resistor: 3.3 Ω, 2 W
- Light sockets with 3 bulbs (#14)
- Potentiometer: 25 Ω, 2 W
- Spring connectors (32)
- Transistor socket
- Storage tube for holding components (components stay with the kit longer)

Components Package containing:

- Resistors (23) (10 Ω - 220 kΩ, 5%, 1/2 W)
- Capacitors (4) (100 μF, 330 μF)
- Diodes (2)
- Transistors (2)
- Wire leads: 22 gauge

Typical Experiments

- Getting Acquainted
- Series vs. Parallel Circuits
- Ohm's Law
- Resistances in Circuits
- Voltages in Circuits
- Currents in Circuits
- Kirchhoff's Rules (nodes and loops)
- Capacitors in Circuits
- Diodes
- Transistors

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Order Information

Basic Electricity Lab
(2 boards).....EM-8622
Required:
"D" Cell Batteries
Basic Digital
Multimeter.....SE-9786A p. 240
Replacement Supplies:
Light Bulbs
(#14, 25 Pack).....EM-8627
Electronic Components –
Basic Electricity Lab.....EM-8663

Innovative physics textbooks and PASCO physics products

Matter & Interactions is a two-volume textbook and curriculum by Ruth Chabay and Bruce Sherwood, published by Wiley & Sons. It is intended for science and engineering students taking calculus-based introductory university physics. For more information on purchasing these textbooks, visit www.wiley.com.

Electric and Magnetic Interactions

Electric and Magnetic Interactions (Vol. 2 of 2) continues the emphasis on atomic-level descriptions and analysis and modeling physical systems. Electrostatics and circuit phenomena are treated as one integrated subject. The Desktop Electricity Kit allows students to carry out just-in-time desktop experiments on electrostatics, magnetism, and circuits.

Desktop Electricity Kit

EM-8675

When used in tandem with the Electric and Magnetic Interactions textbook, this kit gives students the conceptual tools to further their understanding of electric and magnetic interactions. While its components look simple, they provide hands-on opportunities for students to build powerful conceptual models.

Includes:

- Capacitor 1F, 2.5 V
- Resistor 47 Ω, 0.5 W
- Resistor 100 Ω, 0.5 W
- Lamp Holder T3-1/4 (2)
- #48 Miniature Lamp 2.0 V, 0.6 A (2)
- Incandescent Lamp 2.5 V, 0.3 A (2)
- Battery Holder
- Alkaline Battery D-cell (2)
- Bar Magnet (0.375" x 1")
- Compass, Liquid Filled
- Wire-Red 22AWG (6 ft)
- Alligator Clip Leads (12") (7)
- Nichrome Wire #26 (18")
- Nichrome Wire #30 (18")

Order Information

Desktop
Electricity Kit.....EM-8675

CASTLE "2005" Curriculum

Capacitor-aided system for teaching and learning electricity

- Complete electricity curriculum
- Redesigned sections to facilitate beginning CASTLE curriculum in grade 8 or 9

CASTLE Kit

EM-8624A

Economy CASTLE Kit

(for 8 students) EM-8654

The CASTLE™ Approach

CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) is a high school electricity curriculum that leads students from initial naive ideas to an increasingly expert understanding of electrical phenomena. A sequence of self-guided experiments uses large capacitors and transient bulb lighting to help students confront their misconceptions, grasp the physics of current propulsion and build intuitive explanatory models.

Typical Experiments

Core Curriculum investigates:

- What is happening in the wires?
- What do the bulbs do to moving charge?
- Where does the moving charge originate?
- What makes charge move in a circuit?
- How do wires distribute electric pressure in a circuit?
- How are values of circuit variables measured?

Advanced Curriculum investigates:

- Does all matter contain charge?
- What is the cause of distant action effects?
- What pushes on tiny charge carriers like electrons?
- How do semiconductors work?
- What is AC?
- How do motors and generators work?
- How are magnetic and electromagnetic fields produced?

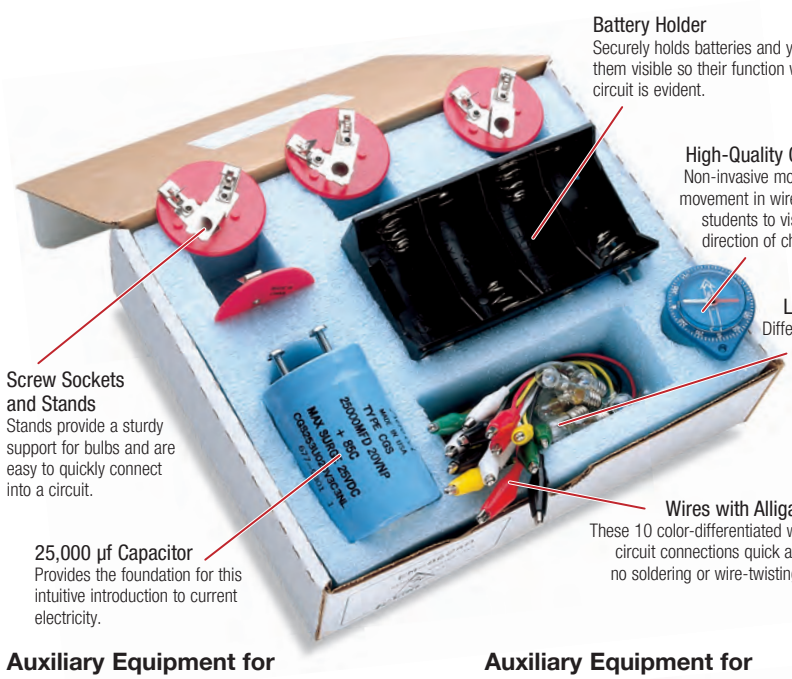
To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

The Curriculum Guide

Download the Manuals FREE.

Download the CASTLE Curriculum Guide for FREE. At *www.pasco.com* just type CASTLE in the search box and click GO!

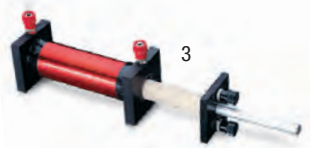
The teacher's manual helps teachers put the CASTLE Kits to the best possible use. The student manual has investigations for each stated experiment, plus commentaries to prepare students for labs, as well as summary exercises to reinforce the lab experience.



Auxiliary Equipment for Core Curriculum

The Mini Generator (1) enables students to distinguish charge circulation from energy transfer. The 100,000 µf Capacitor (2) lengthens the time scale of transient bulb lighting.

Auxiliary Equipment for Advanced Curriculum



Bi-color LEDs detect electric vectors in electromagnetic fields produced in these coils (3) by accelerating charge when current is turned on and turned off.

The Kits

Each CASTLE Kit includes all the materials needed (except for three D batteries) for two students to work through a complete introduction to basic electricity. Each Economy CASTLE Kit includes all the materials needed (except batteries) for eight students.

Materials Included in Each Kit

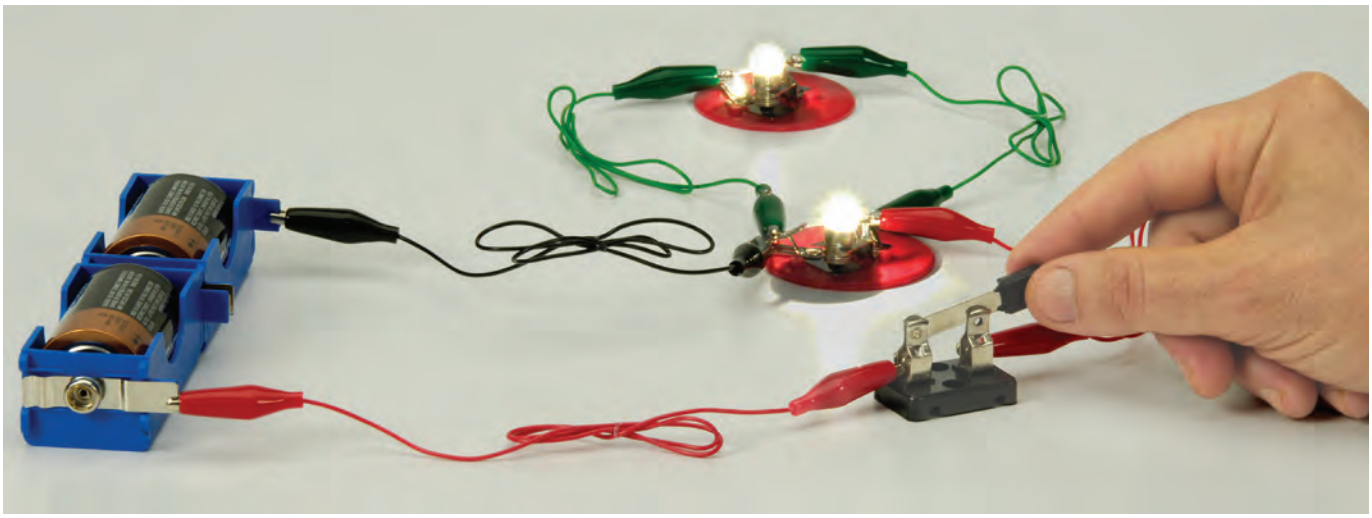
Component	CASTLE Kit	Economy Kit
25,000 µF capacitor (20 V, nonpolar)	1	4
#14 light bulbs (round)	4	25
#48 light bulbs (oblong)	6	25
10 Ohm resistor	4	16
Miniature light bulb sockets and stands	4	16
Wires with alligator clips	10	40
Battery holder (spring-loaded)	1	4
High-quality compass	1	4
Storage box	1	0

Order Information

CASTLE Kit.....EM-8624A
Three "D" batteries are required per kit, (not included).
Economy CASTLE Kit EM-8654
12 "D" batteries are required per kit, (not included).
Recommended:
Mini Generator.....SE-8645 p. 241
Capacitor (0.1 F).....EM-8655
(Minimum of two each per class)
Primary and
Secondary Coils.....SE-8653A p. 247
(Minimum of two each per class)
Replacement Supplies:
We recommend the purchase of one EM-8627 and one EM-8628 spare bulb set for every five CASTLE Kits, or for every Economy CASTLE Kit.
Light Bulbs
(#14, 25 Pack) EM-8627
Light Bulbs
(#48, 25 Pack) EM-8628
Light Bulb Sockets
(10 Pack) EM-8630
Liquid-Filled Compasses
(5 Pack) EM-8631A
Capacitor
(0.025 F, 2 Pack).....EM-8632

Circuit Components

Use these standalone components to build your own circuits.



Series/Parallel Battery Holder (10 Pack)

SE-8799

This unique battery holder allows "D" cell batteries to be easily connected in both series and parallel. Metal extensions on both sides of the holder are also convenient for use with alligator clips.

Features:

- **Series:** Use the snaps to connect the batteries end to end.

- **Parallel:** Use the metal slides to use the batteries side by side.

Order Information

Series/Parallel Battery Holder (10 Pack) SE-8799
Recommended:
Light Bulbs (#14, 25 Pack) EM-8627
Light Bulb Sockets (10 Pack) EM-8630
Alligator Clip Leads (Set of 10)..... EM-8634

Light Bulb Sockets (10 Pack)

EM-8630

Miniature socket has a plastic base with spring-loaded metal clips to hold wire leads. Accepts screw-type miniature bulbs. Includes ten sockets.

Order Information

Light Bulb Sockets (10 Pack) EM-8630

Light Bulbs

EM-8627: 2.5 V, 0.3 A bulbs (25 bulbs)

EM-8628: 2.0 V, 0.06 A bulbs (25 bulbs)

EM-8814: 7.5 V, 0.22 A bulbs (25 bulbs)

Screw-type base, suitable for use with EM-8630 Sockets

Order Information

Light Bulbs (#14, 25 Pack) EM-8627
Light Bulbs (#48, 25 Pack) EM-8628
Light Bulbs (#50, 25 Pack) EM-8814

Knife Switches

EM-8815

This single-pole single-throwknife switch has screw terminals and a Bakelite™ base. Through-holes allow for mounting base to another surface.

Order Information

Knife Switches.....EM-8815

Alligator Clip Leads (Set of 10)

EM-8634

Use these 30 cm long Alligator Clip Leads for almost any application — from hooking up instruments to bread boarding circuits. They come in sets of 10: two each of yellow, white, red, green and black.

Order Information

Alligator Clip Leads (Set of 10).....EM-8634

Replacement Bulbs (5 Pack)

EM-8679

The Replacement Bulbs (5 pack) is a replacement part for the:

- Series/Parallel Circuit (EM-8677)
- Introductory Optics System (OS-8500)

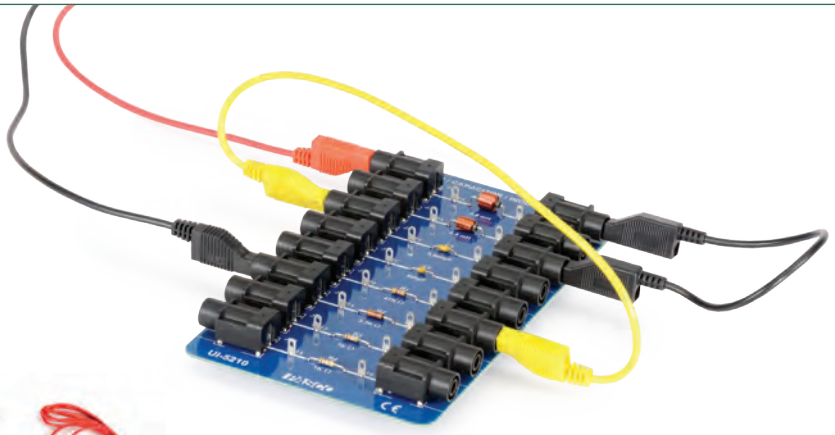
Order Information

Replacement Bulbs (5 Pack) Series/Parallel Circuit.....EM-8679

Patch Cords

These stackable patch cords come in four convenient lengths. The grips are made of soft plastic for flexible strain relief. Spring connectors rotate in the grips, reducing wear due to friction.

Shown in use with UI-5210 circuit board.
See page 232 for more information.



2 Meter Patch Cord Set

SE-9415A

These heavy insulation patch cords are convenient and durable. The grips are stackable and made of soft plastic for flexible strain relief. The spring connectors rotate in the grips, reducing the wear due to friction. The wire itself is 18 AWG.

Set includes 2 red and 2 black patch cords.

Order Information

2 Meter Patch Cord Set SE-9415A

Patch Cord, Jumper Set

EM-9737

This banana plug cord and jumper set includes 5 cords with length of 15 cm. Available in black only.

Order Information

Patch Cord, Jumper Set EM-9737

Banana Plug Cord Sets, 30 cm Length

SE-7123

These insulated 30 cm patch cords are convenient, durable, and inexpensive. The stackable grips are made of soft plastic for flexible strain relief and the spring connectors rotate, reducing wear due to friction. This set of 8 includes 2 red, 2 yellow, 2 blue, and 2 black.

Order Information

Banana Plug Cord Sets, 30 cm Length SE-7123

Alligator Clip Leads (Set of 10)

EM-8634

Use these 30 cm long Alligator Clip Leads for almost any application — from hooking up instruments to bread boarding circuits. They come in sets of 10: two each of yellow, white, red, green and black.

Order Information

Alligator Clip Leads (Set of 10) EM-8634

Banana Plug Cords (5 Pack)

SE-9750 (red) SE-9751 (black)

These heavy, insulated patch cords are convenient, durable and inexpensive. The grips are stackable and made of soft plastic for flexible strain relief. The spring connectors rotate in the grips, reducing wear due to friction.

The 75 cm long cords are available in red or black.

Order Information

Banana Plug Cord-Red (5 Pack) SE-9750
Banana Plug Cord-Black (5 Pack) SE-9751

Shrouded Long Patch Cords

EM-9740 (red) EM-9745 (black)

Set of five 75 cm long shrouded patch cords in red or black.
Terminals are shrouded banana plugs.
Maximum rating: 30 Vrms or 60 VDC, 10 Amps.

Order Information

Shrouded Red Patch Cords EM-9740
Shrouded Black Patch Cords EM-9745

High Voltage Patch Cord Set

SE-9269

Shrouded (4 mm) male banana plug to right-angle shrouded male banana plug 120 cm long (one red and one black).

Order Information

High Voltage Patch Cord Set SE-9269

Alligator Clip Adapters

SE-9756

Convert banana plugs into alligator clips with this set of 10 adapters. The 4 mm banana plug clips are tin-plated steel. These adapters just slide over the end of your 4 mm banana plug. Set includes 5 red and 5 black insulated adapters.

Order Information

Alligator Clip Adapters SE-9756

Shrouded Alligator Clip Adapters

SE-9758

Designed for use with both regular and shrouded banana plugs, this set of adapters comes with 5 red and 5 black shrouded alligator clip adapters.

Order Information

Shrouded Alligator Clip Adapters SE-9758

Spade to Banana Adapter

EM-8629

For use with both regular and shrouded banana plugs. Includes five red and five black adapters.

Order Information

Spade to Banana Adapter EM-8629

Shrouded Alligator Test Leads

PS-3544

These test leads are included with the Wireless Voltage Sensor (PS-3211). They can also be used with the Wireless Current Sensor (PS-3212).
Includes one red and one black lead.

Order Information

Shrouded Alligator Test Leads PS-3544

Resistor Pack

EM-8784

Assortment of electrical resistors including 10 each of the following: 10 Ω, 100 Ω, 330 Ω, 560 Ω, 1000 Ω, 3300 Ω, 10 kΩ, 22 kΩ, 100 kΩ, 220 kΩ, 330 kΩ.

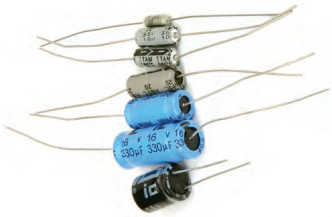
Order Information

Resistor Pack EM-8784

Capacitor Pack

EM-8785

Assortment of electrical capacitors ranging from 1 microfarad to 470 microfarads.



Order Information

Capacitor Pack EM-8785

Capacitor (0.1 F)

EM-8655

(0.1 F) Electrolytic, bipolar, 10 V capacitor with screw terminals, 4.5 cm diameter, 14 cm long.

Order Information

Capacitor (0.1 F) EM-8655

Capacitor (0.025 F, 2 Pack)

EM-8632

Electrolytic, bi-polar, 25 Volt capacitor with screw terminals, 5 cm diameter, 8 cm long. Contains 2 capacitors

Order Information

Capacitor (0.025 F, 2 Pack) EM-8632

Capacitor (1 Farad)

SE-8626

Electrolytic, bipolar, 5 V 1.0 F capacitor. Charge up this capacitor with the Mini Generator and then let go of the crank. The handle will continue to rotate in the same direction as the capacitor discharges.

Order Information

Capacitor (1 Farad) SE-8626

Basic Digital Multimeter

SE-9786A

This basic meter includes all of the functions and ranges needed for most introductory lab work.

Features:

- 10 amp range
- Backlit display with 25 mm digits
- Soft rubber boot for drop protection
- Built-in tilt stand
- Type K thermometer built in for surface or air measurements
- Auto power off saves battery life

Specifications:

DC Voltage: 0.1 mV to 600 V with ±0.5% accuracy

AC Voltage: 1 mV to 600 V with ±0.3% accuracy

DC Current: 0.1 µA to 10 A

AC Current: 0.1 mA to 10 A

Resistance: 0.1 Ω to 20 MΩ

Additional Functions:
Input fuse protection, audible and visible misconnection signals, data hold freezes display reading

Display: 3-1/2 digit display with 25 mm digits, polarity indication, low battery indication

Power: 9 V battery (included)

Order Information

Basic Digital Multimeter..... SE-9786A

Precision Digital Multimeter, Component Tester and Thermometer

SB-9631B

This is an excellent general purpose multimeter that features high-accuracy overload protection on all ranges and a built-in digital thermometer. It can measure capacitance and transistor gain (hFE).

Includes test leads, temperature probe and battery.

Specifications:

DC Current: 200 µA, 2 mA, 20 mA, 200 mA; ± (1% + 1 digit)

AC Current: 200 µA, 2 mA, 20 mA, 200 mA; ± (1.2% + 4 digits)

Capacitance: 20 nF, 200 nF, 2 µF, 20 µF, 200 µF; ± (3% + 10 digits)

Temperature: 4° to 1400°F; 4° to 900°F; ± (2.0% reading + 4°F); 900° to 1400°F; ± (3.0% reading + 4°F)

Power: 200-hour life on 9 V alkaline (battery included)

DC Voltage: 200 mV, 2 V, 20 V, 200 V, 1000 V; ± (0.5% + 1 digit) 10 MΩ input impedance

AC Voltage: 200 mV, 2 V, 20 V, 200 V; ± (1% + 4 digits) 750 V; ± (1.5% + 4 digits) 10 MΩ input impedance

Resistance: 200 Ω, 2 kΩ, 200 kΩ, 20 MΩ; for 200 Ω to 200 kΩ ± (1.0% + 4 digits) for 20 MΩ ± (2.0% + 4 digits)

Additional Functions: Diode test, transistor hFE, audible continuity test, fold-out stand

Display: 3-1/2 digit LCD display, 17 mm high digits, polarity indication, low battery indication

Drop Resistant

Order Information

Precision Digital Multimeter,
Component Tester and Thermometer SB-9631B
Replacement Supplies:
Thermocouple Probe.....SB-9632

Voltaic Cell

SE-7249

- Learn how batteries work
- Includes different types of electrodes

Voltaic cell sets are ideal for demonstrating the characteristics of battery cells. This set includes one plastic cell, complete with a screw-on plastic ring, two adjustable electrode holders, a porous ceramic cup, and ten electrodes (aluminum (1), nickel (1), tin (1), graphite (1), iron (1), copper (1), lead (2), and zinc (2).

Electrolyte is not included.

Order Information

Voltaic Cell..... SE-7249
Recommended:
Basic Digital
Multimeter..... SE-9786A

Mini Generator

SE-8645

The Mini Generator is a hand-cranked generator that produces up to 6 volts DC for basic experiments in electricity, electromagnetism, and electrolysis. It replaces the usual power supply with a device that students can see, operate, and understand.

Order Information

Mini Generator.....SE-8645
Recommended:
Capacitor (1 Farad).....SE-8626
Light Bulb Sockets (10 Pack).....EM-8630
Light Bulbs (#50) 25 Pack.....EM-8814

Light Bulb and Stand

EM-9099

This set of two lamp socket bases includes four #50 miniature screw light bulbs. Great for use with the hand-cranked Mini Generator.

Order Information

Light Bulb and Stand EM-9099

Capacitor (1 Farad)

SE-8626

Electrolytic, bipolar, 5 V 1.0 F capacitor. Charge up this capacitor with the Mini Generator and then let go of the crank. The handle will continue to rotate in the same direction as the capacitor discharges.

Order Information

Capacitor (1 Farad) SE-8626

Energy Transfer – Generator

ET-8771B

- Transfers gravitational potential energy to electrical energy
- Open design: 19 mm neodymium magnet can be seen spinning between the two coils
- Real-time computer measurement of output power

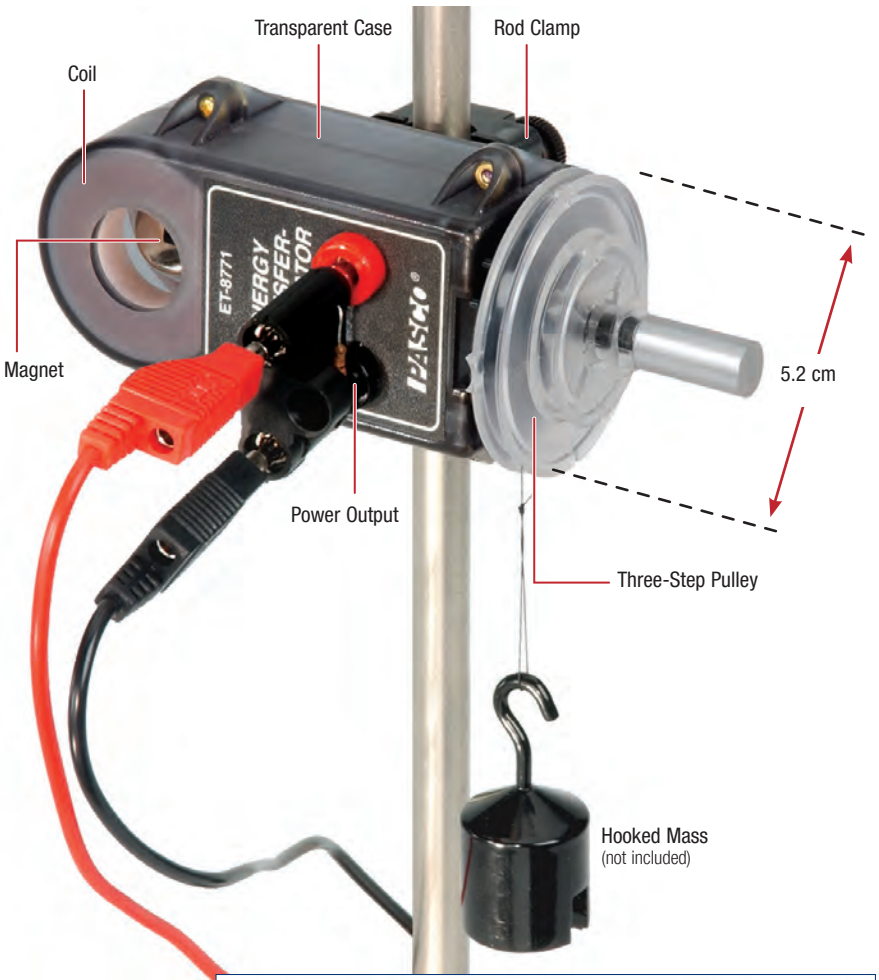
PASCO's Energy Transfer Generator demonstrates the conversion of gravitational potential energy into electrical energy as a falling weight turns a magnet between two coils. The open design permits easy identification of the essential parts of the generator. The supplied lamp or load resistor can be plugged into the output banana jacks. A Voltage Sensor can measure the generated voltage across the load resistor, which can then be used to calculate power generated.

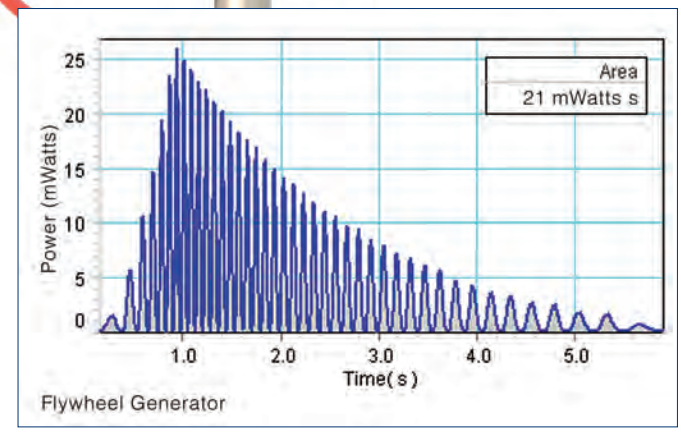
By wrapping the string around different-sized steps on the three-step pulley, the generator will spin at different speeds. The smaller the pulley radius, the slower the weight falls and the greater percentage of the potential energy is converted to electrical energy.

The AC power generated by spinning the shaft by hand easily lights the included red-green LED. The LED goes from red to green, indicating the direction of the current.

The built-in rod clamp is used to mount the generator on a rod stand.

Case Dimensions: 8.7 x 4.4 x 3.6 cm





Includes:

- Generator with three-step pulley
- Red-green LED mounted on plug
- 100-ohm load resistor mounted on plug
- Spool of thread

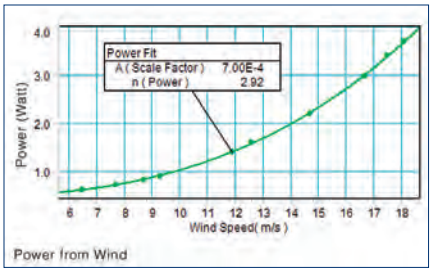
Order Information

Energy Transfer - Generator	ET-8771B	
Recommended:		
2 Meter Patch Cord Set	SE-9415A	p. 238
Energy Transfer - Hydro Accessory	ET-8772	p. 243
Hooked Mass Set	SE-8759	p. 207
Large Rod Base	ME-8735	p. 196
90 cm Stainless Steel Rod	ME-8738	p. 196
No-Bounce Pad	SE-7347	p. 204
Required for use with PASPORT:		
PASPORT Voltage-Current Sensor	PS-2115	p. 49

Energy Transfer – Wind Turbine

ET-8783

Attach this clear propeller to the Energy Transfer Generator for a complete wind energy turbine. Students will better understand the process of electrical energy production from wind after using the turbine.



Includes:

- Fan
- Mounting hardware

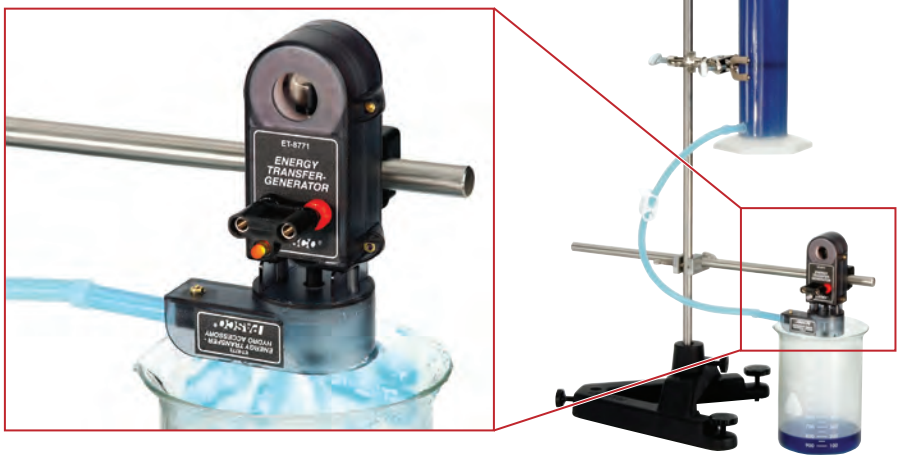
Order Information

Energy Transfer – Wind Turbine	ET-8783	
Required:		
Energy Transfer – Generator	ET-8771B	

Energy Transfer – Hydro Accessory

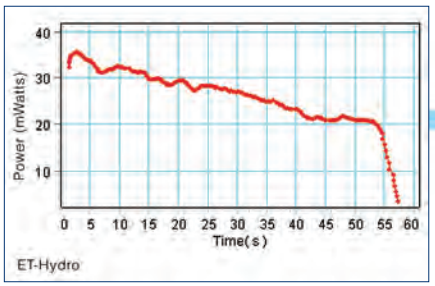
ET-8772

- Demonstrates hydroelectric power generation
- Open design gives view of spinning turbine and water stream
- Falling water lights an LED



The Hydro Accessory is used with the Energy Transfer Generator to demonstrate how falling water generates electricity. The gravitational potential energy of the water is converted into electrical energy as the falling water turns the turbine. The water can be supplied using the optional Water Reservoir. The water that has passed through the turbine is caught in a beaker and measured to determine the total mass that has fallen.

The water nozzle size and angle can be adjusted to optimize performance. By changing the height of the Water Reservoir, different efficiencies are achieved.



Power data as water falls from the reservoir through the turbine

Includes:

- Turbine housing
- Plastic turbine (4 cm diameter)
- Water nozzles (5)
- Tubing (2 m long)
- Plastic hose clamp
- Screwdriver for attaching Hydro Accessory to Generator

Order Information

Energy Transfer - Hydro Accessory	ET-8772	
Required:		
Energy Transfer - Generator	ET-8771B	
Recommended:		
Water Reservoir	ME-8594	p. 205
Large Rod Base	ME-8735	p. 196
90 cm Stainless Steel Rod	ME-8738	p. 196
Three-Finger Clamp	SE-9445	p. 198
Beaker, 1000 mL (6 Pack)	SE-7288	p. 205

Magnetic Demonstration System

EM-8644B

Demonstrate:

- Magnetic damping
- Diamagnetism and paramagnetism
- Magnetic force on a current-carrying wire swing

This all-in-one demonstration system includes the Variable Gap Magnet (EM-8618) and the Magnetic Force Accessory (EM-8642A).

Includes:

- Variable Gap Magnet
- Pole pieces
- Aluminum paddles (solid, slotted, closed slotted) (3)
- Glass rod
- Aluminum rod
- Wire swing
- Special mounting rod

Demonstrate Magnetic Damping

Swing the solid aluminum paddle through the gap and it stops dead, the motion is damped due to eddy currents. Now try the slotted paddles. One swings freely, while the other is immediately damped.

Demonstrate Diamagnetism and Paramagnetism

The diamagnetic glass rod (Figure a) aligns transverse to the field; the paramagnetic aluminum rod (Figure b) aligns with the field.

Demonstrate Force on a Current-Carrying Wire

Pass a current through the wire swing (power supply not included) to investigate the right-hand rule for magnetic forces.

Order Information

Magnetic Demonstration System (Includes EM-8618 and EM-8642A)	EM-8644B	
Required:		
Power Supply (18 VDC, 5 A)	SE-9720A	p. 262
OR		
Mini Generator	SE-8645	p. 241
Base and Support Rod	ME-9355	p. 197
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 238

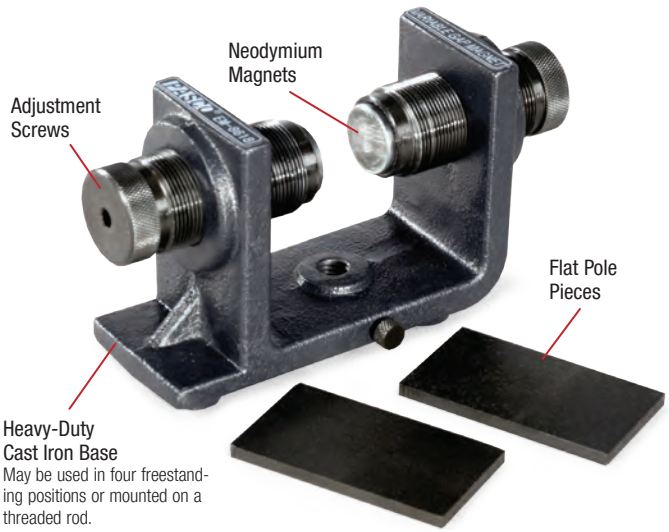
Variable Gap Magnet

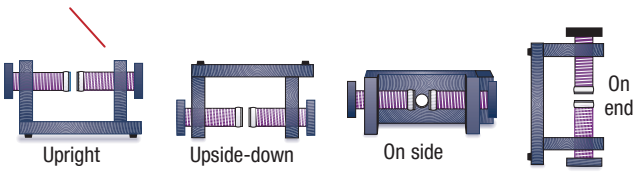
EM-8618

- Lower cost
- Larger magnets (1 inch diameter)
- Greater field (1 Tesla maximum)
- Great for induction experiments

The redesigned Variable Gap Magnet is rugged and durable, while providing excellent results as a demonstration tool. The two one inch (2.54 cm) diameter neodymium magnets are mounted on a heavy-duty cast iron base that has a threaded hole to mount on a support rod, which provides even more versatility.

The gap may be varied from 0.5 cm to 8.9 cm using the adjustment screws. Two flat pole pieces are also included to provide a uniform magnetic field when needed.





Order Information

Variable Gap Magnet.....EM-8618
(Includes Variable Gap Magnet with Pole Pieces)

Magnetic Force Accessory

EM-8642A

Includes:

- Three aluminum paddles (solid, slotted, closed slotted)
- Glass rod
- Aluminum rod
- Wire swing
- Special mounting rod

Order Information

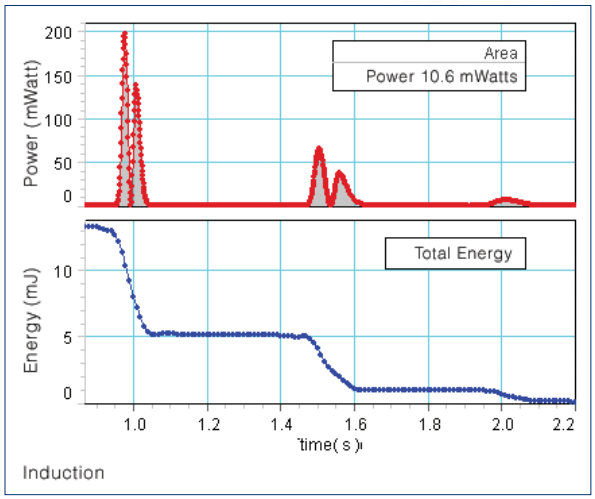
Magnetic Force Accessory EM-8642A

Induction Wand

EM-8099

See EX-5541A Faraday's Law of Induction Experiment on page 369.

The Induction Wand is a rigid pendulum with a coil at the bottom end connected to the banana terminals at the other end. A through-hole allows the pendulum to be connected to a Rotary Motion Sensor, for detailed investigations of induction as the coil is swung through a magnetic field.



The energy of the pendulum decreases with each pass of the coil through the magnet. The energy dissipated in the resistor is obtained from the area under a Power vs. Time plot.

Includes:

- Wand with screw
- Resistive load

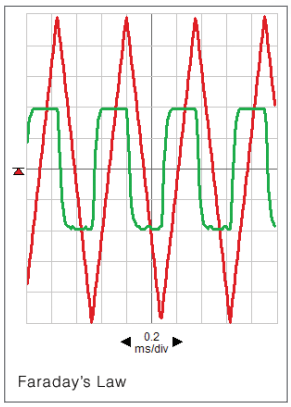
Order Information

Induction Wand.....EM-8099

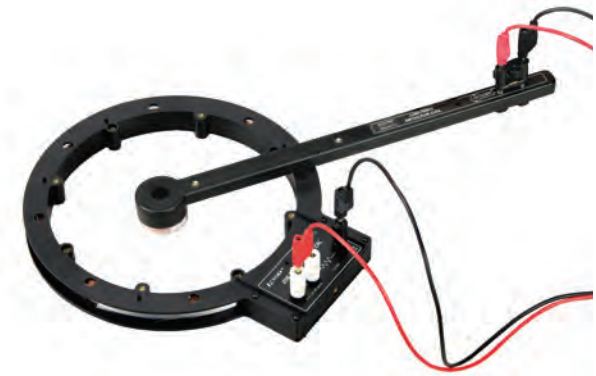
See our Superconductors on pages 254-255.

Field and Detector Coils

1. EM-6711A Field Coil
   200 turns of #22 copper wire, 18.6 cm ID, 22.1 cm OD. Max. current 2 A.
2. EM-6723A Field Coil
   500 turns of #22 copper wire. Max current 2 A.
3. EM-6712 Detector Coil
   400 turns of #28 copper wire.
4. EM-6713 Detector Coil
   2000 turns of #36 copper wire.
5. EM-6714 Bi-Color LED Indicator.



A 5 V triangle wave (red trace) is applied to the Field Coil, and the induced voltage in the 2000-turn Detector Coil is a square wave (green trace).



Features:

- **Verify Faraday's Law:** Verify all aspects of Faraday's Law.
- **Qualitative Demonstration:** With the Bi-Color LED Indicator and the Variable Gap Magnet, students can see when a current is induced in the detector coil. With the LED indicator plugged into a detector coil, the LED flashes red or green as the detector coil passes through the magnet.
- **Quantitative Demonstration:** PASCO's coils can be used with a function generator and an oscilloscope, or connected to the 850 Universal Interface.

Developed for Workshop Physics® activities.

For details of experiments using these coils, see Christopher C. Jones, "Faraday's Law Apparatus for the Freshman Laboratory." *Am. J. Phys.* 1987; 55(12):1148-1150.

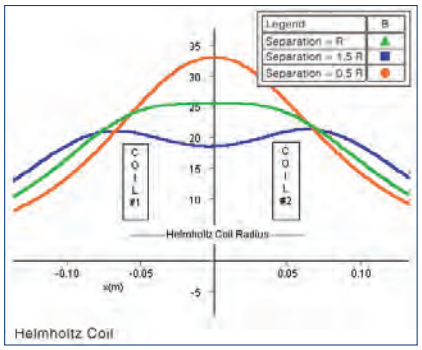
Order Information

Field Coil (200 Turn)	EM-6711A	
500-Turn Field Coil	EM-6723A	
Detector Coil (400 Turn)	EM-6712	
Detector Coil (2000 Turn)	EM-6713	
LED Indicator	EM-6714	
Recommended:		
Variable Gap Magnet	EM-8618	p. 245
850 Universal Interface		pp. 26-27
OR		
Low Voltage AC/DC Power Supply	SF-9584B	p. 264
AND		
Function Generator	PI-8127	p. 266

Helmholtz Coils

EM-6722 with 200-turn Coils
EM-6724 with 500-turn Coils

The Helmholtz Coils consist of two coils mounted on a base to provide a uniform magnetic field between the coils. The base has a slot that allows the coils to be spaced apart at any distance from 3 cm to 20 cm (center-to-center distance). The proper separation for Helmholtz coils (i.e., the radius of the coils) is marked on the base. Two 0.635 cm (0.25 inch) diameter holes between the coils accommodate mounting devices in the uniform magnetic field.



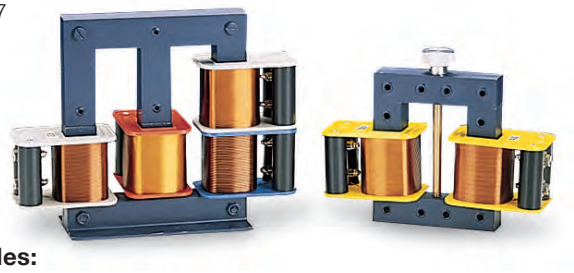
This plot shows the magnetic field strength along the axis of Helmholtz coils for three different coil separations: the green data is the magnetic field with the coils separated at the proper distance (the radius of the coils).

Order Information

Helmholtz Coil Set, 200 Turn	EM-6722
Helmholtz Coil Set, 500 Turn	EM-6724
Helmholtz Coil Base	EM-6715

Complete Coil Set

SF-8617



Includes:

- Coil (200 Turn) SF-8609
- Coil (400 Turn) SF-8610
- Coil (800 Turn) SF-8611
- Coil (1600 Turn) SF-8612
- Coil (3200 Turn) SF-8613
- U-shaped Core
- E-shaped Core

Basic Coil Set

SF-8616

Includes:

- Coil (200 Turn) SF-8609
- Coil (400 Turn) SF-8610 (2)
- Coil (800 Turn) SF-8611
- U-shaped Iron Core

These high-quality coils and laminated iron cores provide an effective introduction to electromagnetic theory. Purchase them individually or as a complete set. The coils are color-coded and each coil is labeled with the number of turns and the direction of the winding. Use them to investigate:

Electromagnetism: Show how the magnetic field can be increased by increasing the current, by adding an iron core, or by using a coil with more turns.

Induction: Pass a magnet through a coil and detect the resulting electromotive force (EMF) with a galvanometer. Show how the EMF depends on the number of turns in the coil and on the relative velocity of the magnet and coil.

Transformers: Mount coils onto the U- or E-shaped iron cores to demonstrate mutual inductance and transformer theory. Then connect a load to investigate power transfer. Investigate basic transformer theory with an AC power supply and a voltmeter. Advanced principles require a high power output function generator (Model PI-9587C or PI-9598) and an oscilloscope. For more in-depth experiments and demonstrations, use a computer with PASCO's 850 Universal Interface.

Using the signal generator capability of the 850 Universal Interface and oscilloscope display of PASCO Capstone™ software, students can investigate transformer theory.

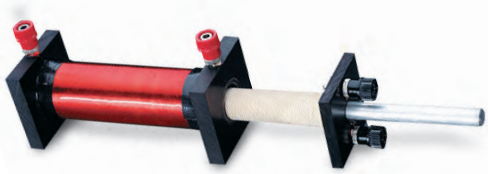
Order Information

Complete Coil Set	SF-8617
Basic Coil Set	SF-8616
Individual parts sold separately:	
Coil (200 Turn)	SF-8609
Coil (400 Turn)	SF-8610
Coil (800 Turn)	SF-8611
Coil (1600 Turn)	SF-8612
Coil (3200 Turn)	SF-8613

Primary and Secondary Coils

SE-8653A

- Study transformer theory with this set of nested coils.
- Drop a magnet through the outer coil to demonstrate induction.



The secondary coil slides over the primary coil, and the soft iron core slides into either or both, providing a look at magnetic induction and transformer theory. This rugged device is sensitive enough to be used with voltmeters instead of galvanometers. The coils are wound around hollow wooden cores, with a turns ratio of approximately 12 to 1. The primary coil is mounted on a wooden stand.

Specifications:

Outer Coil: 2920 turns; length 11 cm; 2 cm ID
Inner Coil: 235 turns; length 12 cm; 1 cm ID
Soft Iron Core: 0.96 cm diameter

Order Information

Primary and Secondary Coils	SE-8653A

Economy Coils, Primary and Secondary

SE-8722

Specifications:

Outer Coil: 1100 Turns;
Length 11.4 cm;
Inner Diameter 4.7 cm
Inner Coil: 210 Turns;
Length 10.9 cm;
Inner Diameter 1.7 cm
Iron Core: 1.6 cm diameter
Connections:
Shielded Banana Jacks

Order Information

Economy Coils, Primary and Secondary	SE-8722

Air Core Solenoid

SE-7585

This Air Core Solenoid has an inner diameter of 5.5 cm and a length of 14.5 cm, allowing ample room to insert an experimental apparatus into its uniform magnetic field. The maximum current of 5 A produces a 125 Gauss magnetic field.

Order Information

Air Core Solenoid	SE-7585

Electromagnet

SE-9655

- Investigate the Zeeman Effect

This electromagnet has a magnetic field strength up to 1.2 T at a maximum current of 5 A. The sturdy base can be rotated and locked into place for viewing perpendicular and parallel to the magnetic field lines. There is a removable iron core that opens a hole through the pole, allowing for viewing parallel to the magnetic field lines. This electromagnet is suitable for the Zeeman Experiment.

Features:

- 1.2 T magnetic field strength at 5 A
- Approximately 7.4 mm pole gap
- Swivel Base
- Hole in pole allows viewing parallel to the axis of the magnetic field

Specifications:

Maximum Magnetic Field Strength: 1.2 T
Maximum Current: 5 A
Pole Gap: Approximately 7.4 mm

This electromagnet provides a magnetic field strength up to 1.2 T for the Zeeman Experiment.

Removing the core allows viewing parallel to the magnetic field axis.

Order Information

Electromagnet	SE-9655	
Recommended:		
Tunable DC Power Supply 6A	SE-9656	p. 261
Magnetic Field Meter	SE-7579B	p. 256

Ring Launcher with Accessories

EM-8817

- Electromagnetic induction
- Shoots ring 2 meters high
- Improved design with thermal shutoff

This Ring Launcher has been optimized to maximize safety by enclosing all wiring inside the case. A thermal shutoff switch protects the coil by preventing overheating.

Includes a coil with a bulb that lights by induction when the coil is placed over the launcher core. Also includes five rings: one split aluminum ring that will not launch, one copper ring, one shorter aluminum ring, and two regular length aluminum rings.

A classic demonstration

In this demo, an aluminum ring is propelled straight up by the Lorentz force that arises from the interaction between the alternating magnetic field of the coil and the current induced in the ring.

For great demo ideas using the PASCO Ring Launcher, check out James Lincoln's AAPT video. James explains how the Ring Launcher works and walks you through all the classic demonstrations.

Ring Launcher design ideas contributed by Carl Schneider and John Ertel from the U.S. Naval Academy.

Lighting a bulb connected to a coil by induction; coil and bulb are included in Ring Launcher Accessories.

Includes:

- Launcher
- Coil with Light Bulb
- Split Aluminum Ring
- Aluminum Ring (2)
- Short Aluminum Ring
- Copper Ring

Order Information

Ring Launcher with Accessories	EM-8817
Also available:	
Ring Launcher	EM-8661
Replacement:	
Ring Launcher Accessories	EM-8662

Millikan Oil Drop Apparatus

AP-8210A

- Nobel Prize-quality physics in the student lab
- Ionization source for changing droplet charge
- Measures the charge of an electron to within ±3%

The Millikan Oil Drop Experiment is one of the most popular experiments in undergraduate physics for several reasons:

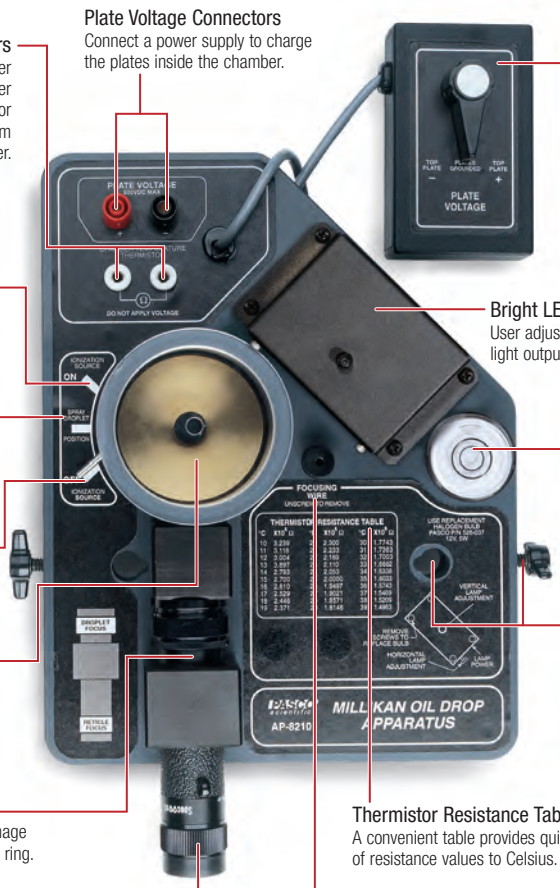
- The experimental principle is straightforward and easy to understand.
- It measures a fundamental atomic constant using a method that won its originator, Robert Millikan, the Nobel Prize.
- The observation of the effects of one or more electrons upon oil drops in an electric field provides a striking demonstration of the quantized nature of electricity.

See complete experiment on page 360.

The Millikan Oil Drop Apparatus mounted on a rod stand for easy, eye-level viewing

Specifications:

Maximum Plate Voltage: 500 VDC
Light Source: Cool LED
Reticle Line Separation::
0.5 mm major divisions
0.1 mm minor divisions
Plate Spacing: 7.62 mm
Plate Diameter: 60 mm



Thermistor Connectors
Attach an ohmmeter to monitor chamber temperature. A thermistor is embedded in the bottom plate of the chamber.

Plate Voltage Connectors
Connect a power supply to charge the plates inside the chamber.

Plate Charging Switch
Allows the operator to ground the plates or charge them to either polarity. The switch box is separate to minimize vibration.

3 Chamber Level Positions

Ionization ON
Introduces a thorium source into the chamber to change droplet charge.

Bright LED Light Source
User adjustable variable light output.

Spray
Allows air to be displaced when oil droplets are sprayed into chamber.

Bubble Level
Bull's-eye level makes sure apparatus is level.

Ionization OFF
Prevents ionization source from affecting the droplets.

Rod Stand Mounts and Screws
Designed to mount on PASCO's Large Rod Stand. Allows the apparatus to be reduced to eye level.

Droplet Viewing Chamber
Unique design minimizes droplet drift due to heat from droplet illumination and outside air currents.

Viewing Scope
30X, bright-field, erect-image microscope with focusing ring.

Thermistor Resistance Table
A convenient table provides quick conversions of resistance values to Celsius.

Reticle Focus
Separate reticle focus and precision etching provide sharp, easy-to-view grid lines with 0.5 mm major and 0.1 mm minor divisions.

Focusing Wire
When placed in the chamber, the focusing wire allows the lamp to be aligned so the light illuminates the center of the chamber, and allows the eyepiece to be focused on the center of the chamber.

Clear droplet observation and low droplet drift are essential for success with Millikan's classic experiment. PASCO's apparatus uses a pre-aligned optical system and special condenser to achieve these conditions.

Accuracy in the Oil Drop Experiment depends on the student's ability to precisely measure all the variables involved: plate voltage, plate separation, time and distance of droplet rise and fall, temperature, oil density, etc. Extreme care taken in the design and manufacture of this unit ensures that the student's best efforts will be rewarded with more accurate results. Typically, a careful student can achieve results within 3% or less of the accepted value.

Includes:

- Millikan Oil Drop Apparatus with Switch
- Non-volatile Oil and Atomizer
- 12 VDC Lamp Power Adapter

Order Information

Millikan Oil Drop Apparatus.....AP-8210A
Required:
Basic Digital Multimeter.....SE-9786A p. 240
High Voltage Power Supply.....SF-9585A p. 263
Recommended for mounting unit at eye level on a standard lab table:
Large Rod Base.....ME-8735 p. 196
45 cm Stainless Steel Rod.....ME-8736 p. 196
Complete System:

Replacement Parts:
4 oz Bottles of Mineral Oil (Qty 4).....AP-8211
Millikan LED Light Source.....AP-8212

e/m Apparatus

SE-9629

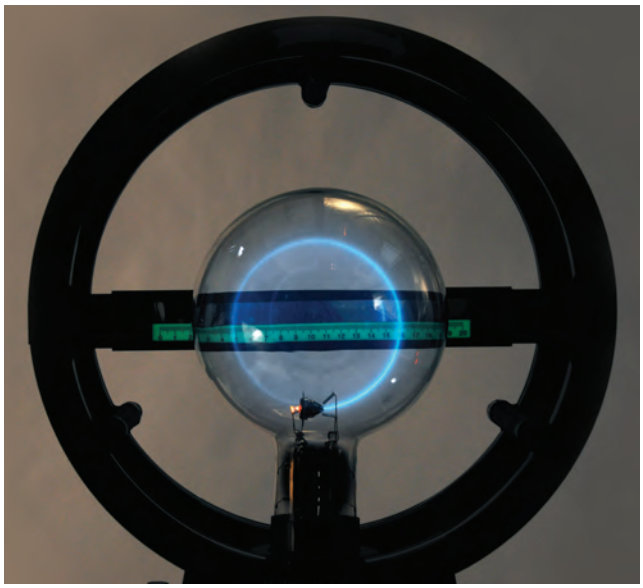
- Sharp, clearly visible electron beam
- Phosphorescent mirrored scale eliminates parallax errors
- Tube rotates for general study of electrons in a magnetic field

In 1897, J. J. Thomson showed that the mysterious cathode rays were actually negatively charged particles—he had discovered the electron. In the same year he measured the charge-to-mass ratio of the electron, providing the first measurement of one of the fundamental constants of the universe.

The Charge-to-Mass Ratio System reproduces one version of Thomson's landmark experiment, providing an accurate measurement of the charge-to-mass ratio of the electron. And, since the electron tube can be rotated through 90°, students can also make a more general study of the behavior of electrons in a magnetic field.

This apparatus also has deflection plates, so students can study the effect of an electric field on moving electrons.

The complete Charge-to-Mass Ratio System includes the power supplies, which can also be used in other experiments (such as the Franck-Hertz experiment, see page 404).



Fluorescent scale is clearly visible behind the electron beam in a dark room.

How It Works

A large, helium-filled electron tube is mounted between a pair of Helmholtz coils. The tube contains an electron gun, which generates a focused beam of electrons. A measured current is applied to the Helmholtz coils so that the magnitude of the magnetic field within the electron tube can be calculated. A measured accelerating potential (V) is then applied to the electron gun. The magnetic field (B) deflects the electron beam in a circular path with a radius (r) that is measured using the illuminated mm scale. From these measured values, the charge-to-mass ratio of the electron is calculated:

$$e/m = 2V/B^2r^2.$$

(The details of the calculations are fully described in the manual.)

Specifications:

Hemholtz Coil Radius: 16 cm
Number of Turns: 130
Maximum Current: 3.5 A
Filament Voltage: 6.3 VAC
Acceleration Voltage: 0–200 V
Tube Diameter: 15.5 cm

Includes:

- Helmholtz Coils for e/m (SE-9626)
- Replacement e/m Tube (SE-9651)
- Tunable DC Power Supply (Constant Current) (SE-9622)
- DC Power Supply II (Constant Voltage) (SE-9644)
- Red and Black Patch Cords

For more information about power supplies, see page 260.

Order Information

e/m Apparatus	SE-9629
If you already have power supplies, you will need:	
Helmholtz coils for e/m	SE-9626
Replacement e/m Tube	SE-9651A
Replacement Parts:	
Replacement Mirror Scale for e/m Apparatus	SE-9649

Ampere's Law Accessory

EM-6720

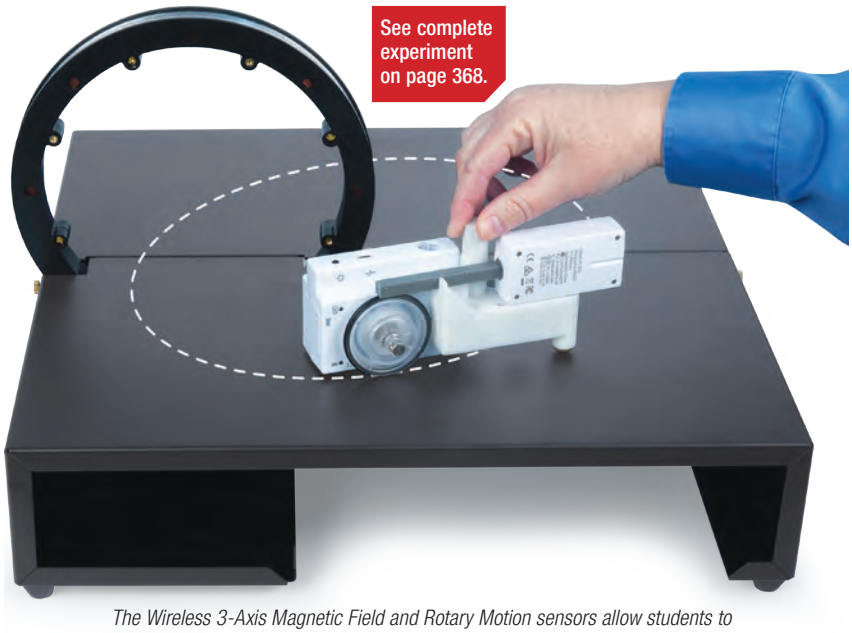
- Verify Ampere's Law
- Plot magnetic field tangent to path
- Closed integral is area under B vs. Distance plot
- Choose to enclose current in path or not

Students can verify Ampere's Law experimentally by graphing the magnetic field strength that is tangent to the path taken along a closed path that encloses a current source.

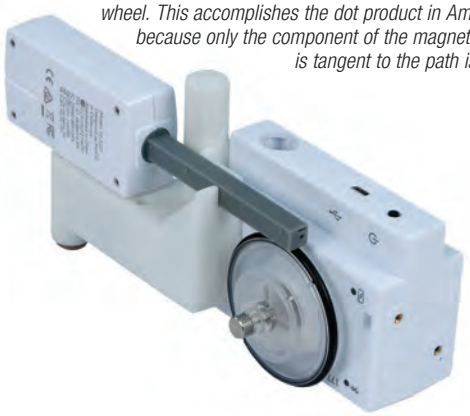
The magnetic field strength is measured with a Wireless Magnetic Field Sensor which rides on a Rotary Motion Sensor. The student pushes the Rotary Motion Sensor, which rolls on its wheel, along a closed path.

If you traverse a path that does not enclose any current source, the area under the curve is zero. The magnetic field of the Earth or any nearby source is measured, but they will cancel out in a closed loop that encloses no current.

See complete experiment on page 368.



The Wireless 3-Axis Magnetic Field and Rotary Motion sensors allow students to move in any shaped path without wires getting wrapped around the coil. Students can choose any path they want; you don't have to follow a circular path because the sensors are recording the field tangent to any path.

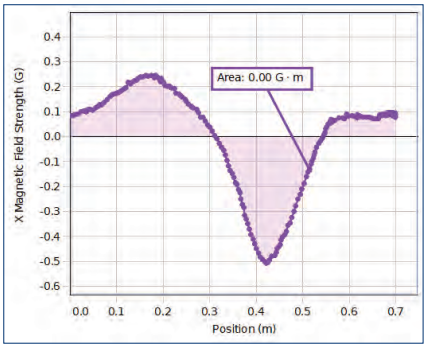


The key to making this work is that the Magnetic Field Sensor element is positioned tangent to the Rotary Motion Sensor's wheel. This accomplishes the dot product in Ampere's Law because only the component of the magnetic field that is tangent to the path is recorded.

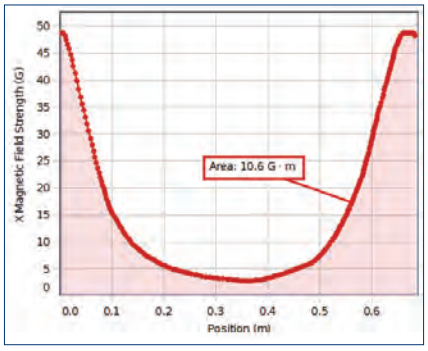
Ampere's Law

$$\oint \vec{B} \cdot \vec{dl} = \mu_o N I$$

Area under B vs. Distance curve = μ_o (# of coil turns enclosed in path) (Current)



No current enclosed: Area is zero.



Current enclosed: Area is $\mu_o NI$.

Includes:

- Aluminum Table (46 cm x 46 cm x 11 cm)
- Sensor Bracket

Order Information

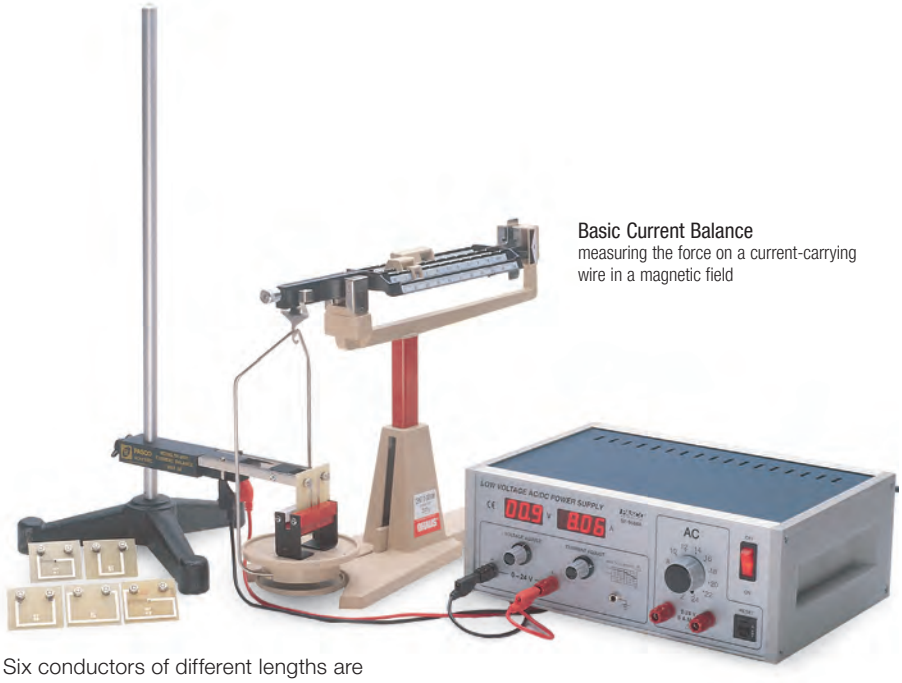
Ampere's Law Accessory	EM-6720	
Required:		
Wireless Magnetic Field Sensor	PS-3221	p. 69
Wireless Rotary Motion Sensor	PS-3220	p. 63
500-Turn Field Coil	EM-6723A	p. 246
PASCO Capstone Software		p. 84-87

Basic Current Balance

SF-8607

- Measure Force vs. Current, Wire Length, Magnetic Field and Angle
- Use a Gram Balance to Measure Force

One to six magnets are mounted on an iron yoke, which is placed on a gram balance. A conductor is suspended between the magnets. The weight of the magnets and yoke is measured, then a current (0-5 A) is passed through the conductor. The change in the reading of the balance (0-4 grams) measures the force between the conductor and the magnetic field.



Basic Current Balance
measuring the force on a current-carrying wire in a magnetic field

Six conductors of different lengths are provided and can be easily changed while maintaining a repeatable position with respect to the magnetic field.

Includes:

- Iron Yoke (holds magnets)
- Removable Magnets (6)
- Conductors (6)
  (1, 2, 3, 4, 6 and 8 cm in length)
- Mount (to hold position conductors)

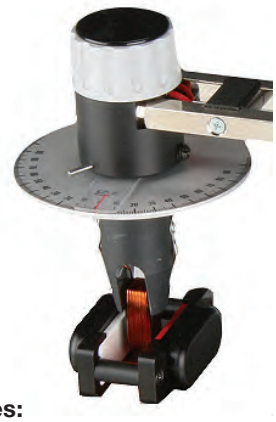
Order Information

Basic Current Balance	SF-8607	
Required:		
Ohaus Cent-O-Gram Balance	SE-8725	p. 206
Low Voltage AC/DC Power Supply	SF-9584B	p. 264
Base and Support Rod	ME-9355	p. 197
Recommended:		
Basic Digital Multimeter	SE-9786A	p. 267
Magnetic Field Meter	SE-7579B	p. 256
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 238

The Current Balance Accessory Kit

SF-8608

This kit completes the Basic Current Balance, allowing the angle between the conductor and the magnetic field to be varied. The experiment is the same as with the Basic Current Balance, but a 10-turn rectangular coil is used. The coil can be turned through a full 180°, and a built-in degree scale lets students accurately measure the angle between the coil and the field of the fixed magnet.



Includes:

- Fixed Magnet with Yoke
- 10-turn Rectangular Coil

Order Information

The Current Balance Accessory Kit	SF-8608

Superconductivity

Superconductor Magnetic Levitation

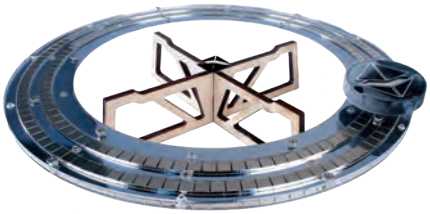
These high-temperature superconductors conduct electricity without energy loss when cooled to liquid nitrogen temperature (77 K). Because a superconductor expels external magnetic fields by forming surface currents, which cancel the external field, it will levitate above a magnet.

Mini MagLev Pro

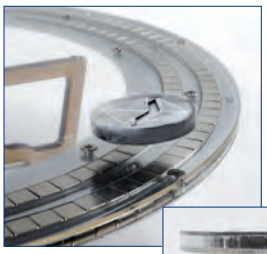
SE-7720

QUANTUM LEVITATION

- Demonstrate superconducting levitation
- Levitating superconductor glides around the circular magnetic track



Experience Quantum Levitation with this portable, lightweight, and easy-to-use MagLev track. The track uses super-strong NdFeB magnets in a unique double-ring design to achieve maximum levitation height. The included handheld magnetic device (Starter Kit) can be passed around for a captivating hands-on experience. Please note that this product requires liquid nitrogen.



Demonstrate frictionless motion in both levitation and suspension.

Includes:

- Round MagLev track (diameter 40 cm, 15.7 in)
- Wooden stand
- Medium Standard Superconductor
- Medium Enhanced Superconductor
- MagLev Starter Kit
- User manual

Order Information

Mini MagLev Pro..... SE-7720
Required:
Liquid Nitrogen
Recommended:
Wireless Force Acceleration Sensor..... PS-3202

Magnetic Levitation

SE-7721

- Perfect for large science demonstrations
- Undergraduate and high school experiments in quantum physics
- Science museums

The 72 cm diameter Magnetic Levitation kit is perfect for large audience demonstrations at science museums, science fairs and student classes. The circular frictionless motion never ceases to amaze. The kit is supplied with large and medium Quantum Levitators, which can be levitated simultaneously in a double levitation configuration. Both suspension below the track and levitation above it can be demonstrated. A handheld magnetic device (MagLev Starter Kit) is included for a complete experience. Please note that this product requires liquid nitrogen.

Includes:

- Round MagLev Track (diameter 72 cm, 28 in)
- Stand
- Standard Medium and Large Superconductors
- MagLev Starter Kit
- User and experiment manual

Order Information

Magnetic Levitation SE-7721
Required:
Liquid Nitrogen
Recommended:
Wireless Force Acceleration Sensor..... PS-3202

MagLev Starter Kit

SE-7732

The MagLev Starter Kit is the most fundamental entry level for classroom demonstrations of quantum levitation and flux pinning. Perfect for high school students as well as university undergraduates, the kit is easy to use, highly durable and portable. Use the rectangular magnetic setup to witness the quantum locking phenomena and the round magnetic setup to demonstrate frictionless motion. When used with a force sensor, the handheld magnetic device serves as a unique experimentation platform where quantum phenomena such as the Meissner effect and flux pinning can be investigated. Please note that this product requires liquid nitrogen.

Includes:

- Standard Medium Superconductor
- Starter Magnetic Kit
- Plastic tweezers
- User manual

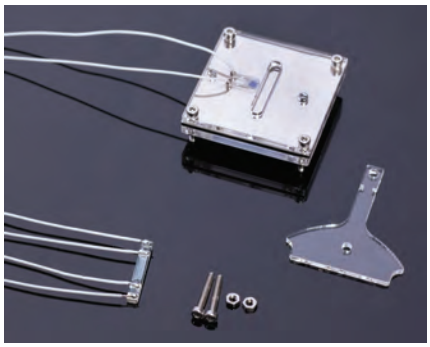
Order Information

MagLev Starter Kit..... SE-7732
Required:
Liquid Nitrogen
Recommended:
Wireless Force Acceleration Sensor..... PS-3202

4-Point Wired Superconductor

SE-7734

Measuring the transition temperature of superconductors is one of the basic and most educational experiments in superconductivity and is now available to students with an easy and instructive experiment that is on par with state-of-the-art scientific research. The 4-Point Wired Superconductor includes a superconducting Bi-2223 bar with four wires attached to it. Students can experiment with 4-wire and 2-wire resistance measurements and learn how to measure the critical temperature of superconductors. The superconductor is thermally attached to a metallic plate to which a Pt100 resistance thermometer is also attached. Please note that this product requires liquid nitrogen.



Includes:

- Replaceable Bi-2223 superconductor bar with attached 4-wire set
- Thermal base with Pt100 RTD thermometer
- Perspex® handle
- User manual

Order Information

4-Point Wired Superconductor SE-7734

Required: Liquid Nitrogen

MagLev Outreach Set

SE-7733

QUANTUM LEVITATION

This is the ultimate outreach package for quantum levitation and quantum locking. This set contains portable, easy-to-use experiments that can be used outside the lab and allow a hands-on experience with quantum levitation. Please note that this product requires liquid nitrogen.

Includes:

- Round MagLev track (diameter 40 cm, 15.7")
- Wooden stand
- DIY MagRail track
- Handheld magnetic device
- Standard Superconductors (2 medium, 1 large)
- Plastic tweezers
- User manual

Order Information

MagLev Outreach Set SE-7733

Required: Liquid Nitrogen

Superconducting Levitators

These superconducting levitators are easy to use and highly durable.

They are provided with a 6 month, no-questions-asked warranty.

Standard Superconductors

The Standard Superconductors are able to carry only their own weight plus liquid nitrogen.

Enhanced Superconductors

The Enhanced Superconductors, having extra superconducting material, are able to carry a light weight (< 200 g) when used in conjunction with a suitable magnetic setup or track.

Extended Duration Superconductors

The Extended Duration Superconductors offer the optimal balance between levitation strength and levitation time. These new levitators offer two- to three-times longer levitation times compared to the standard ones.

Order Information

Standard Medium Superconductor SE-7735

Standard Large Superconductor SE-7736

Enhanced Medium Superconductor SE-7737

Enhanced Large Superconductor SE-7738

Extended Duration Medium Superconductor SE-7741

Extended Duration Large Superconductor SE-7742

Magnetism Supplies

Bar Magnets (2 Pack)

SE-8604

These cylindrical magnets (10 x 50 mm) are small, strong, and color-coded for polarity. Plastic case and keeper plates included.

Order Information

Bar Magnets (2 Pack)..... SE-8604

Alnico Bar Magnets (2 Pack)

EM-8620

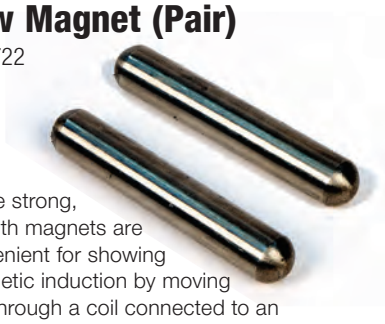
These magnets (150 x 13 mm) are stronger and last longer than iron magnets. They fit a St. Louis motor and the north poles are notched. Case included.

Order Information

Alnico Bar Magnets (2 Pack) EM-8620

Cow Magnet (Pair)

SE-7722



These strong, smooth magnets are convenient for showing magnetic induction by moving one through a coil connected to an ammeter. As the name suggests, the primary purpose of these magnets is to collect metal objects in a cow's first stomach to prevent internal damage.

Length: 7.5 cm

Field Strength:
1400 gauss at pole surface

Order Information

Cow Magnet (Pair) SE-7722

Zero Gauss Chamber

EM-8652

This double-walled, high permeability metal chamber produces a zero gauss field within the chamber. By placing the Magnetic Field Sensor probe into the chamber and pushing the "Tare" button, the sensor may be zeroed. Highly recommended for measurement of Earth's magnetic field.

Order Information

Zero Gauss Chamber EM-8652

Neodymium Magnets, 16 Pack, Solid

EM-8648B

Neodymium magnets are some of the strongest commercial magnets available. This set is also available with a protective coating to prevent the brittle metal from chipping (EM-8621).

Size: 13 mm dia. x 5 mm

Plastic case included.

⚠ WARNING
This product contains small magnets. Swallowed magnets can stick together across intestines causing serious infections and death. Seek immediate medical attention if magnet(s) are swallowed or inhaled.

Order Information

Neodymium Magnets,
16 Pack, Solid..... EM-8648B

Magnetic Field Meter

SE-7579B

This Hall Effect sensor measures AC and DC magnetic field strength.

Features:

- AC and DC magnetic field measurements
- Measures up to 3 T
- Hall Effect sensor with temperature compensation
- Sensitivity on lower scale 0.1 G
- North and South pole indication
- Zero button
- Auto power off
- LCD display
- Data hold and min/max record-recall
- Choice of gauss or mT units

Specifications:
DC Measurement Ranges:
300.00 mT (0.01 mT resolution); 3000.0 mT (0.1 mT resolution)
AC Measurement Ranges:
150.00 mT (0.01 mT resolution); 1500.00 mT (0.1 mT resolution)
Accuracy at 23°C: ±5% of reading
AC Frequency Response: 50 Hz/60 Hz
Display Sampling Time: Approx. 1 second
Operating Temperature: 0 to 50°C
Power Supply: 9 V battery (AC adapter included)
Mass: 275 g with probe
Meter Dimensions: 198 x 68 x 30 mm
Probe Dimensions: 195 x 25 x 19 mm
Probe Tip Thickness: 1.8 mm

Includes:

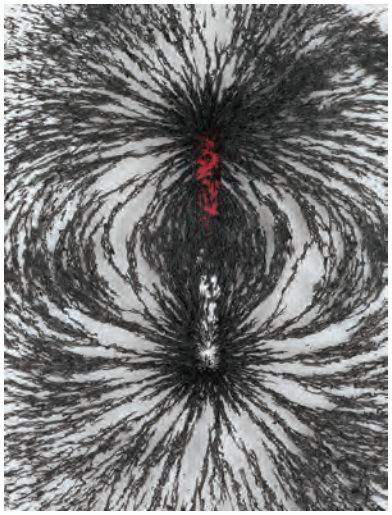
- Magnetic Field Meter
- Uniaxial Magnetic Probe Sensor with Protective Cover
- 9 V Battery
- Universal AC Adapter (9 V, 1 A)
- Hard Carrying Case

Order Information

Magnetic Field Meter SE-7579B

Iron Filings (1 lb)

SE-7723



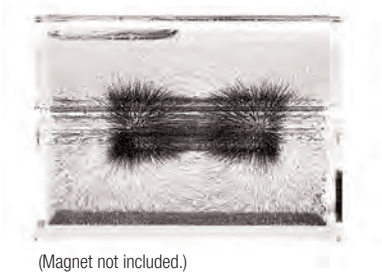
Iron filings sprinkled over a bar magnet instantly make the magnetic field visible.

Order Information

Iron Filings (1 lb) SE-7723

3-D Magnetic Field Demonstrator

SE-8603



(Magnet not included.)

The 3-D Magnetic Field Demonstrator suspends iron filings in oil within a sealed acrylic container. Magnet(s) are inserted into the 10 mm opening, causing the filings to create magnetic field lines. The demonstration can be viewed directly or with an overhead projector.

Order Information

3-D Magnetic
Field Demonstrator SE-8603
Recommended:
Bar Magnets (2 Pack).....SE-8604 p. 256

Liquid-Filled Compasses (5 Pack)

EM-8631A

This compass is perfect for investigating the magnetic fields around straight wires. It has a 4.5 cm diameter liquid-filled plastic case and a 2.5 cm long needle with the north end marked in red.

Order Information

Liquid-Filled Compasses
(5 Pack) EM-8631A

Replacement part for CASTLE Kits
(EM-8624A and EM-8654)

Plotting Compass Set (20 Pack)

SE-8680

(Appearance may vary.)

This Plotting Compass provides an economical way to conduct magnetism labs. Includes 20 compasses marked in red with North-South and East-West lines. Students can place several compasses around a bar magnet and draw the magnetic field lines. Each compass has a diameter of 19 mm.

Order Information

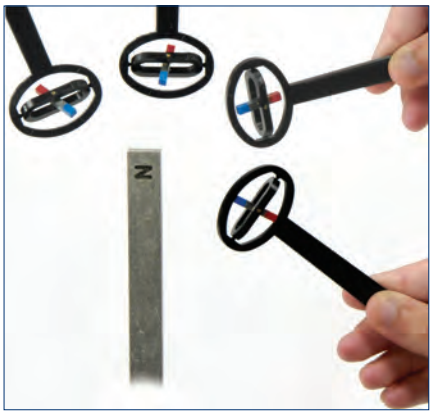
Plotting Compass Set
(20 Pack) SE-8680

Magnaprobe

SE-7390

The Magnaprobe is a great way to demonstrate the 3-D nature of magnetic fields. The probe features a gimbal-mounted Alnico magnet, which is free to move in the x, y, and z dimensions. Suggested activities are included with each probe.

Magnaprobe is 12 cm long.



Order Information

Magnaprobe SE-7390

Magnetism Supplies

Painted Bar Magnet (Pair)

SE-7593

This pair of AlNiCo bar magnets are perfect for studies of magnetism, magnetic polarity, and magnetic field strength. Both magnets are coated with red and blue paint, each color indicating the polarity of that part of the magnet.

Specifications:
Dimensions: 75 mm x 11.2 mm x 6.1 mm
Material: AlNiCo

Order Information

Painted Bar Magnet (Pair) SE-7593

Dip Needle/ Oersted's Apparatus

SE-8619

Find the dip angle of the Earth's magnetic field.

This dual-purpose apparatus can be used as a dip needle or Oersted's apparatus.

- Find the dip angle of the Earth's magnetic field at your location by aligning the horizontal compass needle with the Earth's magnetic field. Then rotate it to the vertical to show the angle at which the Earth's magnetic field points into or out of the horizontal plane.
- Demonstrate that a current loop produces a magnetic field. With the compass needle aligned with the Earth's field in the horizontal plane, connect a DC power supply to the banana jack terminals on the apparatus to run a current through the conducting aluminum loop that forms the frame that holds the compass needle. The compass needle will deflect in response to the magnetic field created by the current loop.

Apply a voltage to run a current through the conducting loop to show that the current produces a magnetic field.

Includes:

- Compass needle
- Rotatable stand

Order Information

Dip Needle/
Oersted's Apparatus SE-8619

Lenz's Law Demonstrator

MG-8600

Magnet 6 cm long
19.8 mm OD

Drop a mass through the 1.5 m tube. It takes about half a second to drop. Then drop a magnet with an identical mass. It takes over 10 times as long to fall. As the magnet falls, it generates a current in the tube, moving in one direction above the magnet and in the opposite direction below. Both currents obey Lenz's Law and induce magnetic fields that oppose the magnet's motion. See the difference in time as the magnet falls through the tube.

Includes:

- Lenz's Law Magnet
- Unmagnetized Slug
- 1.5 m Aluminum Tube (2 cm ID, 0.28 cm wall)
- 10-turn Rectangular Coil
- Attachment Bracket for Spring Scale
- Ohaus Spring Scale 10N

Order Information

Lenz's Law Demonstrator MG-8600

Decade Capacitance Box

SE-8689

This Decade Capacitance Box supplies five decades of capacitance from 100 pF to 11.111 µF in 100 pF steps. Add or subtract capacitance with slide switches. Three color-coded binding posts provide reliable connections.

Specifications:

Accuracy: ±5%

Maximum Voltage: 50 VDC

Order Information

Decade Capacitance Box SE-8689

Decade Resistance Box

SE-7124

Resistance is plainly displayed with this six-decade resistance box since a rotary switch selects the resistance within each decade. With 1% accuracy and 1/2 W resistor, it will accommodate most student experiments.

Specifications:

Resistance:
0 to 1, 111, 110 Ω in 1 Ω increments

Accuracy: ±1.0% ±0.1 Ω

Power Dissipation: 1/2 W resistors

Order Information

Decade Resistance Box.....SE-7124

Digital LCR Meter

SE-8792A

Measure inductance, capacitance, and resistance with this Digital LCR Meter. Test leads are included, along with a battery, a protective holster, and a manual.

Features:

- **Accuracy:** 1% or better on most ranges
- **Easy to Use:** Push-button selection for all measurements
- **Built-in Tilt Stand:** For convenient tabletop use
- Measures Inductance, Capacitance, and Resistance with secondary parameter Q (Quality), D (Dissipation), R (Resistance), P (Phase), ESR (Equivalent Series Resistance)
- Simultaneous 20,000/2,000 count backlit display of the primary parameter (L, C or R) with the secondary parameter
- Auto Select measurement function with 1 kHz default test frequency
- Five test frequencies
- Set Hi/Lo limits using absolute values or percentage limits
- Relative mode function
- Parallel or Series equivalent circuit
- Auto power off, low battery and overrange indicators
- Open and Short calibration removes unwanted stray impedances from the measurement
- Complete with test leads and 9V battery

Specifications:

Inductance: 20 µH, 200 µH, 2000.0 µH, 20.0000 mH, 200.00 mH ±(0.5% rdg + 5 digits); 2000.0 mH, 20.000 H, 200.00 H, 2000.0 H (DF <0.1)

Capacitance: 20 pF, 200 pF, 2000 pF, 20.000 nF, 200.00 nF, 2000.0 nF ±(0.5% rdg + 5 digits); 20.000 µF, 200.00 µF, 2.0000 mF, 20.00 mF (DF <0.1)

Resistance: 20.00 Ω, 200.00 Ω, 2.0000 kΩ, 20.000 kΩ, 200.00 kΩ, 2.0000 MΩ, 20.000 MΩ, 200.0 MΩ ±(0.5% rdg + 5 digits)

Test Frequency: 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz

Power: 9 V alkaline battery (included)

Accessories: Test leads (2), alligator clips (2), protective holder

Order Information

Digital LCR Meter.....SE-8792A

Power Supplies and a Current Amplifier for Advanced Physics Experiments

The power supplies and instruments on this page are used in various advanced physics experiments involving finding fundamental constants (Photoelectric Effect, Franck-Hertz, and e/m). Since each experiment uses some combination of these, it is possible to purchase one of each to perform all three experiments, one at a time.

Experiment	DC Power Supply I	DC Power Supply II	DC (Constant Current) Supply	DC Current Amplifier
Photoelectric Effect (page 379)	X			X
Franck-Hertz (page 381)	X	X		X
e/m (page 317)		X	X	

Connect to a 550 or 850 Interface:

These instruments can be used standalone by reading the digital displays. However, they have special data collection ports that connect a 550 or 850 Universal Interface (see pp. 26-29) to record data and analyze it in PASCO Capstone. Each type of voltage and current reading is automatically identified when the power supply is connected to a 550 or 850 analog port with the special cable (included).

Order Information

Analog 8-Pin DIN Extension Male-to-Male Adapter UI-5219

DC Power Supply I (Constant Voltage)

SE-6615

- 0 to 6.3 V DC, 1 A maximum
- -4.5 to 0 V DC, 10 mA maximum
- -4.5 to 30 V DC, 10 mA maximum

The 0 to 6.3 V output is independent of the -4.5 to 0 V and -4.5 to 30V outputs, which share an output and are selected by pushing a button.

Specifications:

Independent floating ground reference

Ripple: <1%

Includes:

- Includes cords to connect to the 550 and 850 Interfaces.

Order Information

DC Power Supply I (Constant Voltage) SE-6615

DC Power Supply II (Constant Voltage)

SE-9644

- 0 to 12 V DC, 1 A maximum
- 0 to 100 V DC, 30 mA maximum
- 0 to 200 V DC, 30 mA maximum

The 0 to 12 V output is independent of the 0 to 100 V and 0 to 200V outputs, which share an output and are selected by pushing a button.

Specifications:

Independent floating ground reference

Ripple: <1%

Includes:

- Includes cords to connect to the 550 and 850 Interfaces.

Order Information

DC Power Supply II (Constant Voltage)..... SE-9644

Tunable DC Power Supply (Constant Current)

SE-9622

- 0 to 3.5 A DC, 20 V maximum
- Fixed 6.3 V AC, 1 A maximum

This constant current power supply has a digital readout for the current, which can be tuned from 0 to 3.5 A DC. It also has a 6.3 V AC power supply for heating filaments. A High Current Sensor (PS-2193 or CI-6740) can read the current when using this power supply with interfacing experiments. Both DC and AC outputs are available simultaneously on separate floating output terminals.

Order Information

Tunable DC Power Supply (Constant Current) SE-9622

DC Current Amplifier

SE-6621

- Measures picoamp currents
- Six ranges from 10^{-8} A to 10^{-13} A

DC Current Amplifier designed for Franck-Hertz and Photoelectric Effect experiments.

Specifications:

Maximum Voltage Input: 15 V

Zero drift: ≤ 0.2% of full range 10^{-13} A after 30 min.

Includes:

- Includes cords to connect to the 550 and 850 Interfaces.

Order Information

DC Current Amplifier SE-6621

Tunable DC Power Supply 6A

SE-9656

- Used in Zeeman Effect experiment
- Can be used in the e/m experiment to power the coils
- Maximum current of 6 A

The Tunable DC Power Supply supplies power to the pen-type mercury lamp and the electromagnet (SE-9655) in the Zeeman Effect Apparatus (SE-9654). The output for the mercury lamp is 1500 V AC and the output for the electromagnet is zero to 6 A with a maximum voltage of 36 V DC.

Specifications:

AC Output: Fixed 1500 V, maximum current 145 mA

DC Output: Constant current adjustable from zero to 6 A

Maximum Voltage: 36 V

Extra Fuse Included: 250 V T5A

Order Information

Tunable DC
Power Supply 6A SE-9656

DC Programmable Power Supply

PI-9880

- 1 A at 18 VDC
- Digital display
- Ramp or step positive voltage up or down

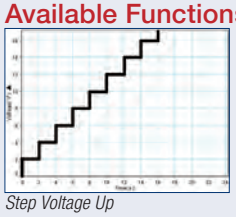
Provides a current of 1 A at 18 V, with a resolution of 0.01 V and typical ripple of 10 mV. This DC power supply has added features to cycle the voltage on and off, to ramp the voltage up or down between the maximum and minimum set, and to change the voltage in steps. A positive offset can be introduced so that the ramp starts at a voltage other than zero. Minimum period is 0.1 sec (10 Hz) and the maximum period is 999 seconds.

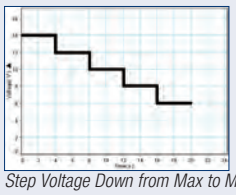
The digital display has four digits (0.76 cm high) and can display voltage, current, or time. The time is displayed to set the period, duration, or duty cycle.

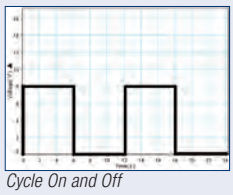
There are both coarse and fine adjustment knobs. As a safety factor, a maximum current and a maximum voltage can be set to protect your students' external circuits. The output is voltage-regulated but not current regulated.

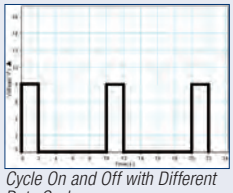
The power supply is connected to AC power using a universal power adapter.

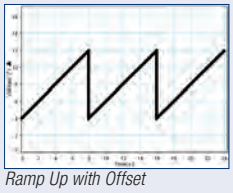
Available Functions:

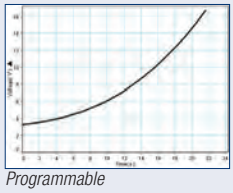

Step Voltage Up


Step Voltage Down from Max to Min


Cycle On and Off


Cycle On and Off with Different Duty Cycles


Ramp Up with Offset


Programmable

Includes:

- DC Power Supply
- Universal Power Adapter

Order Information

DC Programmable
Power Supply.....PI-9880

DC Power Supplies

Power Supply (18 VDC, 5 A)

SE-9720A

- 0-18 VDC at 0-5 A
- Serial and parallel operation

This power supply has a remote control connector and switch on the rear panel, so units can be connected in series or parallel with each other to provide higher voltage, higher current, and higher power output.

Specifications:

Digital Meters: Voltage and current; LED

Constant Voltage Output: continuously variable, coarse and fine control

Constant Voltage Line Regulation: ≤0.01% ±3 mV

Constant Voltage Load Regulation: ≤0.01% ±3 mV

Constant Voltage Ripple and Noise: ≤0.5 mVrms

Constant Current Output: continuously variable, coarse and fine control

Constant Current Line Regulation: ≤0.02% ±3 mA

Constant Current Load Regulation: ≤0.02% ±3 mA

Constant Current Ripple and Noise: ≤3 mArms

Power Source: AC 100, 120, 220, 240 V ±10%, 50/60 Hz; Protection – overload and reverse polarity protected

Dimensions: 29 x 13 x 15 cm (5.5 kg)

Includes:

- Instruction Manual
- Test Lead

Order Information

Power Supply (18 VDC, 5 A)..... SE-9720A

Student Power Supply (18 VDC, 3 A)

SE-8828

- 0-18 VDC at 0-3 A
- Constant voltage or current
- Short-circuit protected
- Current limiting
- Low noise/ripple

This high-quality, compact power supply provides the DC voltage and current levels necessary for most introductory student labs.

Specifications:

Digital Meters: Voltage and current; Backlit LCD

Constant Voltage Output: continuously variable

Constant Voltage Line Regulation: <0.01% ±3 mV

Constant Voltage Load Regulation: <0.01% ±2 mV

Constant Voltage Ripple and Noise: <0.5 mVrms

Constant Current Output: continuously variable

Constant Current Line Regulation: <0.2% ±3 mA

Constant Current Load Regulation: <0.2% ±3 mA

Constant Current Ripple: <3 mArms

Power Source: AC 100, 120, 220, 240 V ±10%, 50/60 Hz; Protection – overload and reverse polarity protected

Dimensions: 34 x 26 x 15 cm (11.5 kg)

Order Information

Student Power Supply (18VDC, 3A) SE-8828

Triple Output Power Supply

SE-8587

- 0-30 VDC at 0-3 A
- Digital Voltage and Current Meters

This power supply offers adjustable voltage output (0-30 V), adjustable current output (0-3 A), and two independent constant voltage outputs (5 V and 12 V) with easy snap terminals. Digital displays of both current and voltage allow students to easily gather data. Features overload and short-circuit protection.

Specifications:

Digital Meters: Voltage and current; 3 digits; LCD

Constant Voltage Output: continuously variable

Constant Voltage Line Regulation: ≤0.05% ±10 mV

Constant Voltage Load Regulation: ≤0.05% ±10 mV

Constant Voltage Ripple and Noise: ≤0.5 mVrms

Constant Current Output: continuously variable

Constant Current Line Regulation: ≤0.05% ±10 mA

Constant Current Load Regulation: ≤0.05% ±10 mA

Constant Current Ripple and Noise: ≤3 mArms

Fixed Output Voltage: 5 V at 0.5 A continuous; 1 A max. 12 V at 0.5 A continuous; 1 A max.

Power Source: AC 110/220 VAC, 50/60 Hz

Dimensions: 29 x 13 x 15 cm (5.5 kg)

Order Information

Triple Output Power Supply..... SE-8587

Power Supply (30 VDC, 6 A)

SE-9721B

- 0-30 VDC at 0-6 A
- 0.01% high regulation
- Constant voltage or current

This single output linear DC power supply is suitable for high-end precision bench top applications. Low load and line regulation for both the constant voltage mode and the constant current mode ensures reliable, predictable output. Overload and reverse polarity protection as well as internal selection for dynamic or constant load are standard.

This power supply has a built-in digital panel control design to replace conventional control methods.

Specifications:

Output Voltage: 0 to 30 VDC
Output Current: 0 to 6 A
Constant Voltage Line Regulation: ≤0.01% + 3 mV
Constant Voltage Load Regulation: ≤0.01% + 3 mV (rating current ≤3A); ≤0.02% + 5 mV (rating current ≤3A)
Constant Voltage Ripple & Noise: ≤1 mVrms (5Hz~1MHz)
Constant Voltage Recovery Time: ≤100μs (50% Load Change, minimum load 0.5A)
Constant Current Line Regulation: ≤0.2% + 3 mA
Constant Current Load Regulation: ≤0.2% + 3 mA
Constant Current Ripple & Noise: ≤3 mArms
Dimensions: 210(W) x 155(H) x 306(D) mm
Product Mass: Approx. 7kg

Includes:

- Instruction Manual
- Test Lead

Order Information

Power Supply
(30 VDC, 6 A).....SE-9721B

High Voltage Power Supply

SF-9585A

- 0 to 50 VDC at up to 50 mA
- 0 to 500 VDC at up to 50 mA
- 2 to 7 VAC at up to 3 A

Appearance may vary.

Here is a versatile and reliable supply for experiments requiring medium to high voltages at relatively low currents, such as the Millikan Oil Drop experiment. The 50 and 500 VDC outputs are independently variable, providing up to 50 mA, and the output displays can be switch-selected to read voltage and current in either range. A separate set of output terminals provides 2, 4, 5, 6 and 7 VAC at up to 3 A, a convenient source for electron tube filaments.

Note: The positive terminal of the 50 V supply is internally connected to the negative terminal of the 500 V supply.

Specifications:

Ripple: Less than 0.1%, ±1 digit line
Regulation: <1% at 98-130 V (line voltage)
Load Regulation: <1% at 0-100% load
Displays: Digital readouts 0-50 V, 0-500 V, 0-50 mA (switch-selectable)
Power Source: 115/220 VAC, 50/60 Hz
Dimensions: 21 x 29 x 11 cm (8 x 12 x 4 in.)

Order Information

High Voltage
Power Supply.....SF-9585A

Kilovolt Power Supply

SF-9586B

- 0 to 6 kVDC
- 6.3 VAC, 2 A filament source
- Digital readout

Appearance may vary.

This Kilovolt DC Power Supply is used for electron tubes and electrostatics.

The high voltage section is by design "floating" relative to ground. This means that either the black (negative) terminal or the red (positive) terminal may be connected to ground to give a voltage range of 0 to +6 kV, respectively 0 to -6 kV relative to ground.

The output is well regulated, and the current is limited for safety.

(The maximum short circuit current is 2 mA).

Specifications:

DC – Output Voltage:
0-6 kV stabilized, continuously adjustable
Short Circuit Current: 2 mA (max.)
Ripple and Noise (max.): less than 1%
Readout Accuracy:
better than 1% + 1 digit
AC – Output Voltage: 6.3 V
Output Current (max.): 3 A
Dimensions:
(W x D x H) 312 x 225 x 117 mm

Order Information

Kilovolt Power Supply SF-9586B
Recommended:
High Voltage
Patch Cord Set..... SE-9269

AC/DC Power Supply (12 V, 3 A)

SF-9581

- Combined DC and AC supply at a low price
- Stabilized, continuously adjustable DC: 0 to 12 V
- AC presets: 2, 4, 6 and 12 V
- Currents up to 3 A for both outputs
- Outputs are overload protected

Appearance may vary.

This power supply delivers a stabilized DC voltage that is adjustable between 0 and 12 V. Moreover, an AC voltage is supplied, which can be set to 2, 4, 6, or 12 V. The two outputs can simultaneously supply up to 3 A with overload protection. The DC portion is electronically protected and resets automatically, while AC protection is provided with a circuit breaker that must be reset manually if it trips.

Specifications:

DC Output Voltage: 0-12 V (stabilized), continuously adjustable

Maximum DC Output Current: 3 A

Maximum Ripple: 100 mV

AC Output Voltage: 2, 4, 6, 12 V, stepwise adjustable

Maximum AC Output Current: 3 A

Power Consumption: 110 W (max)

Fuse: T 1A (slow)

Dimensions: 20.3 x 20.5 x 11.7 cm

Order Information

AC/DC Power Supply (12 V, 3 A) SF-9581

Low Voltage AC/DC Power Supply

SF-9584B

- 0 to 24 VDC at 0 to 10 A
- 0 to 24 VAC at up to 6 A
- Digital readouts

Appearance may vary.

The Low Voltage Power Supply has been designed specifically for use in teaching physics, chemistry, and other science subjects. It can provide both direct current (DC) and alternating current (AC). The Power Supply can provide both types of electrical power at the same time, and they can be adjusted independently of one another. Separate digital displays are provided for DC and AC output.

Specifications:

DC Output Voltage: 0 to 24 V DC

Meter: Digital display (volts/amps); 1% ±2 LSD; Ripple <25 mVpp

AC Output Voltage: 0 to 24 V AC, continuously adjustable

Current: 0 to 6 A

Overload Protection Meter: Digital display (volts/amps); 2% ± LSD

Power Source: AC 115/230 VAC, 50/60 Hz

Power Use: 320 W

Dimensions: 30 x 23 x 12 cm (12 x 9 x 5 in.)

Order Information

Low Voltage AC/DC Power Supply SF-9584B

Wide Range Function Generator

SB-9549A

This function generator is similar to the Basic Function Generator, but it provides a wider frequency range and greater output voltage.

Specifications:

Ranges: 0.2 Hz to 5 MHz in seven ranges, (±1 count)

Waveforms: sine (distortion <1% below 100 kHz); square (2% symmetry, 50 nS max rise and fall time); triangle (98% linearity below 100 kHz, 95% above 100 kHZ)

Outputs: 20 Vpp no load, 10 Vpp max into 50 Ω load; continuously variable, 20 dB range with 20 dB step; DC offset: ±10 V (no load), ±5 V (50 Ω load); TTL/CMOS-compatible pulse

Sweep: external voltage-controlled oscillator, 0-10 V signal can produce 100:1 frequency change

Power Source: 115/220 VAC, 50/60 Hz

Accessories: BNC to insulated clips

Order Information

Wide Range Function Generator SB-9549A

High-Frequency, High-Power Function Generator

SF-9580

- Wide frequency range: 0.001 Hz to 10 MHz
- 10 W up to 100 kHz to drive speakers
- Sweep mode
- Step mode

Appearance may vary.

Simple design

In basic applications, students operate two large buttons: one for frequency, one for amplitude. If they change the waveform or utilize the step and sweep modes, the display keeps them updated on the status of the generator.

Unique frequency control

The frequency is set by a speed sensitive button. Turn it slowly to set the display's last digit. Turn it faster and the response accelerates softly. We have designed this function to work intuitively in practical experiments with common physics equipment.

Drive speaker and vibrators directly

The built-in 10 W power amplifier effortlessly drives power-consuming equipment such as a vibrator or speaker. The amplifier can deliver more than 1 A for all frequencies between 0.001 Hz and 100 kHz.

Advanced features

The generator connects to your PC through a standard USB cable. Custom defined waveforms (e.g. created by means of a spreadsheet) can be saved to the generator. Sequences of settings can be programmed for automatic execution.

Specifications:

Bipolar: Sine, triangle, square

Positive: Square pulse, triangle pulse, ramp up, ramp down

Distortion (sine): <0.1% up to 20 kHz; <1% otherwise

Frequency Range: 50 Ω and sync outputs: 0.001 Hz to 10.00 MHz; Power output: 0.001 Hz to 100.0 kHz

Frequency Stability: Better than 0.005%

Amplitude: 50 Ω output, no load: 0 to 10 V (20 Vpp for bipolar waveforms); Sync output: 5 V (TTL signal: 0 to 5 V); Power output: 0 to 10 V (20 Vpp for bipolar waveforms)

Max Current: 50 Ω output, short circuit: 200 mA (only briefly); 50 Ω output, into 50: 100 mA (unlimited); power output: 1 A (unlimited)

Power Consumption: 85 W (max); 21 W (idle)

Dimensions (WxDxH): 31.2 x 20.5 x 11.7 cm

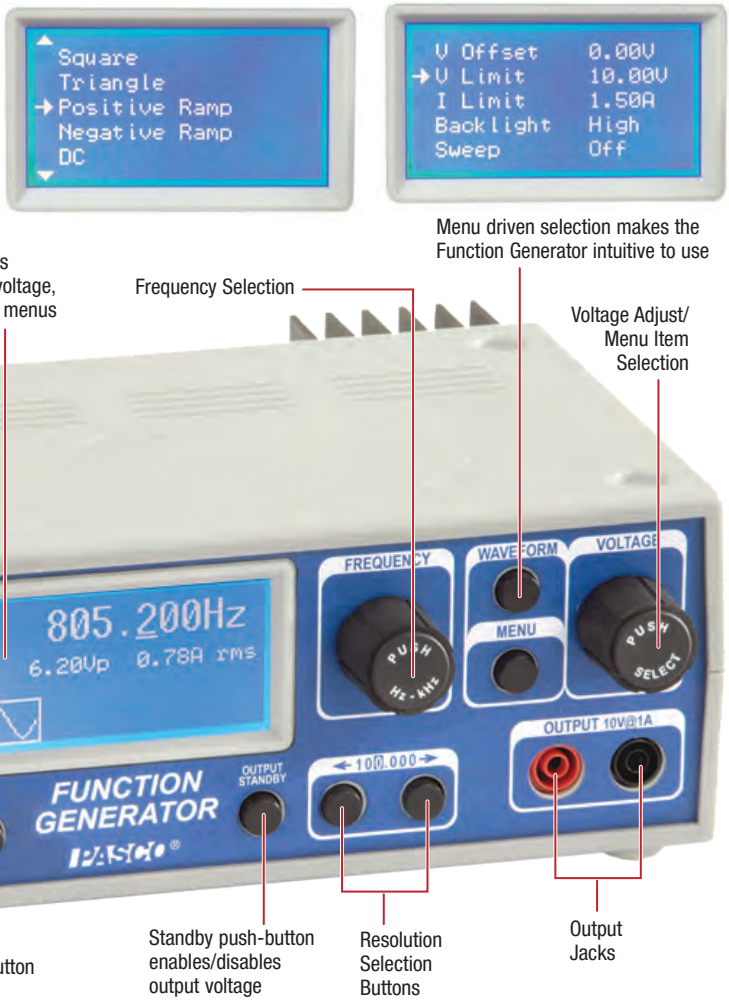
Order Information

High-Frequency, High-Power Function Generator SF-9580

Function Generator

PI-8127

- 0.001 Hz to 150 kHz
- Programmable frequency sweep
- 10 V at 1 A
- Use for circuits and/or driving speakers
- Use the ramp function to vary the speed of DC motors
- Frequency resolution of 0.001 Hz over entire range



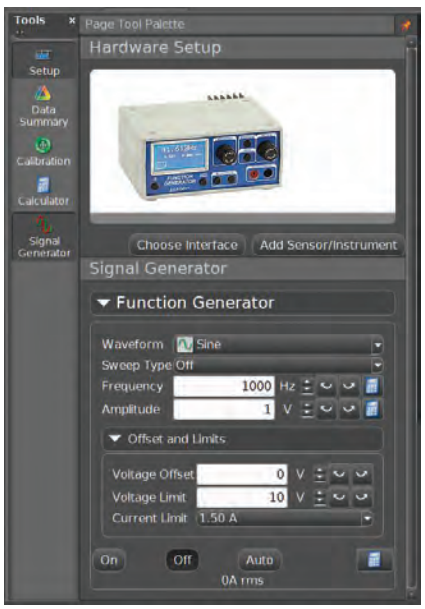
Upgradable Firmware

Download the latest features for your PI-8127: The built-in USB port allows users to access and upgrade firmware whenever the unit is attached to a computer running current versions of PASCO Capstone™ software (pp. 68-71).

Features

The Function Generator outputs sine, square, triangle, positive and negative ramps with a frequency range of 0.001 Hz to 150 kHz in addition to DC. (A replacement for the PI-9587C). Its powerful output, 1 Amp at ±10 Volts, makes it useful for driving speakers, string vibrators, and circuits.

- **LCD Readout:** The LCD displays frequency, voltage, current, waveform, and menus. For viewing demonstrations, there is a Large Digits Mode for increased readability of the frequency. The backlight has both low and high levels, which are selectable in the menu. The low backlight is useful for dark rooms.
- **Frequency/Range Selection:** There are two ranges, 0.001 to 100 Hz and 0.001 to 100 kHz, selected using the range push-button switch (integrated with frequency knob).
- **Output Standby:** Pushing the standby button disables the output without changing settings.
- **Output Current/Voltage Maximum:** The maximum current or maximum voltage can be set using the menu. This is useful when the instructor needs to limit the voltage applied to a light bulb.
- **Offset Voltage:** Any waveform may be offset with a DC voltage ranging from -10 V to +10 V, provided the peak voltage does not exceed 10 V.
- **Frequency Sweep:** Sweep between any two frequencies at a selectable rate.



Use the Function Generator as a standalone or connect it to a computer via USB cable and control all its functions from PASCO Capstone™. Use it with PASPORT interfaces and sensors.

Specifications:

Input Power: 15 V @ 1.6 A

Voltage Output: ±10 V @ 1 A

Frequency Range: DC to 100 kHz. Sine wave retains its form to 150 kHz.

Frequency Resolution: 0.001 Hz over entire range

Offset Voltage: ±10 V

Waveforms: Sine, Triangle, Square, Positive Ramp, Negative Ramp, DC

External Voltage Input: ±10 V Maximum

Trigger Output: TTL Compatible; BNC jack on back of unit

Display: LCD Graphics Monochrome Display, 128 x 64, with two-level backlight

Displays: Frequency, Waveform, Voltage, Current, Offset Voltage.

Amplitude Modulation: Modulate the signal of one function generator using another.

Order Information

Function Generator PI-8127

Digital Storage Oscilloscope (100 MHz)

SB-9621B

- 2-Channel 100 MHz bandwidth
- 2 M points of memory gives finer detail
- FFT/FFTrms/ Zoom FFT
- Delay on/off
- USB flash storage and data logger
- Go/NoGo function
- Print directly to printer
- Remote control via software

This 2-channel oscilloscope is designed to meet educational demands. With 100 MHz bandwidth and a maximum real-time sampling rate up to 1GSa/s, the Digital Storage Oscilloscope supports numerous experiments and studies.

Each channel has 10M memory depth, yielding exquisite measurement results and allowing the retrieved waveform to successfully reveal the details of a signal. Students are often baffled by their inability to retrieve signal details when measuring basic electric circuit signals. Now, with 10M memory depth for each channel, students can uncover all signal details in depth.

A seven-inch, 800 x 480 WVGA LCD display and 256-color gradient display function together to allow this scope to distinctly display waveform details in gradients while measuring rapidly changing analog signals.

The 1Mpts FFT signal display makes the frequency domain display function more delicate. Students can clearly observe the distributed details of frequency domain signals, and use the smooth and rapid response to locate the source of problems. Additionally, the powerful FFT function realizes high efficient spectrum analysis measurement, which is indispensable for technology and education arenas.

This affordable oscilloscope provides serial bus analysis function with 10M long memory depth. Users can trigger, decode, and analyze frequently used I2C, SPI and UART 2 serial bus and CAN/LIN bus, which are often used by automotive communications.

The oscilloscope provides the zero key function for vertical voltage scale adjustment, horizontal time scale adjustment and trigger level adjustment. When processing complicated waveform adjustment and observation, users often require the zero key function to start a new measurement, adjust waveform or reset trigger level. The zero key function can reduce the time consumed turning control knobs.

Specifications:

Bandwidth: 100 MHz, 2 Input Channels
Maximum Sampling Rate:
1 GSa/s real-time; 25 GSa/s equivalent-time
Record Length: 2 Mega points
Vertical Scale: 2 mV to 10 V
Horizontal Range: 1 ns to 50 s
Number of Auto Measurements: Up to 27
Functions: +, -, x, FFT, FFTrms, Zoom FFT
Display: 7-inch, 800 x 480 WVGA LCD display
Ports: USB Host and Device Ports
Data Logger: Yes
Compact Size: (W) 310 x (D) 140 x (H) 142 mm

Order Information

Digital Storage Oscilloscope (100 MHz).....SB-9621B

Basic Digital Multimeter

SE-9786A

This basic meter includes all the functions and ranges needed for most introductory lab work.

Features:

- 10 amp range
- Backlit display with 25 mm digits
- Soft rubber boot for drop protection
- Built-in tilt stand
- Type K thermometer built in for surface or air measurements
- Auto power off saves battery life

Specifications:

DC Voltage: 0.1 mV to 600 V with ±0.5% accuracy
AC Voltage: 1 mV to 600 V with ±0.3% accuracy
DC Current: 0.1 µA to 10 A
AC Current: 0.1 mA to 10 A
Resistance: 0.1 Ω to 20 MΩ
Additional Functions: Input fuse protection, audible and visible misconnection signals, data hold freezes display reading
Display: 3-1/2 digit display with 25 mm digits, polarity indication, low battery indication
Power: 9 V battery (included)

Order Information

Basic Digital Multimeter.....SE-9786A

Precision Digital Multimeter, Component Tester and Thermometer

SB-9631B

This is an excellent general purpose multimeter that features high-accuracy overload protection on all ranges and a built-in digital thermometer. It can measure capacitance and transistor gain (hFE).

Specifications:

DC Current: 200 µA, 2 mA, 20 mA, 200 mA; ± (1% + 1 digit)
AC Current: 200 µA, 2 mA, 20 mA, 200 mA; ± (1.2% + 4 digits)
Capacitance: 20 nF, 200 nF, 2 µF, 20 µF, 200 µF; ± (3% + 10 digits)
Temperature: 4° to 1400°F; 4° to 900°F; ± (2.0% reading + 4°F); 900°F to 1,400°F; ± (3.0% reading + 4°F)
Power: 200-hour life on 9 V alkaline (battery included). Test leads, temperature probe and battery are included
DC Voltage: 200 mV, 2 V, 20 V, 200 V, 1000 V; ± (0.5% + 1 digit) 10 MΩ input impedance
AC Voltage: 200 mV, 2 V, 20 V, 200 V; ± (1% + 4 digits) 750 V; ± (1.5% + 4 digits) 10 MΩ input impedance
Resistance: 200 Ω, 2 kΩ, 200 kΩ, 20 MΩ; for 200 Ω to 200 kΩ ± (1.0% + 4 digits) for 20 MΩ ± (2.0% + 4 digits)
Additional Functions: Diode test, transistor hFE, audible continuity test, fold-out stand
Display: 3-1/2 digit LCD display, 17 mm high digits, polarity indication, low battery indication
Drop Resistant

Order Information

Precision Digital Multimeter, Component Tester and Thermometer SB-9631B
Replacement Supplies
Thermocouple Probe.....SB-9632

Ripple Tank

Ripple Tank System

WA-9899

- Completely redesigned system
- More affordable
- Integrated strobe/ripple generator simplifies operation
- Foam “beach” design dramatically reduces reflections from walls
- Silent operation

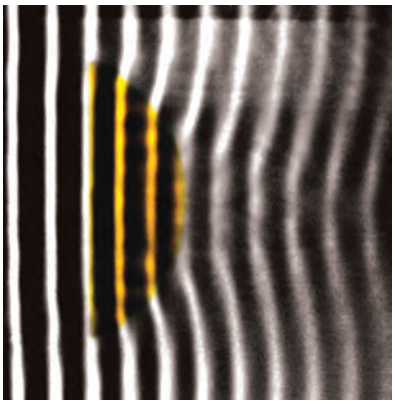
The redesigned Ripple Tank System is easier to use, more reliable, and more affordable. The strobe and rippler are controlled by the same unit, and a new feature makes it possible to introduce a small frequency difference between the strobe and the rippler to make the waves appear to move slowly. A simple switch changes the phase of the two ripplers from 0 to 180 degrees.

The rippler uses voice coil actuators for precise and silent operation. The frequency range (1.0 Hz to 50.0 Hz) includes those important low frequencies that make refraction more prominent. The LED digital frequency readout can be seen in low lighting. The rippler has knobs to easily adjust the dipper depth and the amplitude of the dipper stroke.

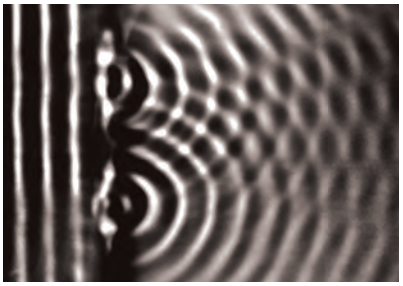
The new light source is a white LED that remains cool during operation and produces a bright, clear wave pattern. The light can be used as a strobe or in steady mode.

Applications:

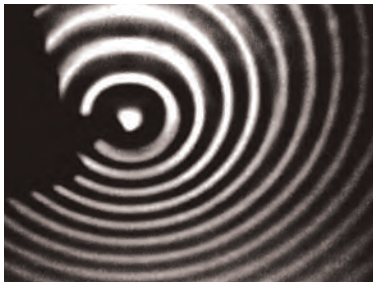
- Speed of Wave Propagation
- Superposition of Waves
- Effects of Varying Water Depth
- Reflection, Refraction, and Diffraction



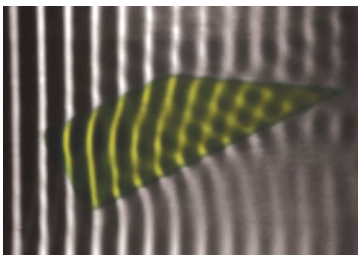
The yellow convex lens focuses the plane water waves. The waves show a pronounced refraction due to the abrupt change in the depth of the water over the plastic lens.



Diffraction Barriers are used to create a double slit to show interference. The barriers can be changed to adjust the slit width and slit separation.



The Doppler effect is clearly demonstrated by moving the dipper. In this picture the movement is downward.



Refraction occurs at the boundaries of this rhomboid shape.

Ripple Tank Specifications (WA-9897):

Viewing Area: 34 cm x 34 cm

Usable Tank Depth: 1 cm

Projection Screen: 35.6 cm x 38.8 cm

Acrylic Mirror: 49.8 cm x 38.8 cm

Light Source Support Rod: 46 cm long

Drain Tube: 30 cm long

Water Resistant Storage Box:
64 cm x 52 cm x 17 cm

Includes:

- Ripple Tank (complete components list at right)
- Ripple Generator/ Light Source
- Water Resistant Storage Box (64 cm x 52 cm x 17 cm)

Ripple Generator/Light Source Specifications (WA-9896):

Voice Coil Actuator Frequency Range:
1.0 to 50.0 Hz with 0.1 Hz Resolution

Adjustable Delta Frequency between Ripple Generator and Strobe:
±45% frequency setting in steps of 9%

Light Source:
5 W White LED

Light Source Modes:
Strobe or Steady Modes

Digital LED Display:
Frequency/Delta

Phase Switch:
0 or 180 degrees

Power Supply: 1
5 VDC at 1.5 A with On/Off Switch

Rippler Case Dimensions:
10.5 cm x 16.3 cm x 3.9 cm

Order Information

Ripple Tank System	WA-9899	
Required:		
90 cm Stainless Steel Rod	ME-8738	p. 196
Large Rod Base	ME-8735	p. 196
Replacement:		
Ripple Tank Optics Replacement Set	WA-9898	

Ripple Tank Assembly

WA-9897

Includes:

- Tank with Legs
- Projection Mirror and Screen
- Strobe Mounting Rod
- Refractors (convex, concave, rhomboid)
- Curved Reflector
- Diffraction Barriers (2 long, 1 short, 1 mini)
- Plastic Storage Box for components
- Surfactant
- Drainage Tube (30 cm) with Clamp
- 1 L Plastic Beaker
- Pipette
- Clear Plastic Ruler
- Water Resistant Storage Box for Entire System

Order Information

Ripple Tank Assembly WA-9897

Ripple Generator/ Light Source

WA-9896

Includes:

- Ripple Generator/Strobe Driver with Power Adapter
- LED Strobe Assembly
- Plane Wave Generator with Multi-point Dippers
- Point Sources (3 sizes)

Order Information

Ripple Generator & Light Source WA-9896

Ripple Tank Replacement Set

WA-9898 See specifications at left.

Includes:

- Plastic Storage Box for Components
- Dippers
- Pipette
- Foam Beach
- Refractors
- Curved Reflector
- Diffraction Barriers

Order Information

Ripple Tank Optics Replacement Set .. WA-9898

Ripple Tank Screen and Mirror

WA-9881

- Includes screen and mirror

Order Information

Ripple Tank Screen WA-9881

Standing Waves

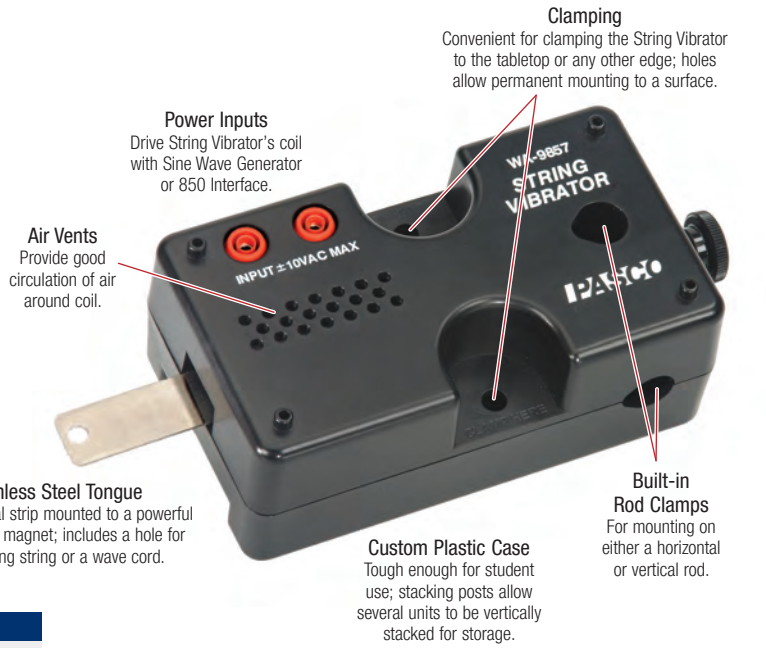
String Vibrator

WA-9857A

- Great tool for mechanical wave demonstrations
- Uses magnetic field to drive flexible tongue

The String Vibrator transforms mechanical wave demonstrations into hands-on activities that every lab group can easily perform. Featuring an elegant design with no motors or speakers, the String Vibrator allows students to study the fundamental characteristics of mechanical waves including wave speed, frequency, wavelength, amplitude, interference, and resonance.

Includes:
- String Vibrator Unit
- 3 Meter Wave Cord (not shown)



Order Information

String Vibrator	WA-9857A	
Required:		
Sine Wave Generator	WA-9867	p. 271

Strobe System

ME-6978

- 1 Hz to 500 Hz
- Variable intensity
- Low cost
- External trigger

This unique modular design makes it easy to light any geometry. The Strobe includes the Strobe Control Box and one Strobe Module. Additional Strobe Modules can be purchased separately (see below) for up to a total of four lamp modules per controller, and multiple control boxes can be connected together using the External Trigger. The Strobe Modules have a tilting lamp head on a sturdy base that sits on the table or fastens to a rod stand.

Accuracy: 0.1%
Frequency Range: 1 Hz to 500 Hz
Resolution: 0.1 Hz
Lamp Life: 50,000 hours
Brightness: 230 lumens (peak) per module

Includes:
- Control Box
- Strobe Module

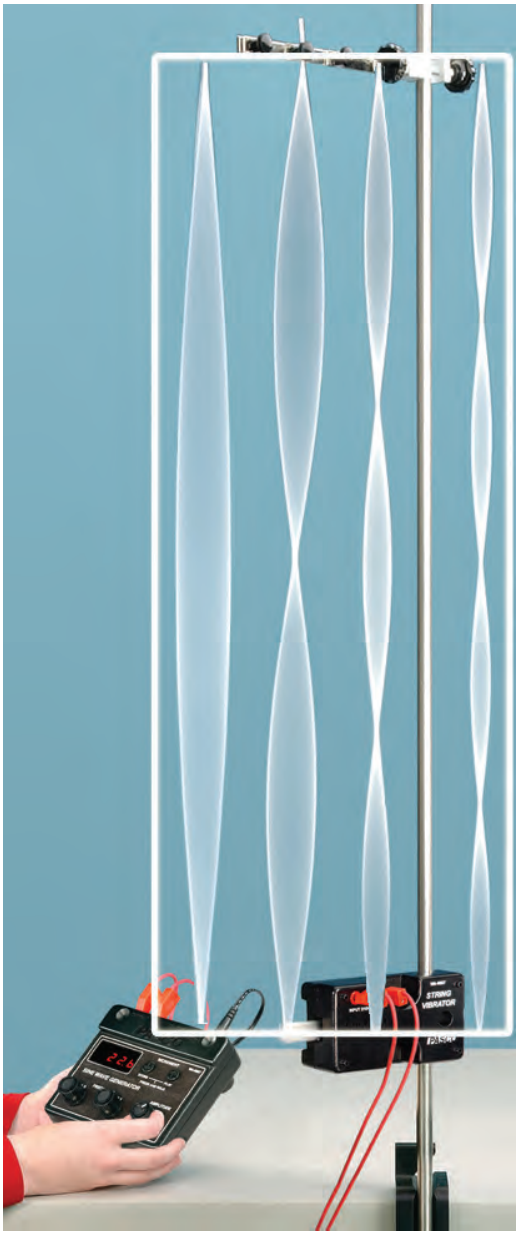
Order Information

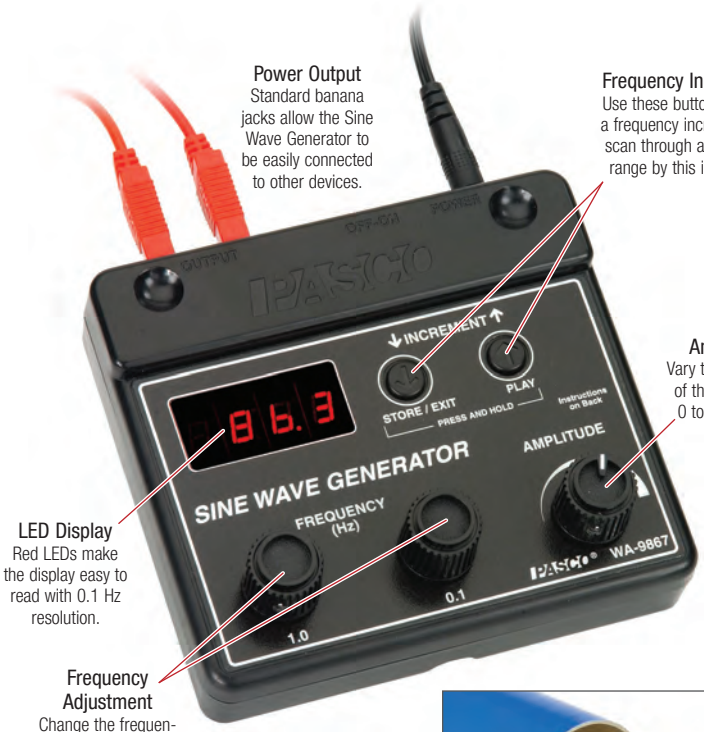
Strobe System	ME-6978	
Shown in use with:		
String Vibrator	WA-9857A	
Round Base with Rod (2)	ME-8270	p. 196
Aluminum Table Clamp (2)	ME-8995	p. 199
Sine Wave Generator	WA-9867	
Multi-Clamp	ME-9507	p. 198

Sine Wave Generator

WA-9867

- Sine wave output up to 800 Hz
- Ideal for driving speakers and wave drivers
- Built-in memory for storage of fundamental frequency
- Auto-scan of resonant frequencies





High Power Output
To drive speakers

- **Custom Plastic Case:** Stackable plastic case includes angled rubber feet and a rear rod clamp for dynamic mounting options
- **Digital Display:** Frequency is digitally displayed with 0.1 Hz resolution using red LEDs
- **Frequency Adjustment:** Adjust the frequency of the output with either the fine (0.1 Hz) or coarse (1.0 Hz) knobs. The knobs include a "Smart Scan" feature so they change frequency more quickly when continuously turned.
- Smart Scan feature enables knobs to change frequency more quickly when continuously turned.
- **Amplitude adjustment:** Change the voltage of the sine wave signal.
- **"Learn" Frequency:** The Sine Wave Generator can store a frequency increment, then it will cycle through the selected frequency range by the increment automatically, which is very useful for resonance demonstrations or activities.

Includes:

- Sine Wave Generator
- Power Supply: 15 VDC 2A

Order Information

Sine Wave Generator	WA-9867	
Recommended:		
String Vibrator	WA-9857A	p. 270
Mechanical Wave Driver	SF-9324	p. 272
Open Speaker	WA-9900	p. 274
Economy Resonance Tube	WA-9495	p. 274
Shown in use with:		
2 Meter Patch Cord Set	SE-9415A	p. 238

Waves

Wave Driver

WA-9855

- New improved design
- Greater amplitude
- Stronger magnet for stronger force
- Sturdy construction

This newly redesigned Wave Driver offers improvements in driving force and amplitude as well as a built-in string guide so tiny parts don't get lost. It is ideal for vibrating waves in a string, driving Chladni plates to show the vibration modes, or for demonstrating resonance vibrations.

Use a function generator (sold separately) to power this Wave Driver.

A coil inside a cylindrical magnet is driven by a sinusoidal signal which comes from the external function generator that is connected to the Wave Driver's banana jacks. The coil is attached to a diaphragm that the actuator rod is connected to.

Specifications:

Frequency Response:
0.1 to 5000 Hz

Driving Signal Required:
Requires a function generator with a minimum of 8 V at 0.5 A.

Includes:

- Wave Driver with built-in rod clamp and string holder
- Sample wave string

Order Information

Wave Driver WA-9855
Required:
Function Generator
Banana Plug Cord-Black (5 Pack).....SE-9751 p. 238

Wave Driver Accessories

Chladni Plate

WA-9406

Set this plate on the Wave Driver and sprinkle sand on it to visualize various modes of vibrations. The sand that collects along the nodal lines of the wave patterns paint clear and beautiful pictures of the various modes of vibration.

The Chladni Plate includes a 24 cm x 24 cm square metal plate, 0.8 kg of extra-fine sand, and a sand shaker.

WARNING! This product can expose you to crystalline silica, which is known to the State of California to cause cancer.
For more information go to www.P65Warnings.ca.gov.

Order Information

Chladni Plate WA-9406

Chladni Violin Plate

SE-7319

This 40-cm-long metal plate is shaped like a standard violin. Place sand on the plate and excite with a wave driver. Includes a standard banana jack connector for use with the Wave Driver.

Order Information

Chladni Violin Plate SE-7319

Metal Resonance Strips

WA-9404

These resonance strips demonstrate standing waves, harmonics, and the relationship between length, frequency, and resonance.

Investigate the unique resonant frequencies of the Metal Resonance Strips.

Order Information

Metal Resonance Strips WA-9404

Resonance Wire Loop

WA-9405

Use this wire loop (29 cm diameter) to introduce Bohr's quantum atom with a classical model.

Order Information

Resonance Wire Loop WA-9405

Longitudinal Wave Spring

WA-9401

Using the Longitudinal Wave Spring accessory, it is easy to demonstrate and visualize the nodes and antinodes of longitudinal waves. Unstretched length is 13 cm.

Longitudinal waves can be easily demonstrated with the Longitudinal Wave Spring.

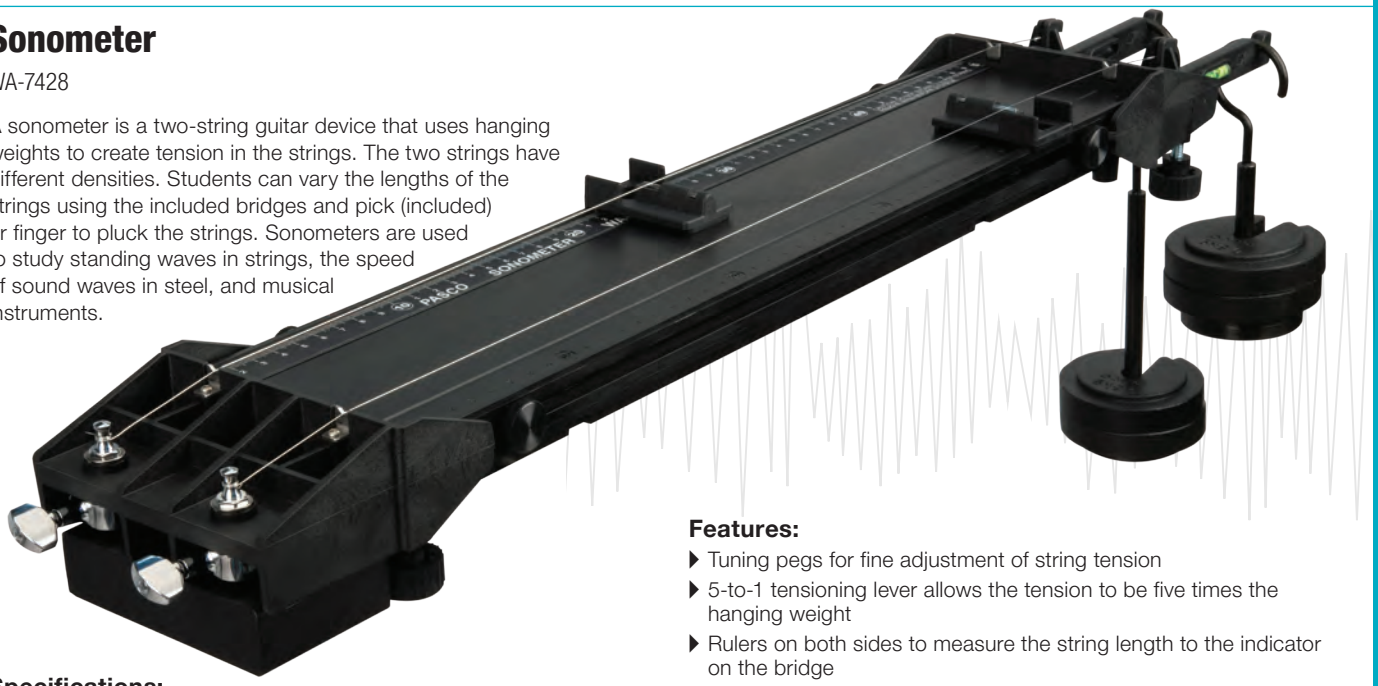
Order Information

Longitudinal Wave Spring..... WA-9401

Sonometer

WA-7428

A sonometer is a two-string guitar device that uses hanging weights to create tension in the strings. The two strings have different densities. Students can vary the lengths of the strings using the included bridges and pick (included) or finger to pluck the strings. Sonometers are used to study standing waves in strings, the speed of sound waves in steel, and musical instruments.



Specifications:

Working length of sounding board: 50 cm

Strings: Steel guitar strings with diameters 0.014-inch and 0.018-inch (4 of each type)

Tuning Pegs: For fine adjustments of the string tension

Built-in Rulers: Rulers on both sides measuring the string length at the indicator on the bridge

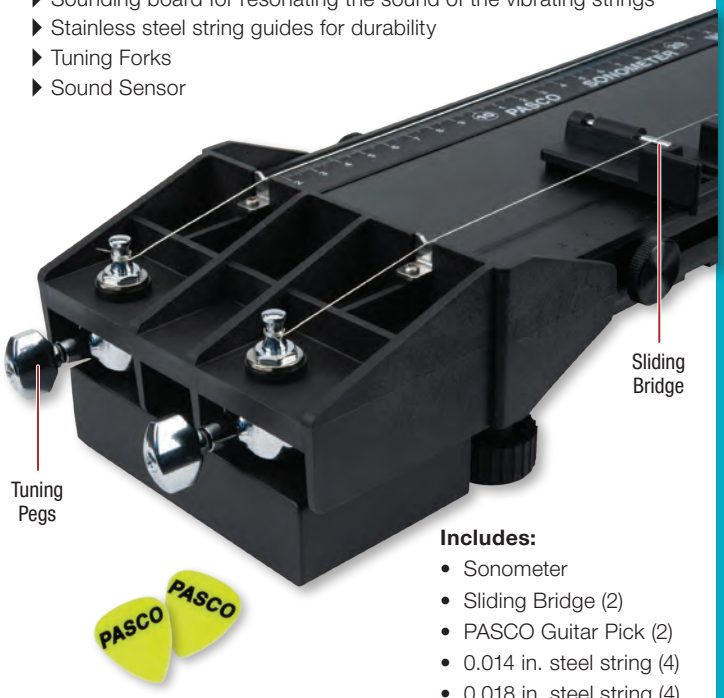
Tensioning Lever: 5-to-1 lever to provide tension in the string with built-in bubble level

Maximum hanging mass per string: 3 kg

PASCO Guitar Pick: Yellow Nylon 0.73 mm thick

Features:

- Tuning pegs for fine adjustment of string tension
- 5-to-1 tensioning lever allows the tension to be five times the hanging weight
- Rulers on both sides to measure the string length to the indicator on the bridge
- Sounding board for resonating the sound of the vibrating strings
- Stainless steel string guides for durability
- Tuning Forks
- Sound Sensor



Includes:

- Sonometer
- Sliding Bridge (2)
- PASCO Guitar Pick (2)
- 0.014 in. steel string (4)
- 0.018 in. steel string (4)

Sonometer Strings

WA-7429

This replacement set of strings for the Sonometer (WA-7428) contains four each of the following strings:

- 0.014 in. steel string
- 0.018 in. steel string

Order Information

Sonometer Strings	WA-7429	

Order Information

Sonometer	WA-7428	
Required:		
Sonometer Strings (Set of 8)	WA-7429	
Large Slotted Mass Set	ME-7566	p. 207
Short Slotted Mass Set (2 kg Set)	ME-7589	p. 207
Recommended		
Wireless Sound Sensor	PS-3227	p. 67
Tuning Fork Set	SE-7342	p. 279
OR		
Tuning Fork Technical Set	SE-7728	p. 279

Demonstrate Acoustic Resonance

Economy Resonance Tube

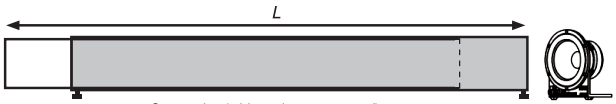
WA-9495

Metric Scale
Directly measures length of air column for open and closed tube.

Students will have no difficulty hearing resonant frequencies from this tube. Two nested cardboard tubes allow the length of the air column to be easily varied. And the inner tube contains a removable end-cap to change from a “closed” to an “open” tube. The length of the resonating column can be read directly off the metric scale for both open and closed operation.

The removable end-cap on the inner tube allows the air column to act as either an “open” or a “closed” tube.

Closed tube (with end cap in place)



Open tube (with end cap removed)

Shown in use with the Open Speaker and the Sine Wave Generator.

Open Speaker WA-9900

Features a high-quality, 13.3 cm woofer mounted on a sturdy base with standard banana jack inputs. The Open Speaker is not enclosed inside a case, making it perfect for resonance experiments.

Frequency Response: 80 - 8000 Hz
Impedance: 8 Ohms
Input Power: 60 W (max)

Order Information

Open Speaker	WA-9900

Includes:

- Outer Tube Length 1.3 m; Diameter 0.15 m
- Inner Tube (includes measuring tape and removable end-cap)
- Tube Stands (2)

Order Information

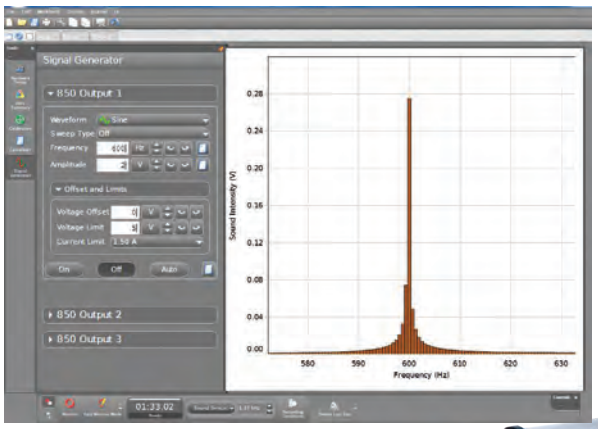
Economy Resonance Tube	WA-9495	
Shown in use with:		
Open Speaker	WA-9900	
Sine Wave Generator	WA-9867	p. 271
2 Meter Patch Cord Set	SE-9415A	p. 238

Resonance Air Column with Speaker

WA-9594

- Very loud resonance
- Tough polycarbonate tube
- Use with speaker or tuning fork

The Resonance Air Column (WA-9606) emits a very loud sound when the plunger is moved to a node position. It also works as well as a water column but without the mess. The secret is in the long molded piston head, which is very efficient in reflecting the sound waves. The plunger handle is made of flexible acetyl so it will not break.



PASCO Capstone controls the sine wave output of the 550 Universal Interface to drive the speaker. The FFT display of the Sound Sensor data shows the tube's resonant response.

The Resonance Air Column has a polycarbonate tube, so it will not break or chip like inferior acrylic. It includes eight plastic snap-on rings that can be slid along the tube to mark the nodes. A meter stick is used to read the positions of the rings.

The Sound Sensor (UI-5101) has a microphone on a 1.4 m long wire, so it can be used to find the nodes inside the Resonance Air Column.

The Resonance Air Column can be used as a closed or open tube. In the closed mode, tuning forks or speakers are suitable for sound sources. In the open mode, a speaker with a signal generator is required to vary the frequency until the tube sounds a resonance.

WA-9594 includes:
- Resonance Air Column (WA-9606)
- Mini Speaker (WA-9605)

WA-9606 includes:
- Tube and plunger
- Node markers (8)
- Detachable stands (2)

Material: Polycarbonate
Length: 4.0 ft (1.2 m)
Diameter: 1.5" O.D. (3.8 cm)
Wall Thickness: 1/16" (1.6 mm)
Plunger Length: 4.2 ft (1.3 m)
Plunger Handle: Acetyl

Mini Speaker WA-9605

The Mini Speaker (WA-9605) is specially made to work with the Resonance Air Column. It can be powered with the Function Generator (PI-8127), an 850 Universal Interface (UI-5000), or a 550 Universal Interface (UI-5001). It is also useful as a standalone speaker for doing interference demonstrations. Two Mini Speakers acting as point sources can output the same frequency and the spatial interference pattern can be explored.

Voltage: 10 V
Power: 2 W
Impedance: 8 Ω
Protection Resistor: 15 Ω, 2 W

Order Information

Mini Speaker	WA-9605

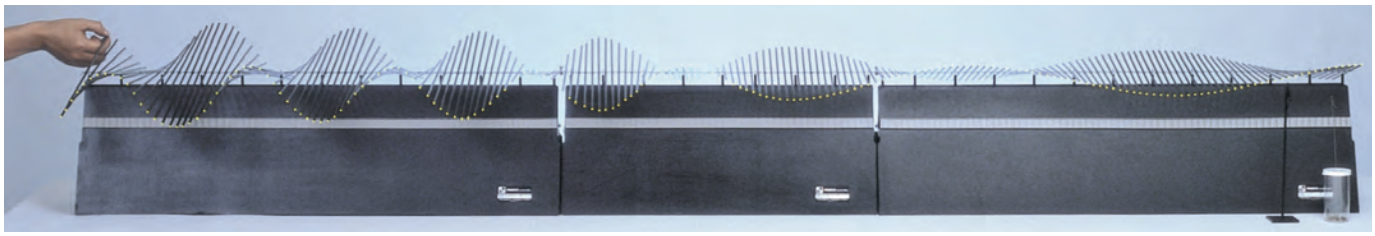
Order Information

Resonance Air Column with Speaker	WA-9594	
Resonance Air Column	WA-9606	
Shown in use with:		
550 Universal Interface	UI-5001	p. 28
Sound Sensor with Microphone	UI-5101	p. 34
Tuning Fork Set	SE-7342	p. 279
2 Meter Patch Cord Set	SE-9415A	p. 238

Complete Wave Motion Demonstrator

SE-9600

- Produces slow-moving, high-amplitude transverse waves
- Demonstrates all basic wave phenomena



The complete Wave Motion Demonstrator in three sections: The high-amplitude, slow-moving waves provide a fascinating introduction to basic wave phenomena.

The PASCO Complete Wave Motion Demonstrator allows mechanical waves to be created to demonstrate the behavior and properties common to many types of waves.

How It Works:

A series of steel rods is attached at their centers to a torsion wire. When a rod is displaced and released, a wave propagates along the rod. Velocity depends on the torsion constant of the wire and the moment of inertia of the rods.

Features:

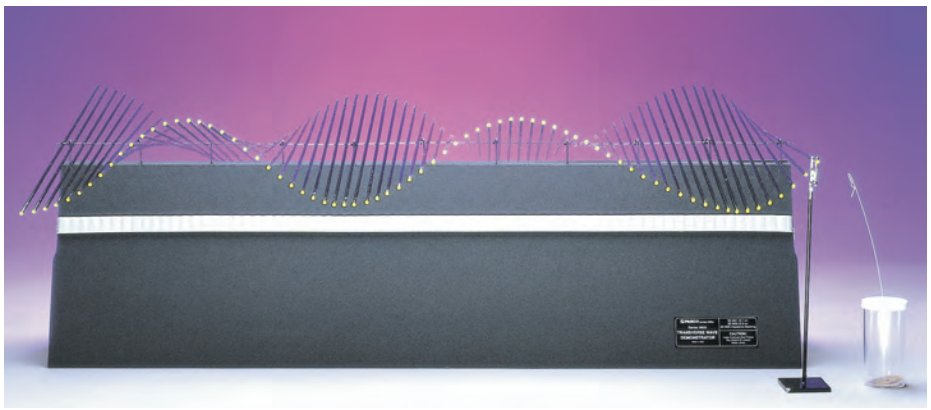
- **2.3 Meters Long:** Plenty of room to watch the wave develop and interact.
- **Three Wave Sections:** Each section has rods of different lengths, allowing reflection and transmission demonstrations.
  - Section 1 is 92 cm long with 46 cm rods.
  - Section 2 is 92 cm long with 23 cm rods.
    The resulting wave velocity is three times as fast.
  - Section 3 is 46 cm long with rods that vary exponentially from 46 cm to 23 cm.
    This section acts as an impedance-matching unit.
- **Yellow Rod Tips:** For easy viewing and to highlight the wave motion.
- **Folds:** For compact storage.
- **Easy Setup**

Order Information

Complete Wave Motion Demonstrator SE-9600

Single Section Wave Motion Demonstrator

SE-9601



A-frame design collapses for easy storage.

Includes:

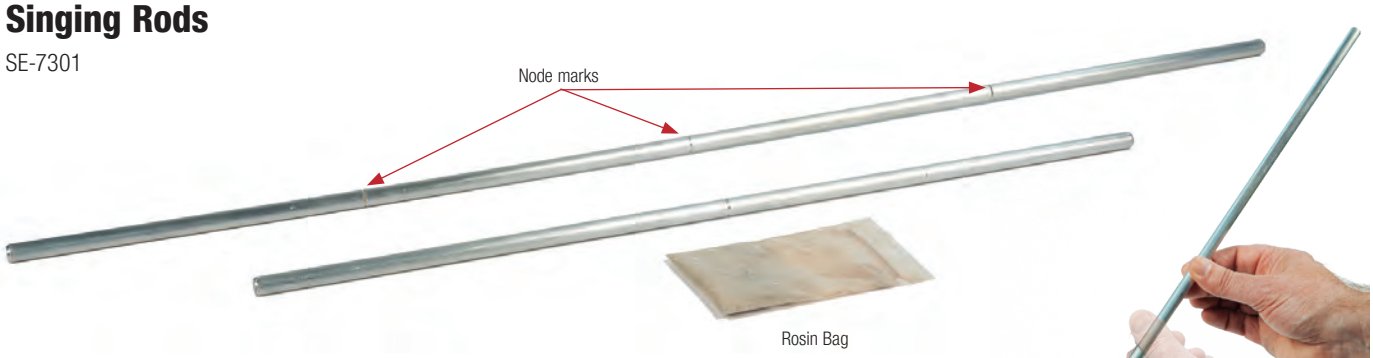
- Section with 46 cm long rods
- Total length of section: 92 cm
- Clamp for rigid termination
- Dash pot for liquid damping

Order Information

Single Section Wave Motion Demonstrator SE-9601

Singing Rods

SE-7301



These rods emit a VERY LOUD pure tone when stroked. The nodes are marked to indicate where you should hold the rod. Standing longitudinal waves can be created by stroking the rod with your fingers (coated with the included rosin). Investigate the effects of different lengths and holding the rod at different nodes.

Includes:

- Two aluminum rods approx. length: 20" (500 mm) and 30" (750 mm).
- Bag of crushed rosin to lightly coat your fingertips

Singing Rods SE-7301
Replacement Supplies:
Rosin Bag SE-6659

Snakey

SE-7331

This extra-long metal spring is ideal for studying mechanical waves.

The Snakey has an unstretched length of 2 meters. Pull the convenient end loops more than 10 meters apart to demonstrate transverse, longitudinal, and standing waves.

Easily create clear standing wave patterns.

Order Information

Snakey SE-7331

Bell Jar

SE-7725

This thick glass bell jar with base plate includes an electric bell on a rubber mount to demonstrate that sound does not propagate in a vacuum. Remove the air from the jar and the sound from the bell gradually fades.

Vacuum Pressure:
≤ -0.06 MPa

Voltage: 3 V DC

Jar: 6.5" dia. x 9.75" tall (inside: dia. 6.25" x 8" tall)

Base: 8" dia. x 1.5" high

Includes:

- Glass bell jar
- Vacuum base plate
- Gasket
- Hose
- Battery-operated electric bell (removable)

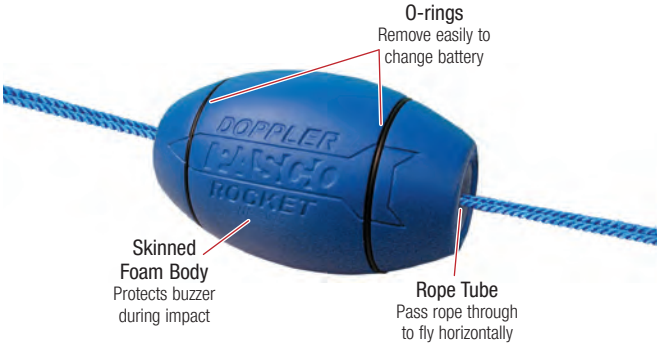
Order Information

Bell Jar SE-7725
Required: 2 AA batteries, Vacuum Pump

Doppler Rocket

WA-9826

- Experience the frequency shift of sound waves
- Easily generate high velocity motion
- Rugged construction



Fly Horizontally

A set of two ropes can be passed through the center of the unit. This allows students to use the included handles to propel the Doppler Rocket across the room at high velocities. The unit is guided by the ropes. Students hear the change in pitch as the Doppler Rocket flies past them.

The Doppler Rocket combines the elements of a toy with an audio Doppler shift to create an educational experience students won't forget. The Doppler Rocket emits a true, sinusoidal sound waveform at a constant frequency of approximately 620 Hz. The circuit and speaker are housed in skinned foam that protects the unit during normal impacts. The circuit is powered by a 9 V battery. As the Doppler Rocket passes the students, they hear a noticeable shift in frequency. Velocities of 10 m/s can be easily achieved, resulting in a 20 Hz shift in frequency.

Includes:

- Doppler Rocket
- Rope (30 m)
- Handles (4)
- Handle Cushions (4)
- Battery (9 V)

Order Information

Doppler Rocket WA-9826

Sound Pipe

SE-7724

When a student spins this pipe, the pipe produces an audible tone similar to that produced by blowing across the mouth of a bottle. As the pipe is spun faster, the resonant frequency increases. Five different frequencies can be achieved. (One pipe included. Color may vary.)

Order Information

Sound Pipe SE-7724

Double-Length Slinky

SE-8760

The Slinky is an excellent tool for demonstrating transverse and longitudinal wave phenomena. This Double-Length Slinky is twice as long as a traditional Slinky, allowing students to create well-defined wave pulses and standing wave patterns. The tension in the Slinky is very low, causing wave pulses to travel slowly throughout its length.

Order Information

Double-Length Slinky SE-8760

Elastic Wave Cord

SE-9409

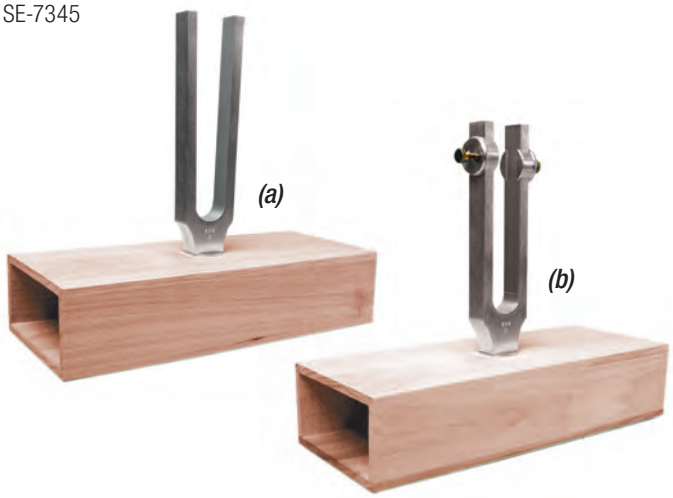
This highly visible elastic cord can be used to set up standing transverse waves, or plucked to demonstrate wave propagation. Approximately 3 mm diameter and 90 meters in length.

Order Information

Elastic Wave Cord SE-9409

Sympathetic Resonance Box Set

SE-7345



Resonance boxes are great instruments for amplifying sound from a tuning fork. These boxes are constructed from hardwood and feature an A4 tuning fork mounted directly to the box. Use Capstone software and a sound sensor (UI-5101) to measure the sound waves and beat frequencies created by these resonance boxes.

Includes:

- Hardwood resonance box with a 256 Hz A4 tuning fork
- Hardwood resonance box with an adjustable tuning fork

Order Information

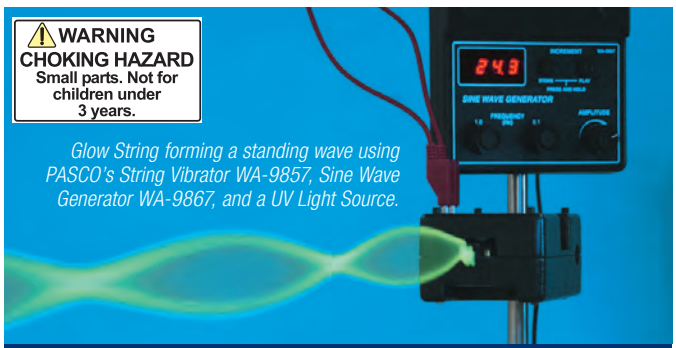
Sympathetic Resonance Box Set.....SE-7345
Recommended:
Sound Sensor UI-5101
850 Universal Interface.....UI-5000
PASCO Capstone

Glow String (2 Pack)

SE-8690

String color may vary.

This stretchy "string" glows in the dark after being exposed to light. Use it to demonstrate wave motion, including resonance and standing wave patterns. Two rolls are included, totaling over 15 meters of string.



Glow String forming a standing wave using PASCO's String Vibrator WA-9857, Sine Wave Generator WA-9867, and a UV Light Source.

Order Information

Glow String (2 Pack) SE-8690

Tuning Fork Set

SE-7342

The tuning fork has long been the tool of choice to help students understand the relationship between wave frequency and pitch. These high-quality aluminum tuning forks are both rugged and economical. The set includes eight forks representing a full octave of frequencies, a soft protective case, and a rubber mallet.

Note	Frequency
C	256 Hz
D	288 Hz
E	230 Hz
F	341.3 Hz
G	384 Hz
A	426.7 Hz
B	480 Hz
C	512 Hz

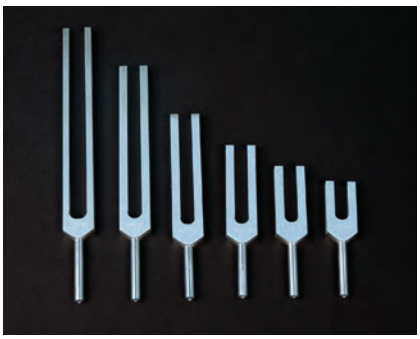
Order Information

Tuning Fork Set.....SE-7342

Tuning Fork Technical Set

SE-7728

This tuning fork set consists of six aluminum tuning forks: 125, 250, 500, 1000, 2000, and 4000 Hz. The frequencies are stamped on the forks.



Order Information

Tuning Fork Technical Set SE-7728

Basic Optics System

OS-8515C

- Geometric and ray optics
- Concave and convex lenses
- Concave/convex mirror

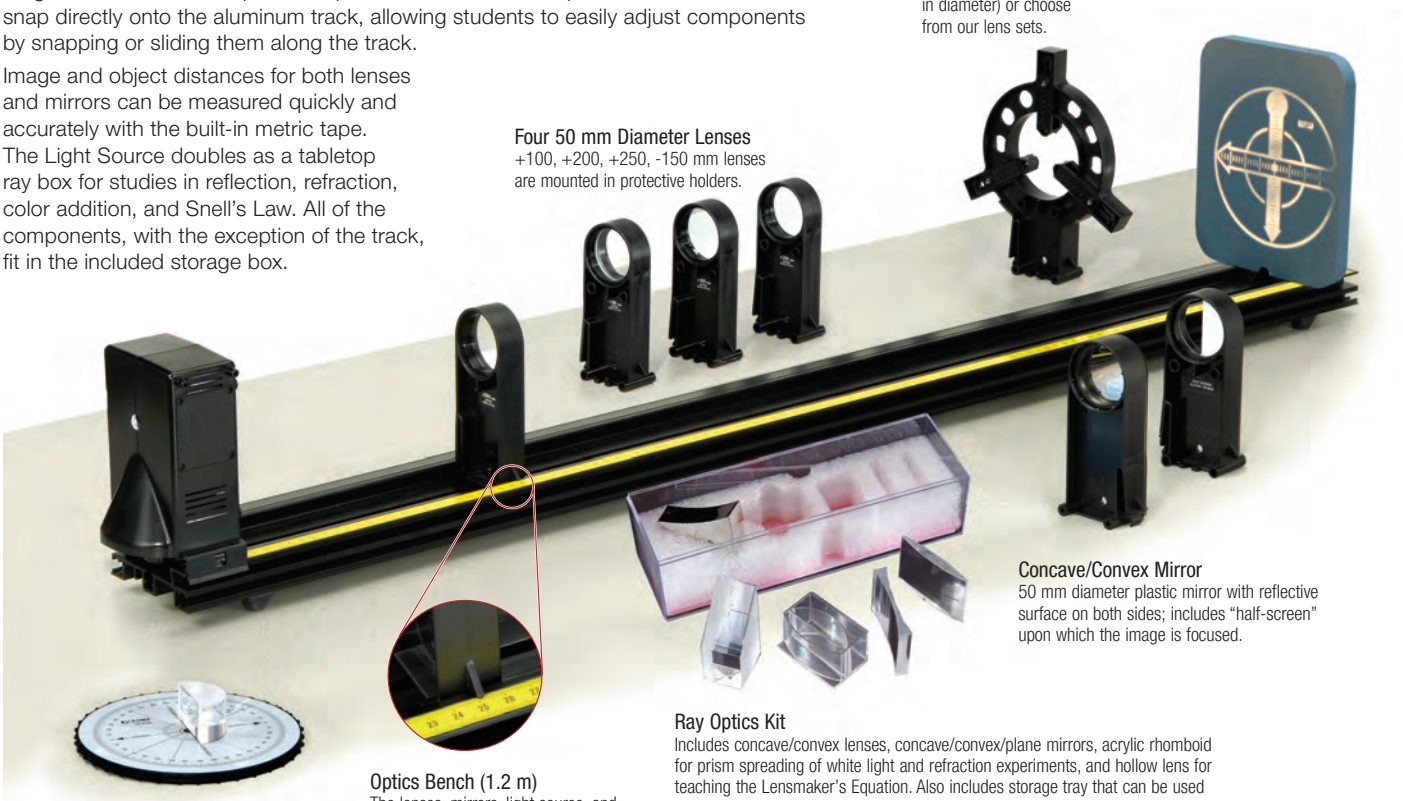
PASCO's Basic Optics System is easy-to-use, affordable, and ruggedly designed. Large, 50 mm diameter optics components are mounted in protective holders that snap directly onto the aluminum track, allowing students to easily adjust components by snapping or sliding them along the track.

Image and object distances for both lenses and mirrors can be measured quickly and accurately with the built-in metric tape. The Light Source doubles as a tabletop ray box for studies in reflection, refraction, color addition, and Snell's Law. All of the components, with the exception of the track, fit in the included storage box.

Viewing Screen
White plastic screen snaps into the optics bench and the position of the screen can be read directly on the bench scale.

Adjustable Lens Holder
Use your own lenses (from 19 mm to 75 mm in diameter) or choose from our lens sets.

Four 50 mm Diameter Lenses
+100, +200, +250, -150 mm lenses are mounted in protective holders.

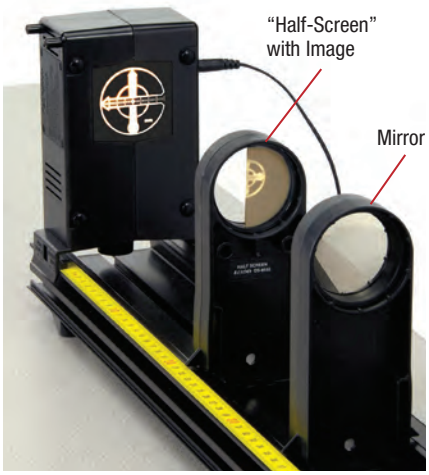


Concave/Convex Mirror
50 mm diameter plastic mirror with reflective surface on both sides; includes "half-screen" upon which the image is focused.

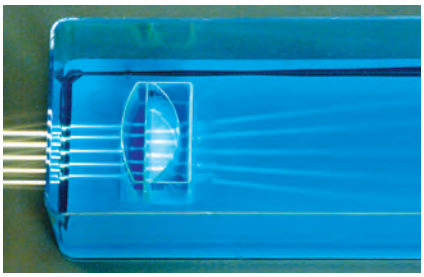
Ray Optics Kit
Includes concave/convex lenses, concave/convex/plane mirrors, acrylic rhomboid for prism spreading of white light and refraction experiments, and hollow lens for teaching the Lensmaker's Equation. Also includes storage tray that can be used as a water tank for the hollow lens.

Optics Bench (1.2 m)
The lenses, mirrors, light source, and screen snap into this rugged aluminum extrusion. The metric tape makes position measurements easy.

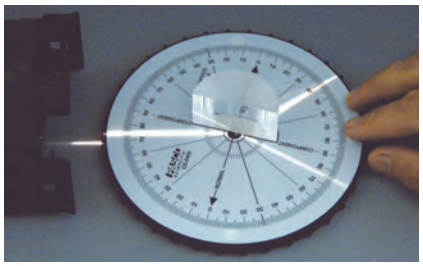
Ray Table
Two-piece construction allows the table to be rotated to study Snell's Law or the Law of Reflection. Includes D-shaped acrylic lens.



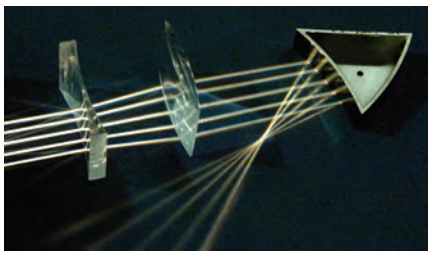
Light Source: Has a well-lit crossed arrow target with metric scale for focusing images through lenses or for use with the concave mirror.



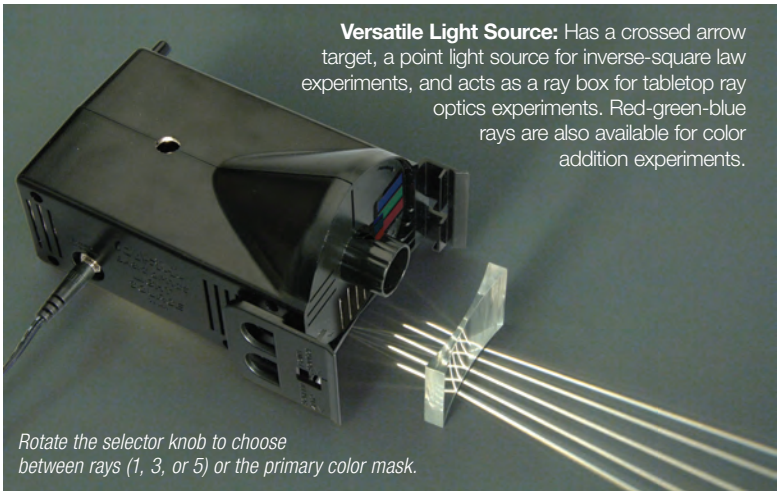
The storage tray is used to create a "hollow" air-filled convex lens. Note that the rays diverge.



Ray Table in use showing both the reflected and refracted rays

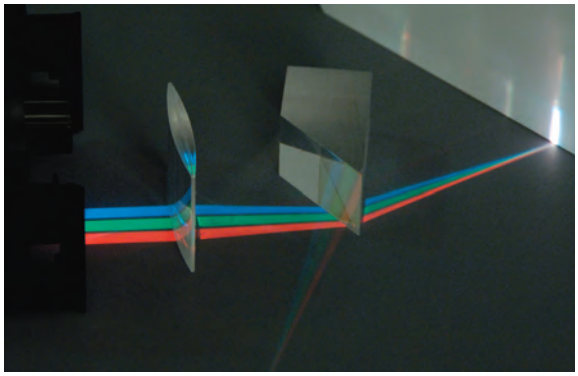


Components from the Ray Optics Kit showing refraction and reflection



Versatile Light Source: Has a crossed arrow target, a point light source for inverse-square law experiments, and acts as a ray box for tabletop ray optics experiments. Red-green-blue rays are also available for color addition experiments.

Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.



The primary color mask supports experiments in color addition using components from the Ray Optics Kit.

Perform These Experiments:

- Color Addition
- Prism
- Reflection
- Snell's Law
- Total Internal Reflection
- Convex and Concave Lenses
- Hollow Lens
- Lensmaker's Equation
- Apparent Depth
- Reversibility
- Dispersion
- Focal Length and Magnification of a Thin Lens
- Focal Length and Magnification of a Concave Mirror
- Virtual Images
- Telescopes and Microscopes
- Index of Refraction
- Shadows

Basic Optics System Storage Box

All components (except the track) fit in the custom foam box. There are additional slots for accessory lenses (see pp. 284-285).

Includes:

- 1.2 m Optics Track: OS-8508
- Basic Optics Light Source: OS-8470
- Accessory Lens Set: OS-8519
- Adjustable Lens Holder: OS-8474
- Ray Optics Kit: OS-8516A
- Basic Optics Viewing Screen: OS-8460
- Basic Optics Ray Table: OS-8465
- Basic Optics Geometric Lens Set: OS-8456
- Storage Box

Order Information

Basic Optics System OS-8515C

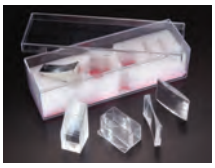
Basic Optics Components and Accessories

Dynamics Track Optics

p. 282

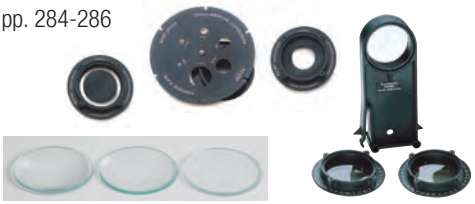
System Components

p. 283



Accessories & Lens Sets

pp. 284-286



Color Mixer

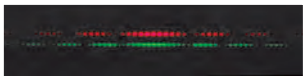
p. 287

Human Eye Model

pp. 288-289

Diffraction

pp. 290-295

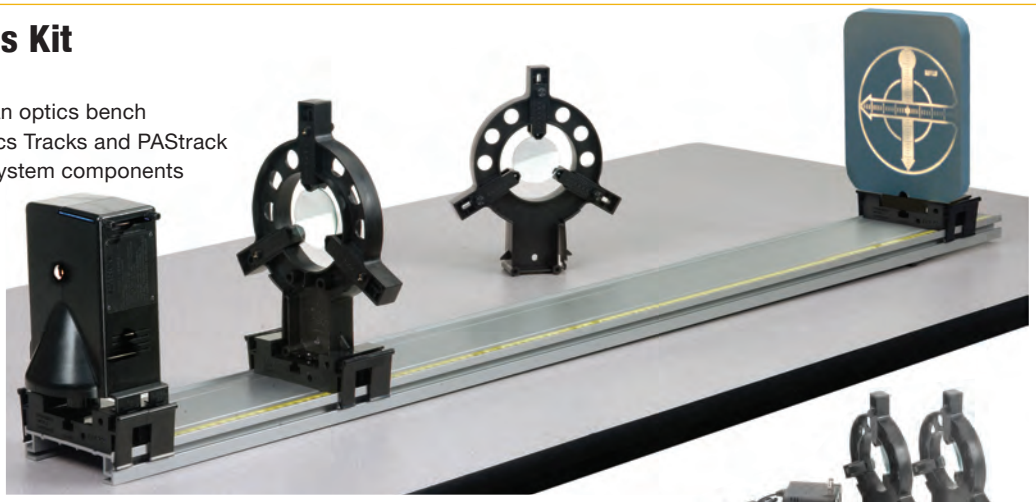


Dynamics Track Optics Kit

OS-8471A

- Turns your dynamics track into an optics bench
- Use with 1.2 m or 2.2 m Dynamics Tracks and PAStrack
- Expandable with Basic Optics System components

The PASCO Dynamics Track Optics Kit includes specially designed slides (carriages) that snap on the dynamics track. PASCO Basic Optics components attach directly to the carriage for positioning anywhere on the track. Choose from a wide range of optics components to expand your system.



Typical Experiments

- Focal Length and Magnification of a Thin Lens
- Telescope
- Microscope
- Shadows
- Virtual Images

To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Includes:

- Basic Optics Light Source
- Two Adjustable Lens/Mirror Holders +100 mm, +200 mm, and -150 mm Focal Length Lenses
- Viewing Screen
- Three Optics Carriages

Order Information

Dynamics Track Optics Kit	OS-8471A
Required:	
1.2 m Aluminum Dynamics Track	ME-9493
OR	
2.2 m Aluminum Dynamics Track	ME-9779
OR	
PAStrack	ME-6960

Beginning Optics System

OS-8459

This system is perfect for finding the focal length of a lens. This is a great starter system for studying optics, and it can be expanded using the components of the Basic Optics System.

Perform These Experiments:

- Focal Length and Magnification of a Thin Lens
- Telescope
- Microscope
- Shadows
- Virtual Images

Includes:

- Basic Optics Light Source (OS-8470)
- Adjustable Lens Holder (OS-8474) (2)
- Geometric Lens Set (OS-8466A)
- Basic Optics Viewing Screen (OS-8460)
- 1.2 m Optics Track (OS-8508)

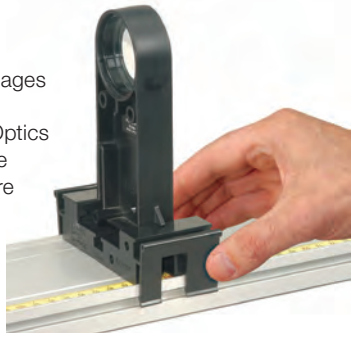
Order Information

Beginning Optics System	OS-8459

Dynamics Track Optics Carriages (Set of 4)

OS-8472A

The Dynamics Track Optics Carriages are designed to snap onto the PASCO Dynamics Track. Basic Optics components attach directly to the carriages for positioning anywhere on the track.



Includes:

- Carriages (4)

Order Information

Dynamics Track Optics Carriages (Set of 4)	OS-8472A

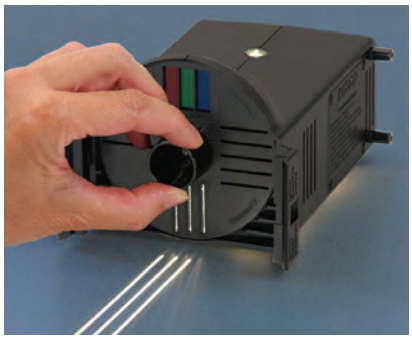
Basic Optics Light Source

OS-8470

- One, three, or five parallel rays
- Three primary colors source
- Crossed arrow object and point source

The Basic Optics Light Source is an excellent source for a variety of optics experiments. A single 10-watt quartz-halogen bulb provides bright, easy-to-see illumination without a lot of heat. By turning the box to a different side, it becomes a:

- Crossed Arrow Object with Metric Scale: ideal for showing images, focal point, and magnification.
- Bright Point Source: The very small filament of the halogen bulb provides an excellent point source for experimenting with shadows or the Inverse Square Law.
- Three Primary Colors Source: The red, green, and blue filters provide three rays of light that are easily combined with a lens for color mixing.
- One, Three or Five Ray Sources: Just rotate the knob in front of the light source to vary the number of rays produced.



Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.

The Basic Optics Light Source provides a point source and an extremely bright crossed arrow target. Use free-standing or easily clip directly to Basic Optics Track.

Includes:

- Universal AC Adapter
- Spare Bulb (stored under access cover)

Order Information

Basic Optics Light Source OS-8470

Ray Optics Kit

OS-8516A

The Ray Optics Kit is a basic set of optic components for ray and color experiments.

Includes:

- Double-Convex Lens
- Double-Concave Lens
- Rhomboid
- Eye-Dropper
- Triangular mirror accessory with concave, convex, and plane reflective surfaces
- Hollow lens to fill with a liquid or use as an air lens.

Order Information

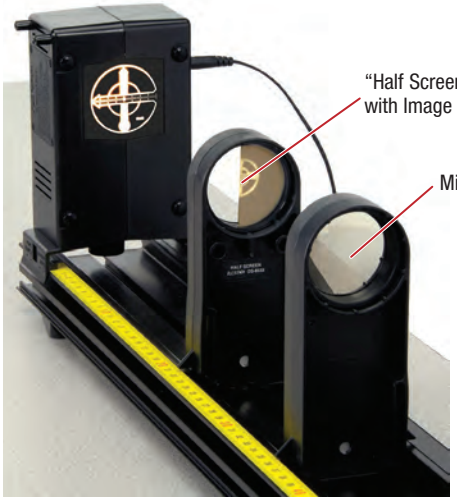
Ray Optics Kit OS-8516A

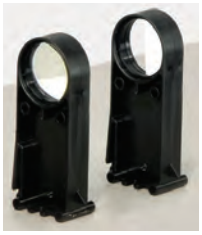
Concave/Convex Mirror

OS-8457

- 50 mm diameter
- ±100 mm focal length
- Plastic mirror

This double-sided convex/concave plastic mirror is mounted in a lens holder for easy placement on the Basic Optics Track. This accessory also includes a "half screen" that allows light to pass through on one side, and an opaque screen on the other half to focus the real image formed by the concave mirror.





Includes:

- Concave/Convex Mirror
- Half Screen

Order Information

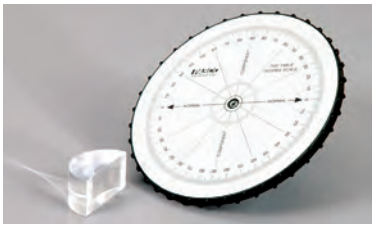
Concave/Convex Mirror OS-8457

Basic Optics Ray Table

OS-8465

- Angle of reflection
- Snell's Law
- Total internal reflection

The Ray Table provides an excellent viewing surface for ray optics. The table can be rotated about its axis to quickly change the incident angle of the ray. The resulting angles of reflection and refraction are easily measured directly off the polar grid printed on the table. The included acrylic cylindrical D lens simplifies the experiment by having the rays bend at only one surface. Investigate Snell's Law for both cases of rays either entering or leaving the acrylic lens.



Includes:

- Table
- D-shaped Lens

Order Information

Basic Optics Ray Table OS-8465

Aperture Accessories

OS-8524

Aperture Disk:

Simulate the compound lens system of a camera using the Aperture Disk. Simply snap the disk onto one face of a lens. The disk offers six different f-number settings for controlling the amount of light that reaches the viewing screen.

The ƒ-number is designated as ƒ / #, where # equals the focal length of the lens (ƒ) divided by the diameter of the aperture (D). Example uses a +100 mm lens.

ƒ-Number	*Aperture Diameter (mm)*
ƒ / 4	*25.0*
ƒ / 5.6	*17.7*
ƒ / 8	*12.5*
ƒ / 11	*8.8*
ƒ / 16	*6.3*
ƒ / 22	*4.4*

The Peripheral Mask passes light through the center only.

Spherical Aberration Attachments:

Do the center and outside parts of a lens focus light differently? With the Spherical Aberration Attachments, students will be surprised by the answer. Simply snap the attachments onto a lens from the Basic Optics System and compare the image distance (di) for each attachment.

Peripheral Mask shown mounted on +250 mm lens

The Center Mask passes light through an outside ring.

Includes:

- Aperture Disk and Holder
- Spherical Aberration Attachments

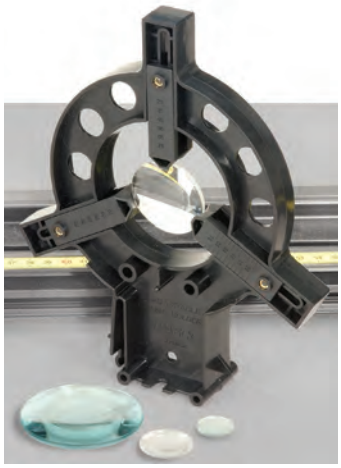
Order Information

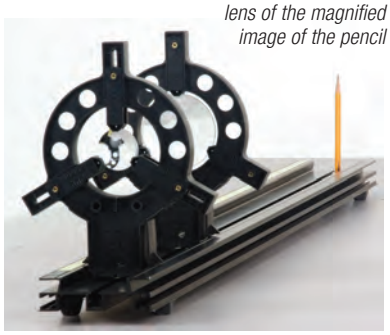
Aperture Accessories OS-8524

Adjustable Lens Holder

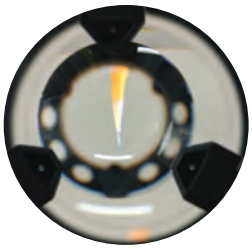
OS-8474

The Adjustable Lens Holder for the Basic Optics System is designed for use with lenses and mirrors with diameters between 19 mm and 75 mm. Simply place the lens or mirror in the holder and adjust the three arms to hold it. A set screw in each adjustable arm ensures that the mirror or lens will remain in place. The holder snaps into the Basic Optics Track and is designed to position all mirrors and lenses at the same height as the rest of the Basic Optics System components.





Actual view through the lens of the magnified image of the pencil



Build a telescope or microscope; shown with 1.2 m Basic Optics Track OS-8508.

Includes:

- Adjustable Lens Holder (lenses not included)

Order Information

Adjustable Lens Holder OS-8474

Lens Holder Set

OS-8522

These holders for the Basic Optics System are an excellent way to permanently mount 50 mm diameter lenses.

Just push in the two retaining rings to hold the lens in place.

Order Information

Lens Holder Set OS-8522

50 mm Diameter Lens Assortment

SE-7581

This set of 6 lenses is made of polished glass with ground edges, and comes in a wooden storage box.

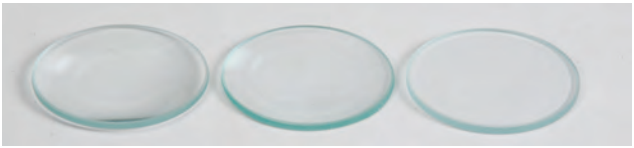
Focal Length (mm)	Description	Focal Length (mm)	Description
+1000	double convex	-1000	double concave
+300	double convex	-200	double concave
+150	double convex	-150	double concave

Order Information

50 mm Diameter Lens Assortment SE-7581

Geometric Lens Set

OS-8466A



This is a set of three unmounted 50 mm diameter glass lenses with focal lengths of +100 mm, +200 mm, and -150 mm. These are the same lenses included in the Dynamics Track Optics Kit (OS-8471A) and the Beginning Optics System (OS-8459). They can be mounted in the Adjustable Lens Holder (OS-8474).

Order Information

Geometric Lens Set OS-8466A

Lens Sets

Basic Optics Geometric Lens Set (Set of 2)

(+200, +100 mm) OS-8456

Accessory Lens Set (Set of 2)

(+250, -150 mm) OS-8519

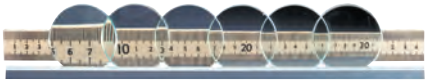
Each lens is mounted in a lens holder for protection and easy storage. The lens holder clips directly to the Basic Optics Track.

Order Information

Basic Optics Geometric Lens Set..... OS-8456
Accessory Lens Set OS-8519

Ground Glass Lenses (Set of 6)

SE-9013



These precision ground glass lenses provide a useful range of focal lengths. Each lens has a 50 mm diameter – small enough for easy mounting, yet large enough for effective viewing. The set of six comes in a convenient storage box.

Focal Length	Description	Focal Length	Description
500 mm	concave convex	-150 mm	double concave
300 mm	plano convex	-300 mm	plano concave
150 mm	double convex	-500 mm	convex concave

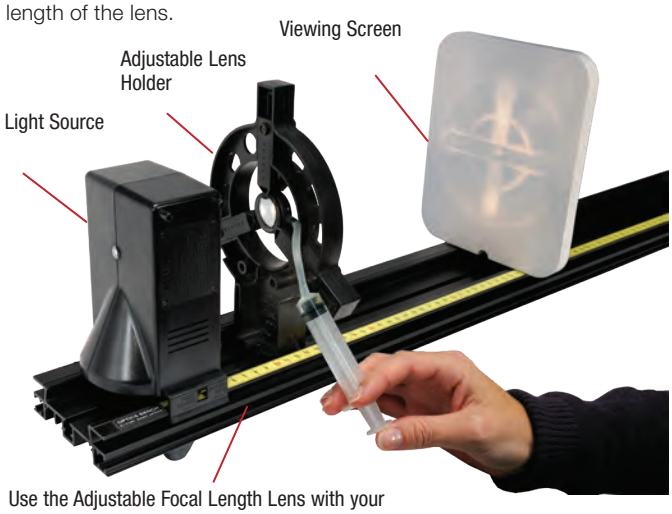
Order Information

Ground Glass Lenses (Set of 6) SE-9013

Adjustable Focal Length Lens

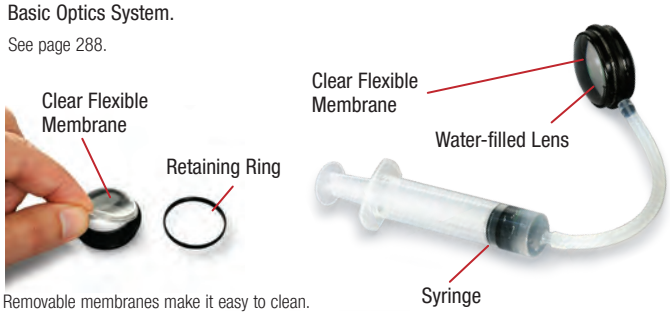
OS-8494

Using the syringe to adjust the amount of water in the lens changes the curvature of the clear flexible membranes and, therefore, the focal length of the lens.



Use the Adjustable Focal Length Lens with your Basic Optics System.

See page 288.



Removable membranes make it easy to clean.

Includes:

- 10 mL Syringe
- 1 ft. Silicon Tubing
- Lenses (2)

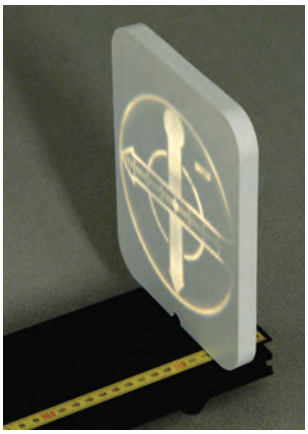
Order Information

Adjustable Focal Length Lens..... OS-8494
Shown in use with:
Basic Optics System ..... OS-8515C p. 280

Basic Optics Viewing Screen

OS-8460

This white plastic screen is used with the Basic Optics System. The screen snaps into the optics bench, and the position of the screen can be read directly on the bench scale. Also fits the Dynamics Track Optics Carriages (OS-8472 on page 280) for use with a Dynamics Track.



Order Information

Basic Optics Viewing Screen OS-8460

Basic Optics Spares Kit

OS-8510

All parts are organized in a plastic case for easy storage.

The Basic Optics Spares Kit includes many of the small parts that are sometimes lost after student use. Also includes two replacement bulbs for the Light Source. Suitable for all versions of the Basic Optics System (OS-8515).

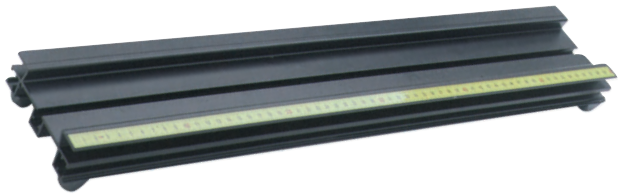
Includes:

- 10 W bulb for Basic Optics Light Source OS-8470 or OS-8517 (2)
- 6-32 1-1/2" Screw for the Basic Optics Light Source OS-8517A (8)
- 3/8" Screw for optics accessories (6)
- 3/8" Brass thumbscrew for optics track brackets (4)
- 1/4-20 1/2" Nylon thumbscrews (8)
- 1/4-20 Square nuts (20)
- Nylon washers (6)
- 1/4-20 9/16" Round steel thumbscrews (4)
- 1/4-20 3/8" Round steel thumbscrews (4)
- 6-32 5/8" Round steel thumbscrews (6)
- 6-32 3/8" Round steel thumbscrews (4)
- 4-40 5/16" Round steel thumbscrews (4)
- 6-32 3/16" Round steel thumbscrews (4)
- Replacement rubber feet for optics bench (6)
- Replacement rubber feet for Basic Optics Light Source OS-8517 (15)
- Replacement screws for Basic Optics Light Source OS-8470 (4)
- Plastic storage box

Order Information

Spares Kit OS-8510

Optics Benches



Optics Bench (60 cm)

OS-8541

This short optical bench is for experiments in polarization and spectrophotometry.

1.2 m Optics Track

OS-8508

The 1.2 m Optics Track is the perfect length for studying the inverse square law, diffraction/interference patterns, and the behavior of light traveling through lenses or off of curved mirrors. It is made of extruded aluminum and has a wide central channel for PASCO optics components, such as mounted lenses, mirrors, and light boxes.

Order Information

Optics Benches (60 cm) OS-8541
1.2 m Optics Track OS-8508

Optics Bench Rod Clamp (Set of 2)

OS-8479

Rod Clamps are used to elevate Basic Optics benches to match the height of various light sources.

Includes:

- Rod Clamps (2)

Order Information

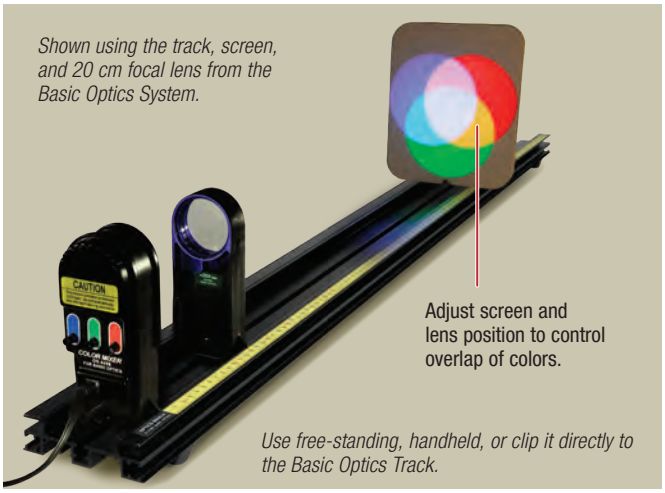
Optics Bench Rod Clamp (set of 2) OS-8479
Shown in use with:
Round Base with Rod ME-8270

Color Mixer

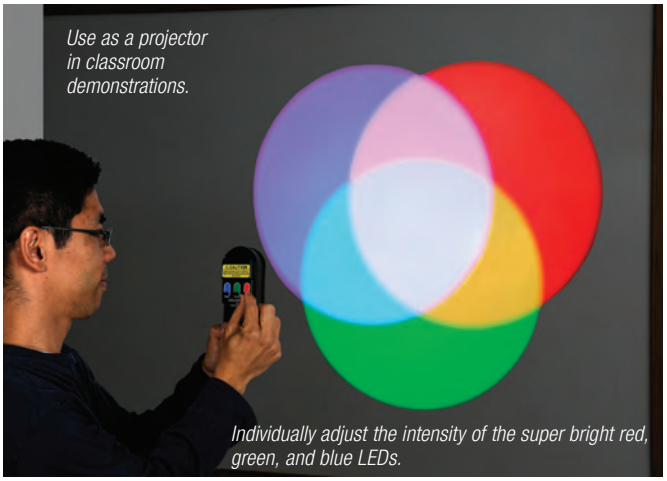
OS-8496

- Demonstrates additive color mixing
- Accessory to Basic Optics System

Three independently controllable LEDs offer a simple way to explore light and color. The Color Mixer can be used as both a demonstration tool and as an expansion piece to the Basic Optics System.



The intensity of the red, green and blue LEDs of the Color Mixer can be individually adjusted to easily vary the intensity of any or all of them. Demonstrating additive color mixing is as simple as using any flat surface to project the light upon.



Includes:

- Tri-color light source
- Power supply

Order Information

Color Mixer OS-8496

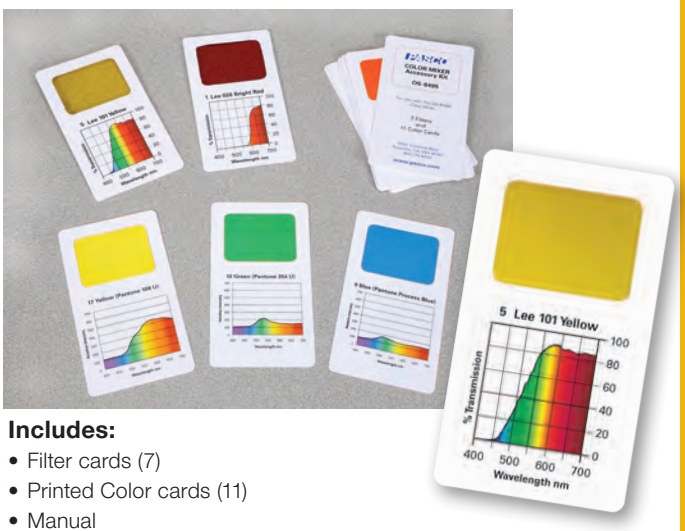
Color Mixer Accessory Kit

OS-8495

- Accessory to the Color Mixer
- 7 filter cards
- 11 printed color cards
- Manual with 9 lab activities

The red filter's spectral chart shows it transmits only red light. Students observe that the blue and green circles disappear and the overlapping areas of magenta, yellow, and white become red.

The Color Mixer Accessory Kit has 18 cards (64 mm x 89 mm) and a manual with 9 associated lab activities. Each of the 7 filter cards has its transmission spectrum printed on the card. Each of the 11 color cards is printed with a different color and its associated relative reflectance spectrum. Printed colors are defined by the Pantone color matching system. This accessory kit was designed especially for use with the Color Mixer.



Includes:

- Filter cards (7)
- Printed Color cards (11)
- Manual

Order Information

Color Mixer Accessory Kit OS-8495

Optics of the Human Eye

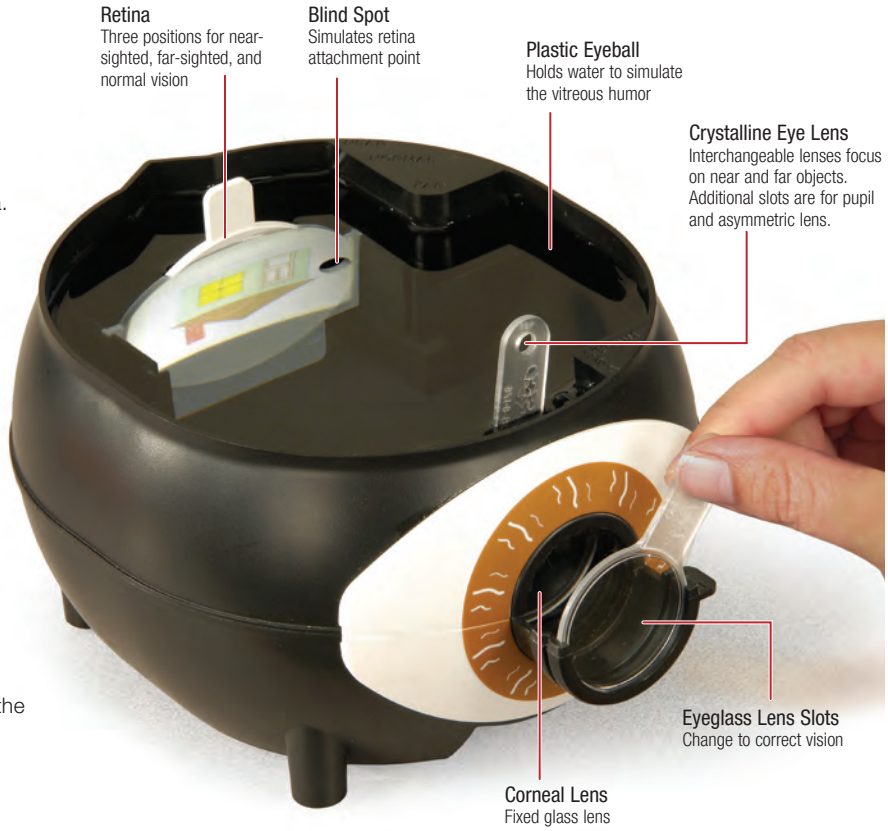
Human Eye Model

OS-8477A

- Classic eye model at an affordable price
- 3-D working model of the human eye

Features:

- **Working Model of the Human Eye:** Two lenses are used to form images on the retina. Sealed tank holds water to simulate the vitreous humor. Size and orientation of the illuminated object can be easily measured.
- **Study the Optics of Normal Vision and Vision Correction:** Use the included plastic lenses to create images for normal vision, far-sightedness, near-sightedness, and astigmatism. Additional lenses are placed in front of the eye to correct for vision problems.
- **Fixed Corneal Lens and Interchangeable Crystalline Lens:** The crystalline lens is surrounded by water (vitreous humor). By changing the crystalline lens, the eye can focus on both near and far objects.
- **Movable Retina:** Three positions demonstrate near-sightedness, far-sightedness, and normal vision.
- **Variable Pupil Size:** Students can observe the change in brightness and clarity of the image as the pupil size is reduced.



Use the Pupil Aperture to reduce the pupil size or to change the shape to a "cat's eye."

Use the Eye Model to image any illuminated picture, or use it with the Basic Optics System and Eye Model Bracket on page 289.

Includes:

- Molded Plastic Eyeball
- Plastic Lenses (2 sets of 6)
- Pupil Aperture
- Retina Screen
- Optics Caliper
- Adjustable Focal Length Lens with Syringe, Tubing, and 2 Flexible Lenses
- Experiment Manual

Specifications:

Focal Lengths in Air of Plastic Lenses: +62 mm (+16d), +120 mm (+8.3d), +400 mm (+2.5d), -1000 mm (-1.0d), -128 mm (-7.8d) cylindrical, +307 mm (+3.26d) cylindrical

Corneal Lens Focal Length in Air: +140 mm (+7.1d)

Dimensions: 15 cm x 17 cm x 10 cm high

Order Information

Human Eye Model	OS-8477A	
Recommended:		
Basic Optics Light Source	OS-8470	p. 283
Lens Replacement Set (includes lenses, screen, and pupil)	OS-8476	
Optics Caliper	OS-8468	p. 289

Eye Model Bracket

OS-8469

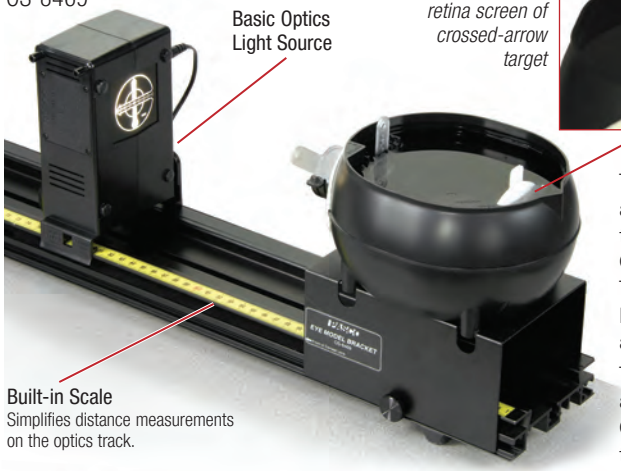
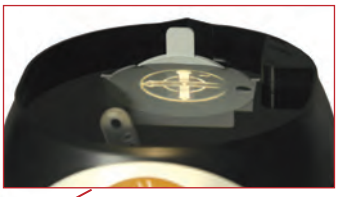
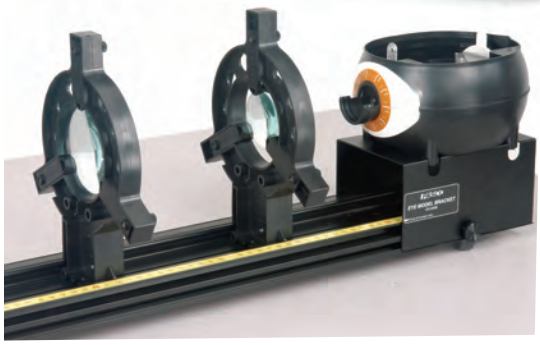


Image on retina screen of crossed-arrow target



The Eye Model Bracket allows the Human Eye Model to be used with the Basic Optics System (OS-8515C). The bracket holds the Eye Model securely on the track at the correct optical height.

The illuminated crossed-arrow target on the Basic Optics Light Source makes the perfect object. Easily measure object and image distances, as well as the size of the object and image for calculations of magnification.



Eye Model and Bracket are shown with a telescope made using two Adjustable Lens Holders (OS-8474) and accessory lenses. Students can see the image through the telescope with their own eyes, and then place the Eye Model on the track and see the same image projected on the retina screen.

Includes:

- Bracket
- Two 1/4-20 thumb screws with nuts (2)

Order Information

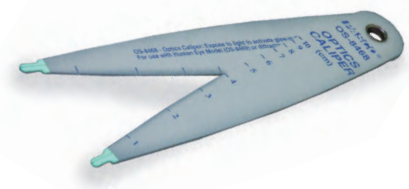
Eye Model Bracket..... OS-8469
Shown in use with:
Basic Optics System OS-8515C
Human Eye Model..... OS-8477A

Optics Caliper

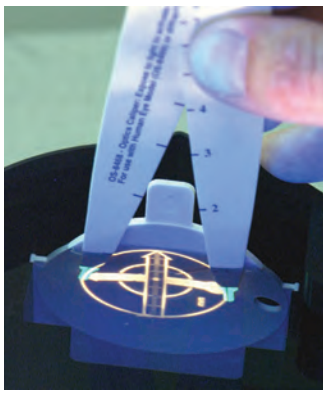
OS-8468

- Glow-in-the-dark tips
- Waterproof

This lightweight plastic caliper is perfect for measuring images in the dark. Simply span the object and then use a scale to measure the distance. For approximate measurements, use the built-in cm scale on the calipers.



The tips of the caliper glow in the dark. Activate with an incandescent or UV lamp.



Use the Optics Caliper to measure image sizes in the Human Eye Model. Glow-in-the-dark tips are activated using a UV light source.

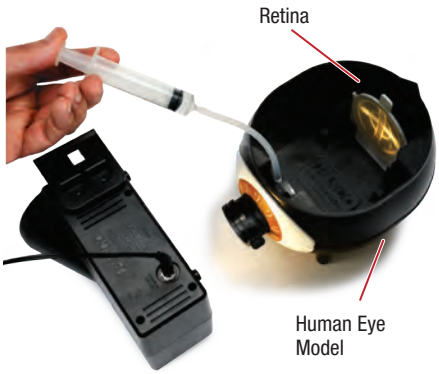
Order Information

Optics Caliper
(set of 5).....OS-8468

Adjustable Focal Length Lens

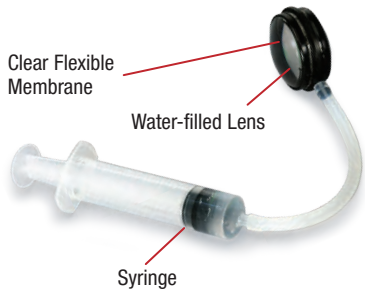
OS-8494

Using the syringe to adjust the amount of water in the lens changes the curvature of the clear flexible membranes and, therefore, the focal length of the lens.



Demonstrate accommodation:
Show how the eye lens changes focal length by changing its surface curvature.

See page 280 for use with Basic Optics System.



Includes:

- 10 mL Syringe
- 1 ft. Silicon Tubing
- Lenses (2)

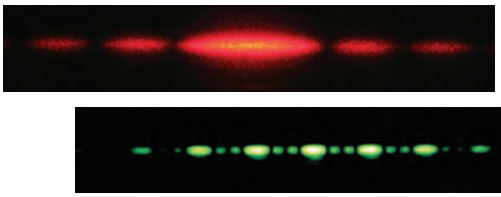
Order Information

Adjustable Focal
Length Lens..... OS-8494
Shown in use with:
Human Eye Model..... OS-8477A

Wireless Diffraction System with Track

OS-8439

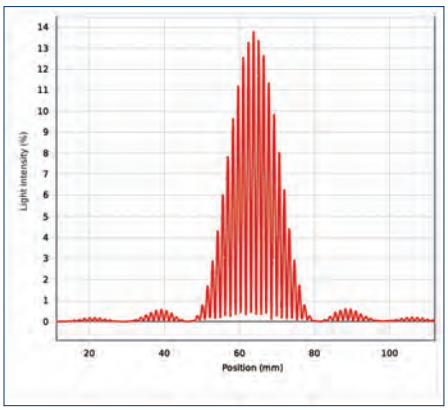
- Everything needed to scan diffraction and interference patterns
- Improved design at a lower price
- Integrated Bluetooth® light and position sensors



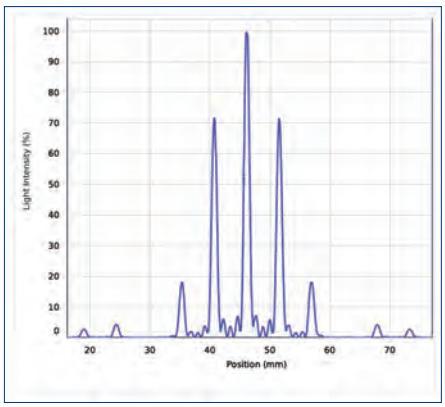
Four slits illuminated with a green laser reveal the expected two minor maxima.

Extremely easy setup and great results!

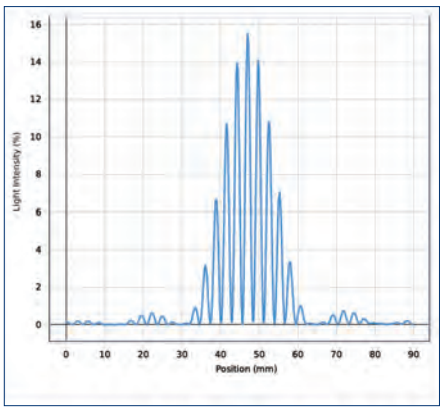
This new design incorporates Bluetooth® light and position sensors into one convenient unit. Smooth hand-cranked scanning is achieved with a precision worm gear. The reduced number of parts makes assembly and alignment very easy.



This system works so well that many orders of diffraction can be detected.



The high resolution enables students to see the three minor maxima when scanning five slits.



Actual double-slit graph of Intensity vs. Distance looks just like the textbook illustrations.

Includes:

- Red Diode Laser: OS-8525A
- Diffraction Slits: OS-8442
- Wireless Diffraction Scanner: OS-8441
- 1.2 m Optics Track: OS-8508

Order Information

Wireless Diffraction System with Track OS-8439
Recommended:
Green Diode Laser ..... OS-8458B p. 295

Wireless Diffraction Scanner

OS-8441

- Real-time Intensity vs. Position graphs
- Single-slit diffraction
- Double-slit interference
- Precision hand crank for smooth, consistent travel
- Light sensor aperture adjustment
- 0.01 mm position measurement resolution
- Wireless Bluetooth® Low Energy technology

The Wireless Diffraction Scanner combines a position sensor with a light sensor for scanning diffraction patterns. Compatible with PASCO optics benches and dynamics track adapter carriages, the Wireless Diffraction Scanner is the perfect update to existing PASCO-based optics systems that use the snap-in optics components. An included aperture setting allows for the adjustment of width-measurement resolution and light attenuation. A hand crank allows for smooth scanning of diffraction patterns. And, with its wireless design, smooth scans are achieved effortlessly!

This unit enables students to scan many diffraction and interference patterns during one lab period. They can study the differences caused by changing the slit width, slit separation, and number of slits. And, by comparing patterns created by a Red Diode Laser to those of a Green Diode Laser, they can study the difference caused by a change in wavelength.

Data collection is performed using either PASCO Capstone or SPARKvue software (required). Connect to software using either USB or Bluetooth Low Energy.

Specifications:

Aperture Range: 0.1 mm to 1.5 mm

Position Resolution: .01 mm

Battery: Rechargeable Lithium-Polymer 1000 mA

Connectivity: USB or Bluetooth® Low Energy

Scan Travel: 155 mm

Includes:

- USB Charging Cable

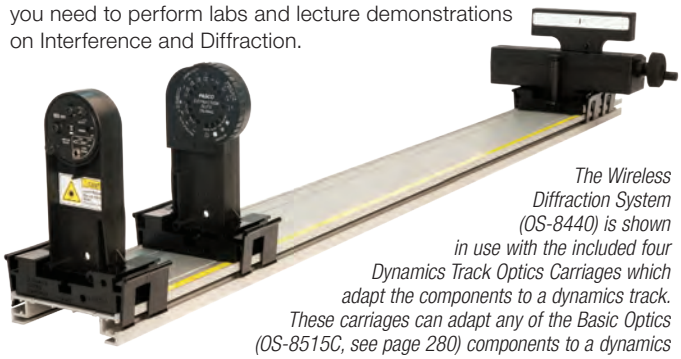
Order Information

Wireless Diffraction Scanner	OS-8441

Wireless Diffraction System

OS-8440

If you already have a PASCO Optics Track, or a PASCO Dynamics Track, the Wireless Diffraction System contains all the equipment you need to perform labs and lecture demonstrations on Interference and Diffraction.



The Wireless Diffraction System (OS-8440) is shown in use with the included four Dynamics Track Optics Carriages which adapt the components to a dynamics track. These carriages can adapt any of the Basic Optics (OS-8515C, see page 280) components to a dynamics track, turning your dynamics track into an optical bench.

Includes:

- Red Diode Laser: OS-8525A
- Wireless Diffraction Scanner: OS-8441
- Diffraction Slits: OS-8442
- Dynamics Track Optics Carriages (Set of 4): OS-8472A

Order Information

Wireless Diffraction System	OS-8440	
Required:		
1.2 m Optics Track	OS-8508	p. 286
OR		
1.2 m Aluminum Dynamics Track	ME-9493	p. 115
OR		
PAStrack	ME-6960	p. 116

Diffraction Slits

OS-8442

The Diffraction Slits include a selectable wheel with 16 interference patterns designed to match the height of the PASCO Diode Lasers. The slits are constructed using vacuum deposited chromium on glass and clip directly to a PASCO Optics Bench.

Specifications:

Compatible System:
PASCO Optics Track

Slit Width Tolerance (mm): ± 0.005

Slit Spacing Tolerance (mm): ± 0.010 (spacing > 0.125)

Slit Spacing Tolerance (mm): ± 0.005 (spacing < 0.125)

Printing Type: Vacuum-deposited Chromium on glass

Single Slit Width (mm): a = 0.02, 0.04, 0.08, 0.16

Double Slit Width, Separation (mm):
a = 0.04, d = 0.25 ; a = 0.04, d = 0.50

Double Slit Width, Separation (mm):
a = 0.08, d = 0.25 ; a = 0.08, d = 0.50

Multiple Slits (mm): 2, 3, 4, 5 (a = 0.04, d = 0.125)

Patterns: Square, Hexagonal, Dots, Holes

Order Information

Diffraction Slits	OS-8442

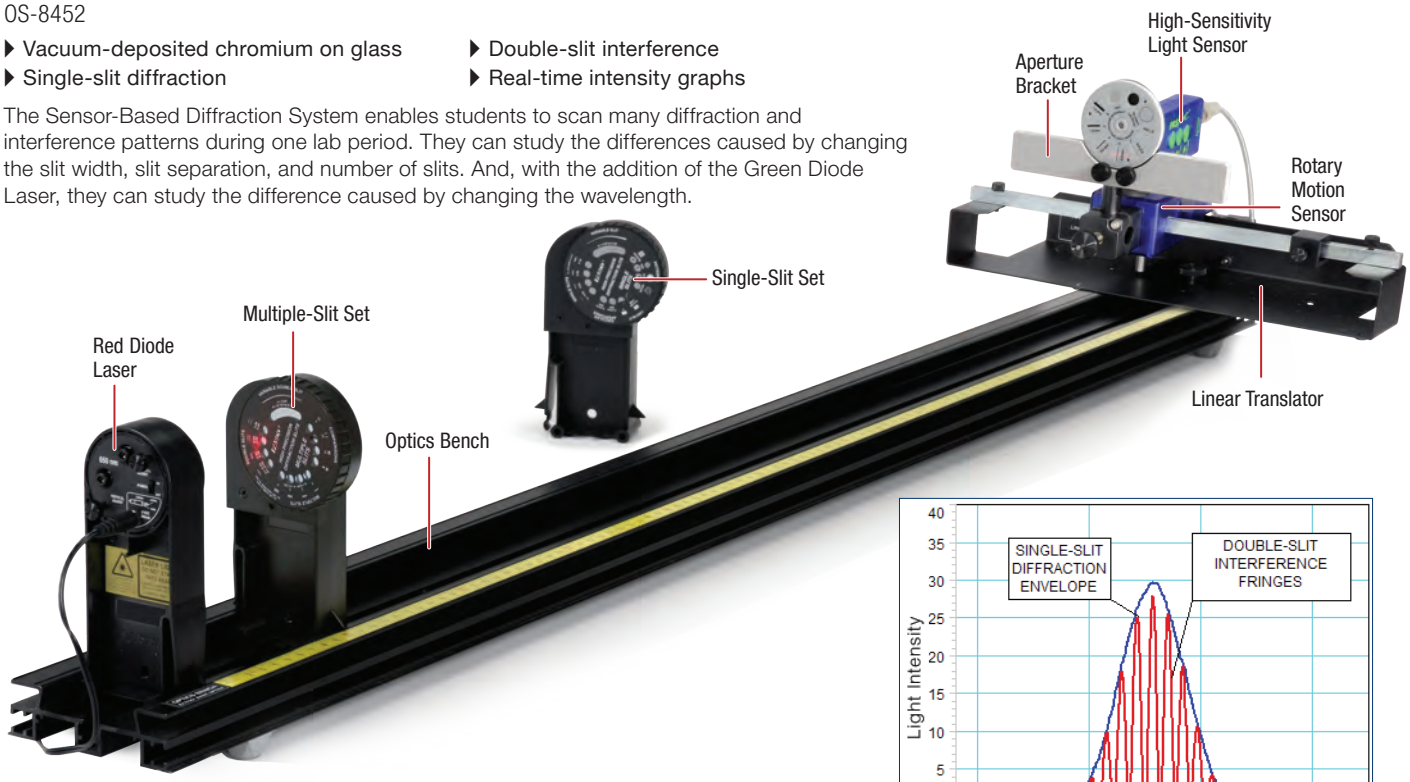
Sensor-Based Diffraction System

OS-8452

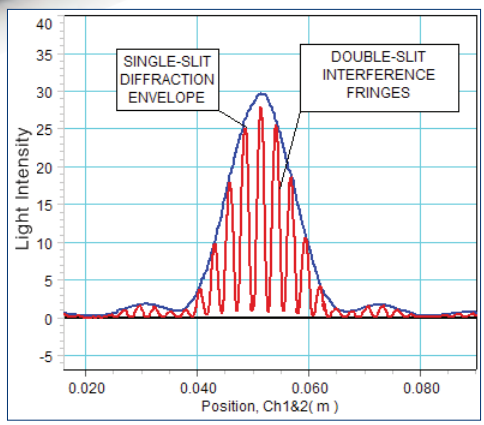
CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

- Vacuum-deposited chromium on glass
- Single-slit diffraction
- Double-slit interference
- Real-time intensity graphs

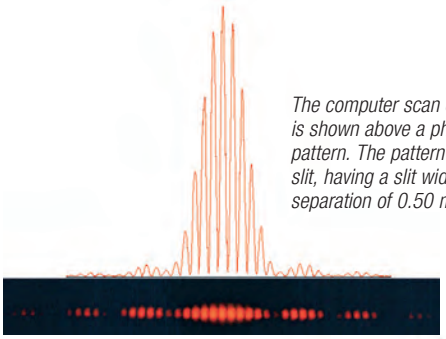
The Sensor-Based Diffraction System enables students to scan many diffraction and interference patterns during one lab period. They can study the differences caused by changing the slit width, slit separation, and number of slits. And, with the addition of the Green Diode Laser, they can study the difference caused by changing the wavelength.



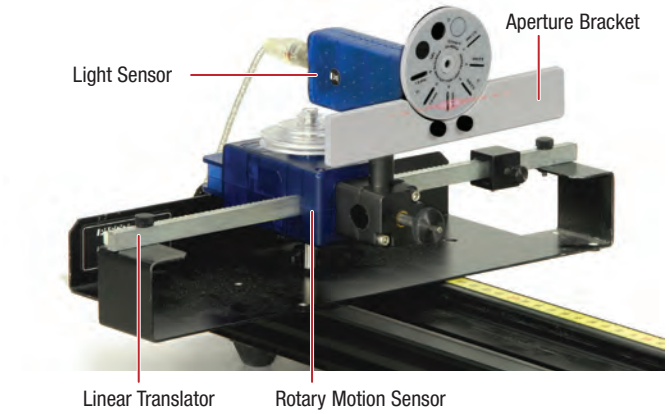
Scanning with the Linear Translator (on page 295): In this unique scanning system, the diffraction pattern is scanned using a Light Sensor attached to a Rotary Motion Sensor. As the wheel on the Rotary Motion Sensor is rotated by hand, the Rotary Motion Sensor moves along a gear rack (called the Linear Translator). Students make the association between the diffraction pattern they see and the real-time graph of the light intensity vs. position.



Computer scan of a single-slit and double-slit having the same slit width



The computer scan of an interference pattern is shown above a photograph of the actual laser pattern. The pattern was produced with a double-slit, having a slit width of 0.08 mm and a slit separation of 0.50 mm.



Includes:

- Red Diode Laser: OS-8525A
- Linear Translator: OS-8535A
- Aperture Bracket: OS-8534A
- 1.2 m Optics Track: OS-8508
- Precision Diffraction Slits: OS-8453

For components and accessories, see pages 294-295.

Order Information

Sensor-Based Diffraction System (with Optics Bench)	OS-8452	
Required for use with ScienceWorkshop:		
Light Sensor	CI-6504A	p. 36
Rotary Motion Sensor	CI-6538	p. 32
Required for use with PASPORT:		
PASPORT High Sensitivity Light Sensor	PS-2176	p. 48
PASPORT Rotary Motion Sensor	PS-2120A	p. 41
Recommended:		
Green Diode Laser	OS-8458B	p. 295

Diffraction Optics Kit

OS-8531A

Add this kit to the Basic Optics System to allow the investigation of a wide variety of diffraction slit patterns. The slits are constructed using vacuum-deposited chromium on glass.

The following patterns are included:

- Single Slit (four variations)
- Variable Width Single Slit
- Double Slit (four variations)
- Multiple Slit (3,4,5)
- Single Slit/Double Slit Comparison
- Variable Spacing Double Slit

Single Slit Pattern (a = 0.04 mm)

Double Slit Pattern (a = 0.08 mm, d = 0.05 mm)

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

4-Slit Pattern (a = 0.04 mm, d = 0.125 mm)

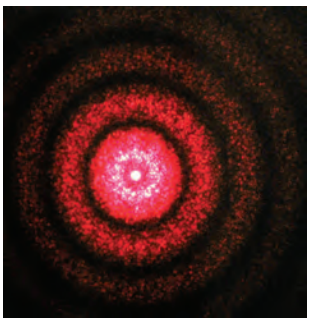
Single/Double Slit Comparison

Easy Laser Alignment

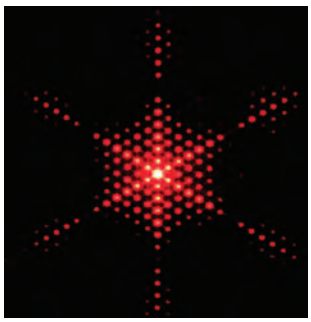
The laser beam can be aimed through the slits using two thumb screws. Once the beam is aligned, either the laser or the slits can be removed from the optics bench and returned to the bench without re-aligning the beam.

Change Slits in the Dark Without Re-aligning Everything

The slit wheels eliminate the frustration of trying to change the slits in a darkened room. Simply rotate to the next positive click to lock a different slit into position. The alignment of the disk only has to be done once. After that, all the slits on that wheel will be aligned.



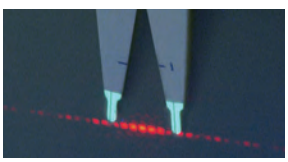
Circular Diffraction Pattern



Hex Diffraction Pattern

Optics Caliper

OS-8468



This lightweight plastic caliper is perfect for measuring images in the dark. Simply span the object and then use a scale to measure the distance. For approximate measurements, use the built-in cm scale on the calipers. See page 281 for more information.

Order Information

Optics Caliper	OS-8468

Includes:

- Red Diode Laser: OS-8525A
- Precision Diffraction Slits: OS-8453

For components and accessories, see pages 294-295.

Order Information

Diffraction Optics Kit	OS-8531A	
Required:		
1.2 m Optics Track	OS-8508	p. 286
Basic Optics Viewing Screen	OS-8460	p. 286
Recommended:		
Green Diode Laser	OS-8458B	p. 295

Diffraction Components

Precision Diffraction Slits

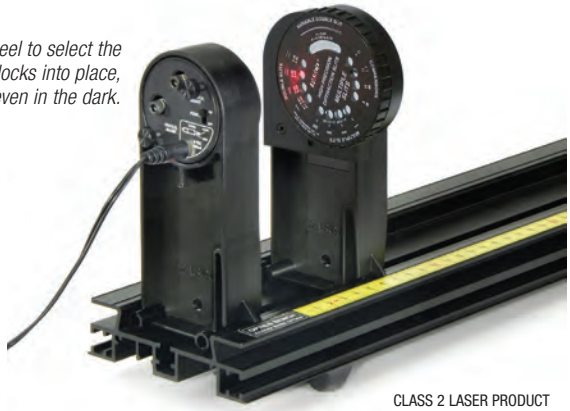
OS-8453

- Vacuum-deposited chromium on glass
- Single-slit and double-slit wheels

OS-8453 includes two slit wheels with holders designed to match the height of the slits to the height of the diode laser. All components clip directly to the Optics Bench from the Basic Optics System OS-8515C. The slit wheels eliminate the frustration of trying to change the slits in a darkened room. To change the slit being illuminated by the laser, the slit wheel is simply rotated to the next positive click, which locks another slit into position.

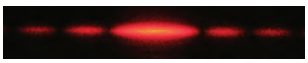
Shown in use with the Red OS-8525A and Green OS-8458 Diode Lasers.

Simply rotate the wheel to select the desired slit. Each position locks into place, making it easy to use, even in the dark.

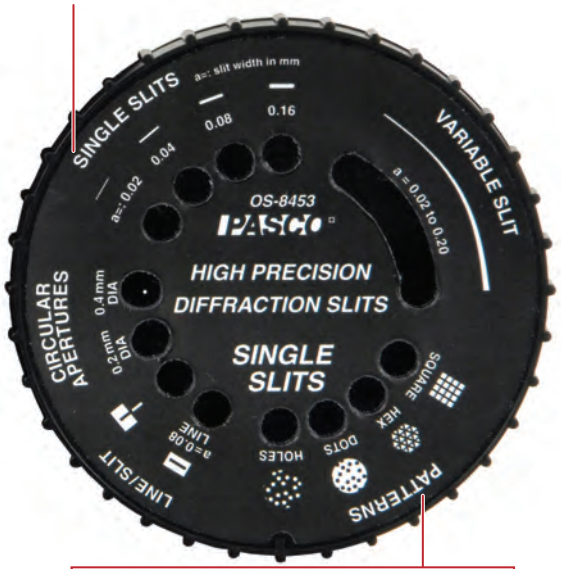


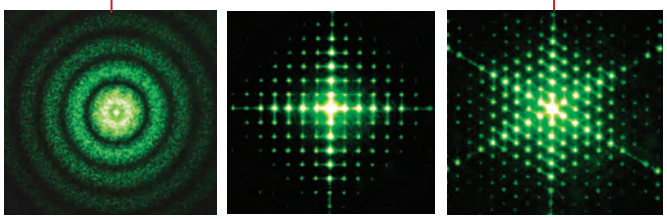
CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

The Single-Slit Wheel includes four single slits of different widths, two circular apertures, one line/slit comparison, one opaque line, a variable width slit, and four patterns.



Single-Slit Diffraction Pattern





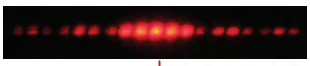
The Circular Diffraction pattern has the same dimensions for both the dots and the holes.

The diffraction geometry represents the structure of the Square and Hex patterns.

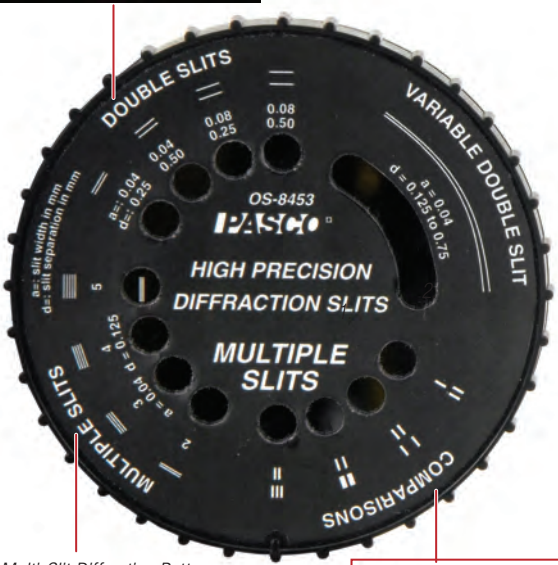
Includes:

- Single-Slit Wheel with Holder
- Multiple-Slit Wheel with Holder

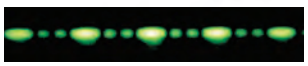
The Multiple-Slit Wheel includes four double slits, a set of four multiple slits having the same slit width and separation (2, 3, 4, and 5 slits), four slit comparisons, and a variable double slit.



Double-Slit Diffraction Pattern

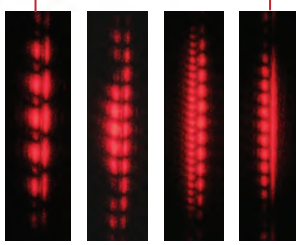


Multi-Slit Diffraction Pattern



The comparisons have two slits illuminated by the same red laser beam, so that the patterns can be viewed side by side.

1. *Two-slit and three-slit comparison*
2. *Different slit widths*
3. *Different slit separation*
4. *Single-slit and double-slit*



1. *2.* *3.* *4.*

Order Information

Precision Diffraction Slits	OS-8453	
Recommended:		
Basic Optics System	OS-8515C	p. 280
Red Diode Laser	OS-8525A	p. 295
Green Diode Laser	OS-8458B	p. 295

Red Diode Laser

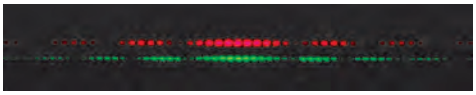
OS-8525A

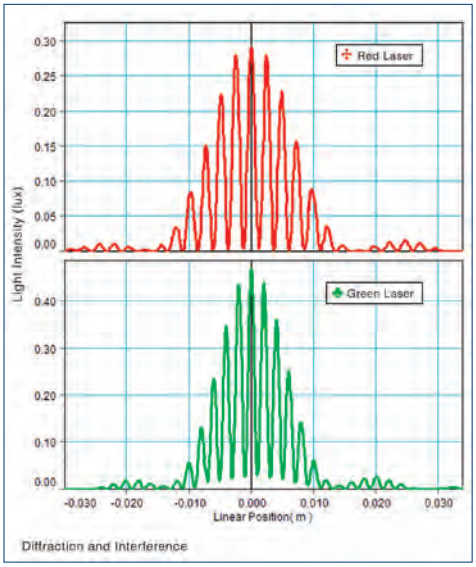
Green Diode Laser

OS-8458B

These unique diode lasers take the frustration out of aligning the laser beam with the diffraction slits. With both lasers, you can demonstrate the effect of changing wavelength on the diffraction and interference patterns.

A red laser beam was passed through a double slit. Then the Red Diode Laser was replaced by the Green Diode Laser by simply pulling the Red Laser off the optics track and clipping the Green Laser into its place. The recorded patterns from red and green lasers show clearly that the longer red wavelength is spread out more than the green.





The horizontal and vertical positions of the beam can be adjusted by turning the thumb screws on the back of the laser.

Demonstrate the effect of changing wavelength on the diffraction and interference patterns.

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Specifications:

Output Power: <1 mW

Wavelength: 650 nm (OS-8525); 515 nm (OS-8458B)

Power Supply: 9 V adapter (included)

Order Information

Red Diode Laser	OS-8525A
Green Diode Laser	OS-8458B

Linear Translator

OS-8535A

The Linear Translator transforms a Rotary Motion Sensor into a linear motion device. The toothed rack of the Linear Translator fits into the slot in the side of the Rotary Motion Sensor. As the Rotary Motion Sensor pulley is rotated by hand, the Rotary Motion Sensor moves along the rack. Rotary Motion Sensor not included.

Specifications:

Resolution for Rotary Motion Sensor: 0.055 mm (CI-6538); 0.020 mm (PS-2120)

Maximum Travel: 20 cm

Order Information

Linear Translator	OS-8535A

Aperture Bracket

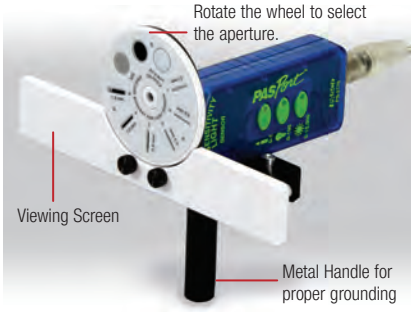
OS-8534A

The Aperture Bracket acts as a mask for a light sensor. The wheel is rotated to select different size slits, defining the spatial resolution. Narrow slits are used to scan diffraction patterns having fine detail. Wider slits are used to let in more light when scanning dimmer patterns. The diffuser selection is used for inverse square law experiments.

Specifications:

Six Slits: From 0.1 mm to 1.5 mm width

Open Aperture: No reduction in intensity 10% transmittance diffuser



Includes:

- Aperture Bracket with Screen
- Metal Handle
- Accessory Holder

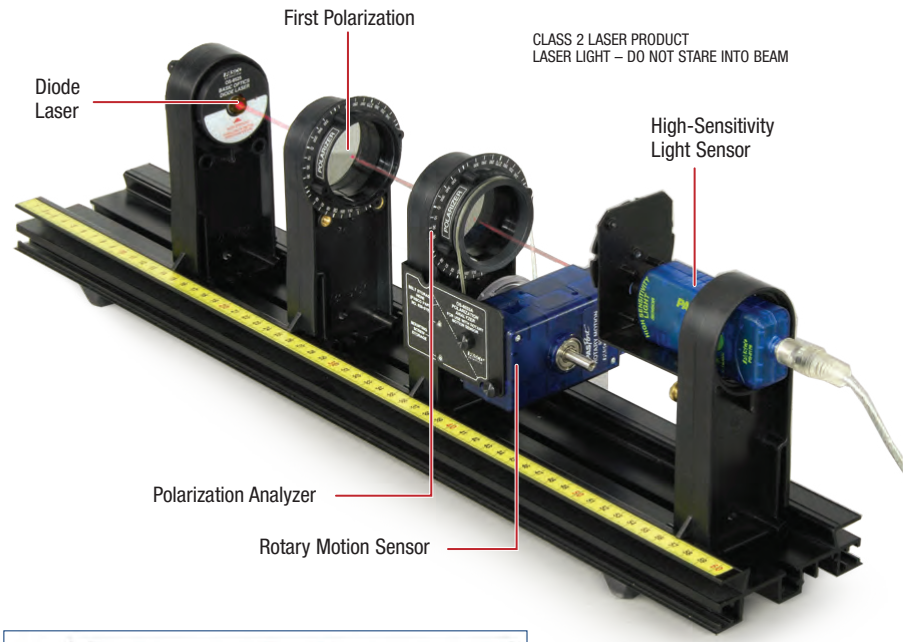
Order Information

Aperture Bracket	OS-8534A

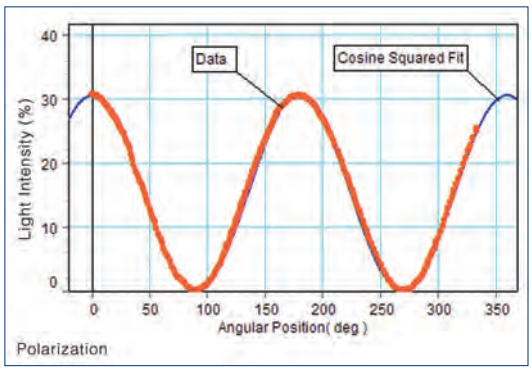
Polarization Analyzer

OS-8533A

Students can confirm Malus' Law of Polarization by using the Polarization Analyzer with the Basic Optics System. All components mount directly to PASCO's Basic Optics Bench OS-8541. The Rotary Motion Sensor is used to measure the angle between the two polarizing disks. The Light Sensor measures the intensity of light that passes through both polarizers.



Shown with Optics Bench OS-8541, 60 cm track



As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.

Includes:

- Polarizer Disks (2)
- Polarizer Holder
- Aperture Bracket
- Accessory Holder with Mounting Bracket
- Accessory Holder for Aperture Bracket
- Retarder Disk

Order Information

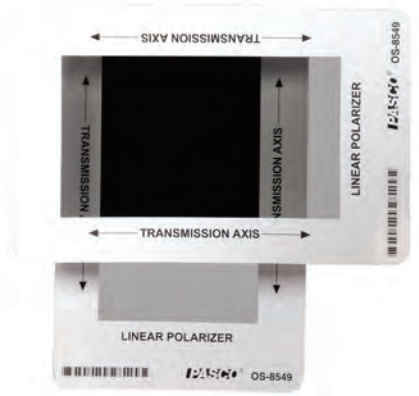
Polarization Analyzer	OS-8533A	
Required:		
PASPORT Rotary Motion Sensor	PS-2120A	p. 41
PASPORT High Sensitivity Light Sensor	PS-2176	p. 48
Basic Optics System	OS-8515C	p. 280
Red Diode Laser	OS-8525A	p. 295

See page 375 for complete experiment.

Linear Polarizer (2-Pack)

OS-8549

This pair of rectangular polarizers are mounted in cardboard frames. The polarizing film dimensions are 3.5" x 6". Includes two polarizers.



Order Information

Linear Polarizer (2-Pack)..... OS-8549

Polarizer Set

OS-8473

This accessory set includes two polarizer disks and an optics holder. Rotate the polarizers relative to one another to view the effect on light intensity.

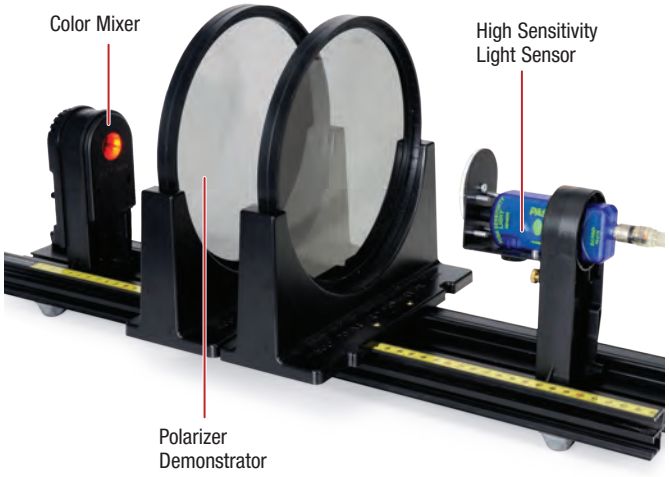
Order Information

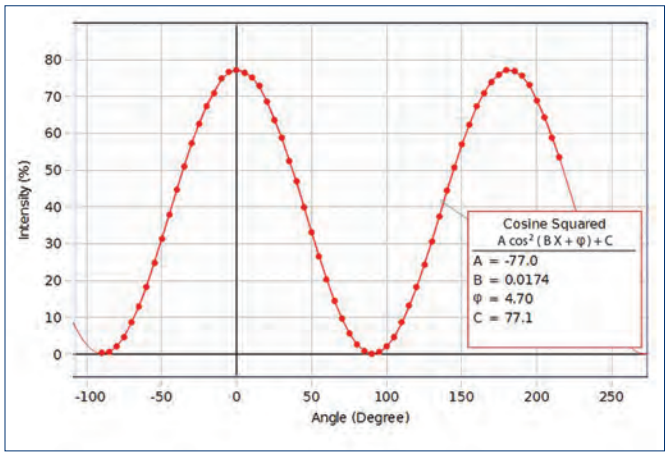
Polarizer Set OS-8473

Polarizer Demonstrator

OS-9477A

Confirm Malus' Law using the Polarizer Demonstrator and a Light Sensor. The angle is read directly from the polarizer, which is marked in 5° increments. Any light source can be used, but the experiment works especially well with the Color Mixer, as shown here.





As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.

Includes:

- Round Polarizer Discs with Stands

Order Information

Polarizer Demonstrator	OS-9477A	
Shown in use with:		
Optics Benches (60 cm)	OS-8541	p. 286
Aperture Bracket	OS-8534A	p. 295
Color Mixer	OS-8496	p. 287
PASPORT High Sensitivity Light Sensor	PS-2176	p. 48

Polarizer Demonstration Accessory

OS-8172

This accessory adds a central platform and diffuser to the Polarizer Demonstrator (OS-9477A). Put sugar water in one of the two supplied square glass bottles and put it on the platform between crossed polarizers. Use a desk lamp or Color Mixer (OS-8496) behind the diffuser and rotate one of the polarizers to see the sugar water change colors as the axis of polarization of different colors rotates to different angles.

Demo with Karo® corn syrup shows wavelength dependence of optical rotation. The light source used was a compact florescent (not included).

Includes:

- Square Glass Bottles (2)
- Metal Stand for Bottles
- Diffusion Screen

Order Information

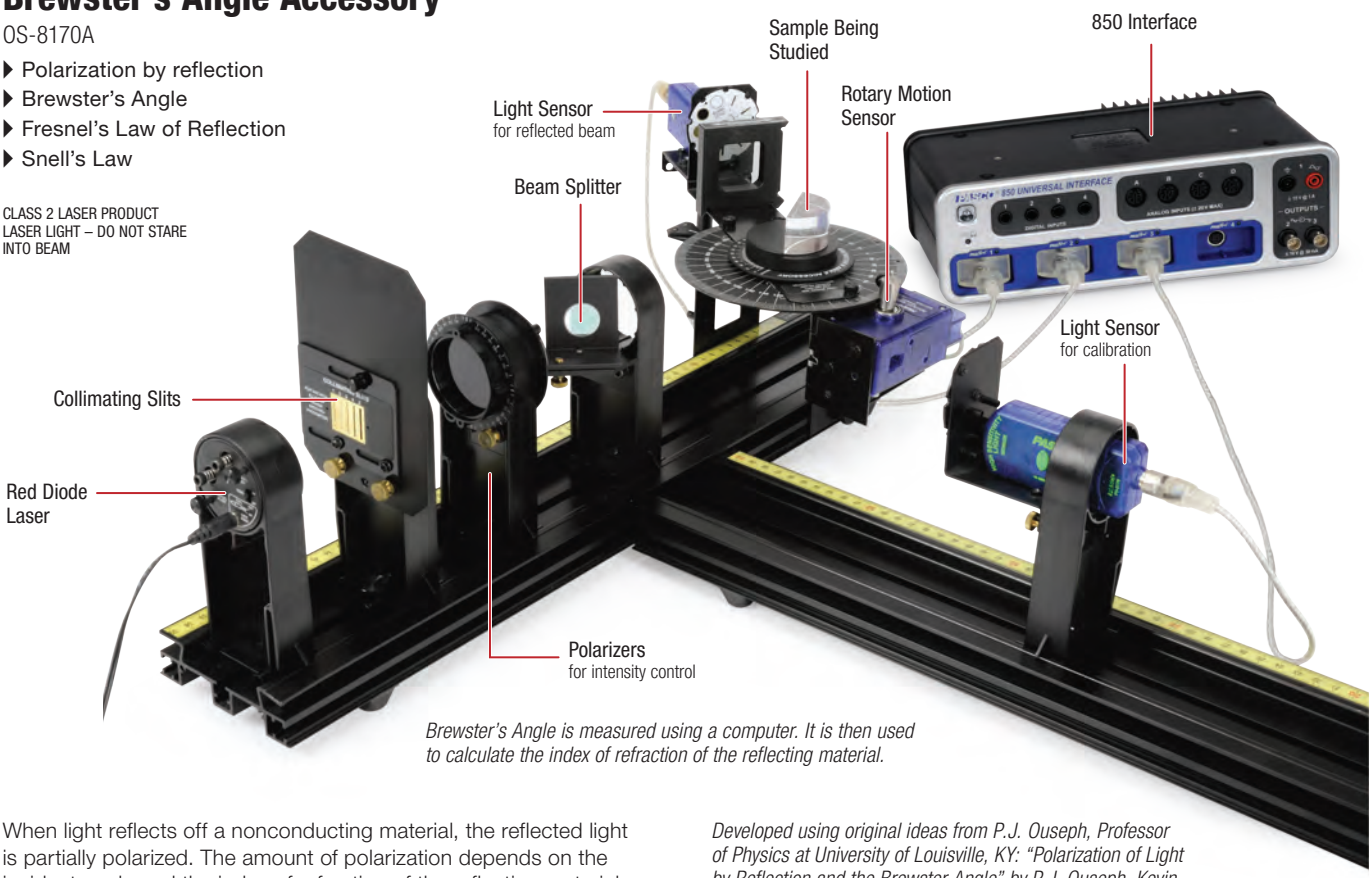
Polarizer Demonstration Accessory	OS-8172	
Required:		
Polarizer Demonstrator	OS-9477A	
Suggested:		
Color Mixer	OS-8496	p. 287

Brewster's Angle Accessory

OS-8170A

- Polarization by reflection
- Brewster's Angle
- Fresnel's Law of Reflection
- Snell's Law

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

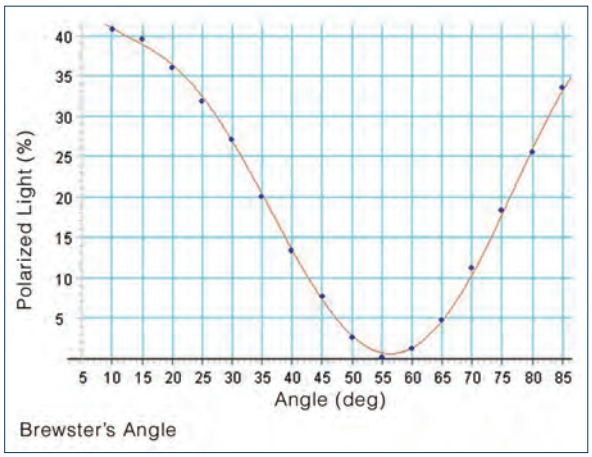


Brewster's Angle is measured using a computer. It is then used to calculate the index of refraction of the reflecting material.

When light reflects off a nonconducting material, the reflected light is partially polarized. The amount of polarization depends on the incident angle and the index of refraction of the reflecting material. The incident angle that gives maximum polarization is called Brewster's Angle.

Light from a diode laser (wavelength = 650 nm) is reflected off the flat side of an acrylic semicircular lens. The reflected light passes through a polarizer and is detected by a Light Sensor. The angle of incidence is measured by a Rotary Motion Sensor mounted on the spectrophotometer table. The intensity of the reflected polarized light vs. incident angle is graphed to determine the angle at which the light intensity is a minimum. This is Brewster's Angle, which is used to calculate the index of refraction of acrylic.

Developed using original ideas from P.J. Ouseph, Professor of Physics at University of Louisville, KY: "Polarization of Light by Reflection and the Brewster Angle" by P.J. Ouseph, Kevin Driver, and John Conklin, Am. J. Phys. 69, 1166 (2001). This modification to the experiment was suggested by Cristian Bahrim and Wei-Tai Hsu in the American Journal of Physics *article: "Precise measurement of the refractive indices for dielectrics using an improved Brewster angle method," Vol. 77, page 337 (2009).*



The intensity of the reflected polarized light as a function of the incident angle; see Brewster's Angle Experiment on page 376.

Includes:

- Acrylic semicircular lens
- Lens platform
- Polarizers with holder (2)
- Analyzing polarizer
- Beam splitter

Order Information

Brewster's Angle Accessory OS-8170A
Basic Optics Beam Splitter OS-8171
For other required equipment, see the Brewster's Angle experiment EX-5544A on page 376.

Meter Stick Optics Complete System

OS-7052

PASCO's Meter Stick Optics Complete System includes all of the components needed to explore essential optics topics like image magnification, lens focal length, real and virtual images, combination of lenses, and so much more! This simple but robust system is designed to fit directly onto the included PASCO Aluminum Meter Stick, making measurements of object distance and image distance easy and straightforward for students.

The rechargeable LED light source provides long-lasting battery life and is bright enough to form clear images in a fully-lit classroom! The component holders and the viewing screen mount firmly on the meter stick, but can also be easily moved along the length of the meter stick. This makes the formation of real images easy to find and measure.

The high-quality lenses are clearly labeled and held firmly inside component holders. Using the built-in holding tabs, the lenses can be quickly exchanged in the component holders. Each lens comes with built-in standoffs to protect the lens surface from scratching and scuffing when placed flat on a tabletop.

Includes:

- Aluminum Meter Stick
- Meter Stick Optics Light Source OS-7054
- Meter Stick Optics Component Holder (2) OS-7055
- Meter Stick Optics Viewing Screen OS-7056
- Lens, -150 mm; +100 mm; +200 mm
- Storage Box

Features:

- Bright, rechargeable LED light source
- Lenses mounted in holders to protect from damage
- Organized storage box for easy classroom management

Specifications:

Lens Diameter: 30 mm
Lens Focal Lengths: +100 mm, +200 mm, -150 mm
Light Source Peak Wavelength: 520 nm to 540 nm
Height of Optical Axis: 9.5 cm
Viewing Screen Dimensions: 16.5 cm x 14.0 cm
LED Light Source Battery: USB Rechargeable Lithium Polymer 3.7 V 1000 mAH
Aluminum Meter Stick Dimensions: 6.95 mm x 28.0 mm x 1.0 m

Order Information

Meter Stick Optics Complete System	OS-7052
Available Separately:	
Meter Stick Optics Light Source	OS-7054
Meter Stick Optics Component Holder	OS-7055
Meter Stick Optics Viewing Screen	OS-7056
Meter Stick Optics Lens Set	OS-7057

Meter Stick Optics Components Kit

OS-7053

PASCO's Meter Stick Optics Components Kit includes all the components of the Meter Stick Optics Complete System, except for the meter stick.

Includes:

- Meter Stick Optics Light Source OS-7054
- Meter Stick Optics Component Holder (2) OS-7055
- Meter Stick Optics Viewing Screen OS-7056
- Lens, -150 mm; +100 mm; +200 mm
- Storage Box

Optics Components Kit shown in included storage box.

Specifications:

Designed to be used with PASCO's Aluminum Meter Stick: 6.95 mm x 28.0 mm x 1.0 m

LED Light Source Battery: USB Rechargeable Lithium Polymer 3.7 V 1000 mAH

Order Information

Meter Stick Optics Components Kit	OS-7053

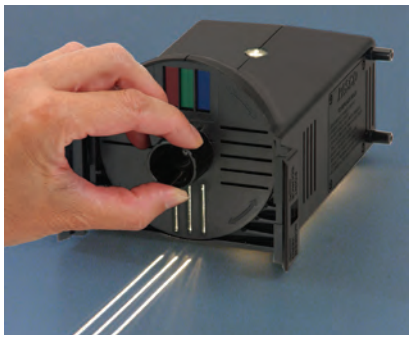
Basic Optics Light Source

OS-8470

- One, three, or five parallel rays
- Three primary color source
- Crossed arrow object and point source

The Basic Optics Light Source is an excellent source for a variety of optics experiments. A single 10-watt quartz-halogen bulb provides bright, easy-to-see illumination without a lot of heat. By turning the box to a different side, it becomes a:

- Crossed Arrow Object with Metric Scale: ideal for showing images, focal point, and magnification.
- Bright Point Source: The very small filament of the halogen bulb provides an excellent point source for experimenting with shadows or the Inverse Square Law.
- Three Primary Colors Source: The red, green, and blue filters provide three rays of light that are easily combined with a lens for color mixing.
- One, Three or Five Ray Sources: Just rotate the knob in front of the light source to vary the number of rays produced.



Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.

The Basic Optics Light Source provides a point source and an extremely bright crossed arrow target. Use free-standing or easily clip directly to Basic Optics Track.

Includes:

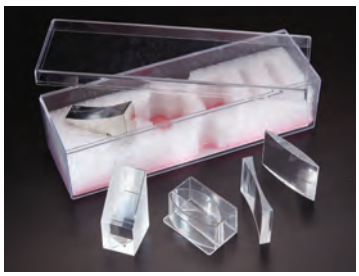
- Universal AC Adapter
- Spare Bulb (stored under access cover)

Order Information

Basic Optics Light Source OS-8470

Ray Optics Kit

OS-8516A



The Ray Optics Kit is a basic set of optic components for ray and color experiments.

Includes:

- Double-Convex Lens
- Double-Concave Lens
- Rhomboid
- Eye-Dropper
- Triangular mirror accessory with concave, convex, and plane reflective surfaces
- Hollow lens to fill with a liquid or use as an air lens

Order Information

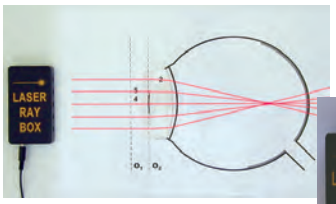
Ray Optics Kit OS-8516A

Ray Optics Laser System

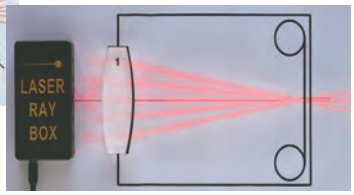
CLASS 2 LASER PRODUCT
LASER LIGHT –
DO NOT STARE INTO BEAM

SE-8506

- No need to dim the lights
- Wide variety of optical components
- Templates simulate real-world optical devices



The laser rays are focused in front of the retina by the myopic lens used with the human eye template.



The laser rays are redirected by the converging lens and focused on the "film" of the camera template.

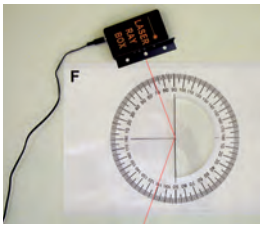
This demonstration optics set uses a Laser Ray Box that has bright, well-defined rays because it uses lasers rather than an incandescent light source. The Laser Ray Box projects five parallel laser beams onto any flat surface. It contains five 1 mW diode lasers (wavelength 635 nm). The laser beams are spread out into clearly visible lines by cylindrical lenses inside the box.

The ray box has a magnetic back for mounting on any steel board. The unit is powered by an included AC adapter.

This exceptional optics set includes six magnetically-backed templates that have guidelines showing where to put components to perform different demonstrations, including:

- Modeling the human eye and eyeglasses
- How a camera works
- Two types of telescopes
- Spherical aberration
- Refraction and reflection

Each component has a magnetic backing for mounting on any steel board.



The included protractor template can be used to demonstrate refraction.

Specifications:

Dimensions: 11 cm x 6 cm x 2 cm
Laser Ray Separation: 1.8 cm
Power Adapter: 3 VDC, 300 mA (included)
Wavelength: 635 nm

Includes:

- Laser Ray Box
- Laser Ray Mask
- Double-convex lenses (4)
- Double-concave lens
- Plano-concave lens
- "D" lenses (4.5 cm and 7.5 cm radius) (2)
- Plane, convex, and concave mirrors
- Right-angle prism
- Rectangle (6 cm x 10 cm)
- Optical fiber (2 cm x 20 cm)
- Templates (6)
- Steel whiteboard (56.5 cm x 41.5 cm)
- Most components are 10 cm tall and 1.7 cm thick.

Order Information

Ray Optics Laser System SE-8506
Laser Ray Box SE-8505

Mirage

SE-7302

These two concave mirrors create a real image of any object you place at the bottom. The image appears at the opening in the top and when students try to touch it, they find that it is only an image, not the real thing!

Includes:

- Concave mirror (14 cm diam.)
- Plastic frog

Order Information

Mirage SE-7302

Equilateral Prism

SE-9021A

Demonstrate the dispersion and refraction of white light with this high-quality glass prism. It's 30 mm on a side and 50 mm long.

Right Angle Prism

SE-9022A

Use this Right Angle Prism to demonstrate chromatic dispersion or to bend a beam of light by 90 degrees. It's 50 mm long with 23 x 32 mm sides, and made of high-quality optical glass.

Order Information

Equilateral Prism SE-9021A
Right Angle Prism SE-9022A

Demonstration Mirror, Convex

SE-7574

This convex large mirror comes with a convenient stand and is ideal for demonstrating the formation of real and virtual images. Diameter is 60 cm.

Demonstration Mirror, Concave

SE-7573

This concave large mirror comes with a convenient stand and is ideal for demonstrating the formation of real and virtual images. Diameter is 60 cm. Stand is included.

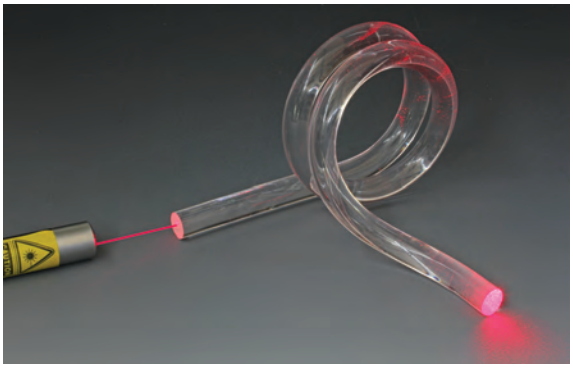
Order Information

Demonstration Mirror, Convex SE-7574
Demonstration Mirror, Concave SE-7573

Optical Fiber Model

SF-7201

This bent acrylic rod simulates the operation of optical fibers. The laser beam undergoes repeated total internal reflections and is emitted at the other face of the rod as a divergent beam.



Specifications:

Dimensions: 50 cm length and 1.0 cm diameter, with two windings of approx. 5 cm diameter.

Order Information

Optical Fiber Model SF-7201
Required:
Red Diode Laser Pointer ..... SE-9716C p. 308

Wireless Spectrometer (Vis)

PS-2600A

For iOS, Android™, Computers, and Chromebooks™

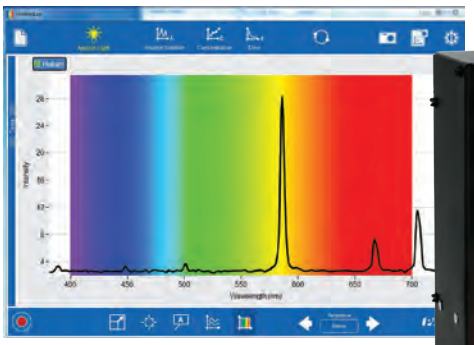
Now includes Spectrometry 2.0 functionality!

- Measures intensity, absorbance, transmittance, and fluorescence.
- Works on all computing platforms
- Bluetooth® or USB connectivity
- Includes free award-winning Spectrometry software

//CODiE// 2017 SIIA CODiE WINNER

bett AWARDS 2017 FINALIST

winner 2016 AWARDS EXCELLENCE TECH&LEARNING



Helium spectrum

Perform these labs with the Wireless Spectrometer:

- Emission Spectra of Light
- Absorbance Spectra
- Beer's Law
- Kinetics
- Fluorescence

Shown using the optional Fiber Optic Cable.

Specifications:

Resolution: 2–3 nm FWHM
Detection Range: 390–950 nm
Fluorescence Excitation Wavelengths: 405 nm and 500 nm
Light Source: LED-boosted tungsten
Bluetooth: Bluetooth Low Energy

Includes:

- Cuvettes (10)
- Spectrometry Software

Order Information

Wireless Spectrometer (Vis) PS-2600A

Fiber Optic Cable

PS-2601

This 1m Fiber Optic Cable extends the Wireless Spectrometer's capabilities beyond simple cuvette investigations. The cable is transparent to support the entire range reported by the Wireless Spectrometer PS-2600.

Order Information

Fiber Optic Cable PS-2601

UV-Vis Spectrometer

SE-3607

- Uses PASCO's award-winning Spectrometry software
- Intuitive calibrations
- Spectral scans from 180 to 1050 nm

The SE-3607 is an easy-to-use, wide range UV-Vis spectrometer that delivers fast, accurate and reliable performance for routine analyses in college and university teaching labs. With USB connectivity and cross-platform Spectrometry Software, the PASCO UV-Vis Spectrometer improves collaboration between lab members, enabling data collected on a computer or laptop to be analyzed on tablets, iPads, and Chromebooks*.

* Chromebooks are not compatible with the PASCO UV-Vis Spectrometer for data collection (analysis only).

Includes:

- Semi-Micro Volume Cuvettes (Qty. 10)
- Cuvette Rack (EC-3590)
- USB-A to USB-B Cable
- External AC Adapter, 24 V Power Supply
- Foam Lined Carrying Case (ABS)

Order Information

UV-Vis Spectrometer SE-3607

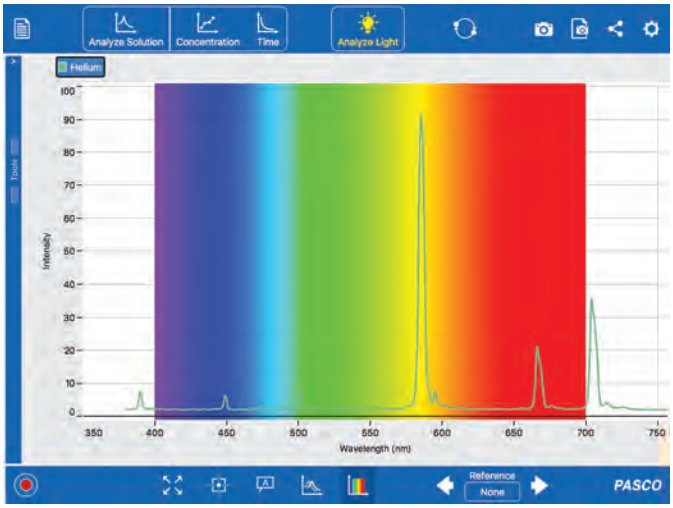
PASCO's FREE! Spectrometry Software Puts Learning First

PASCO's award-winning software for iOS, Android™, Computers, and Chromebooks*

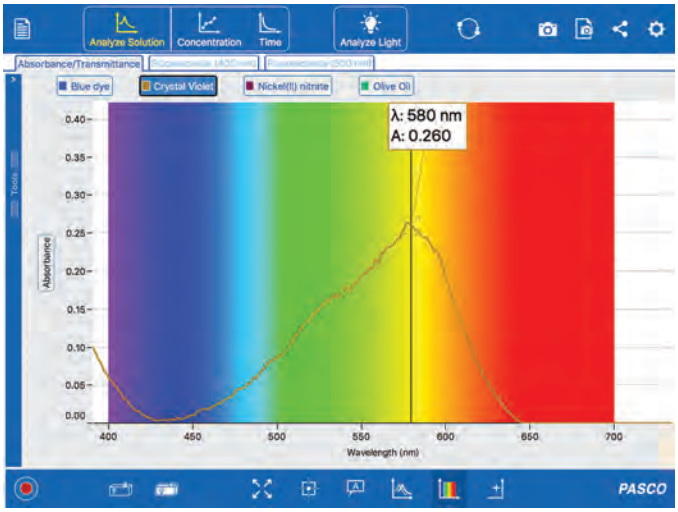
- Designed by teachers
- Specialized software specifically targets spectrometry activities
- Program guides students through the four common types of spectrometer uses
- Calibration routine is made clear and intuitive

The four specially targeted activities are:

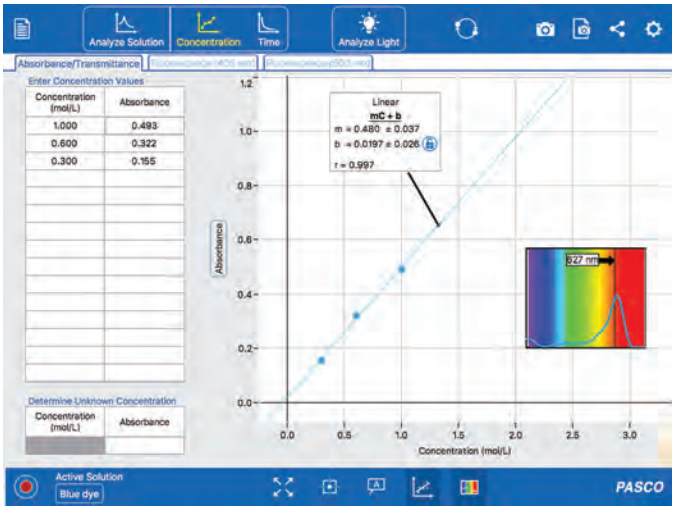
1. Analyze light sources with the optional Fiber Optic Cable.
2. Analyze the absorbance, transmittance, and fluorescence of colored solutions.
3. After the analysis wavelength is set, you can easily create calibration curves and determine the unknown concentration (Beer's Law).
4. Observe the kinetics of a reaction involving a colored solution. Easily create the required graphs (ln(x), 1/x) to determine the order of the reactants.



Analyze light sources with the optional Fiber Optic Cable.



Visualize the absorbance of visible wavelengths with corresponding colors (optional).



Create Beer's Law plots to relate absorbance and concentration.

Quickly plot calculations of Concentration vs. Time to determine the order of a reaction.

The Wireless Spectrometer comes with **PASCO's FREE award-winning Spectrometry software**.

- Free software for iOS, Android™, Mac® and Windows®.
- Will run on Chromebooks™ with Google Play store.
- Designed specifically for student spectrometry experiments.

Download at **pasco.com/downloads**

Our list of compatible Chromebooks is expanding rapidly. Check* **pasco.com/spectrometer *for the latest updates.*

Spectrophotometer

Educational Spectrophotometer System

OS-8450 (PASPORT) OS-8539 (ScienceWorkshop)

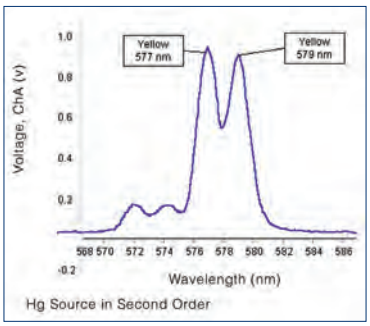
Educational Spectrophotometer Accessory Kit

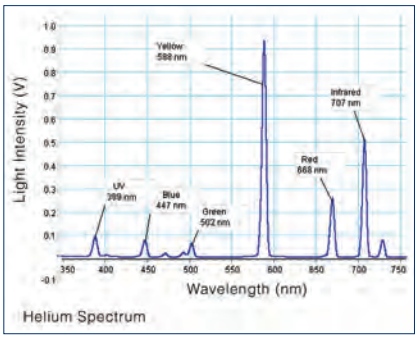
OS-8537

- Analyze and graph spectral lines
- Explore relationships between angle, wavelength, and intensity
- Versatile and inexpensive

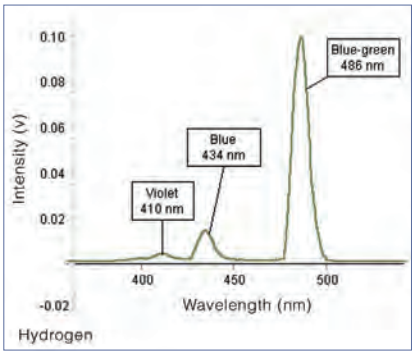
PASCO's Educational Spectrophotometer teaches basic optical principles and allows quantitative measurements rivaling those of more expensive units.

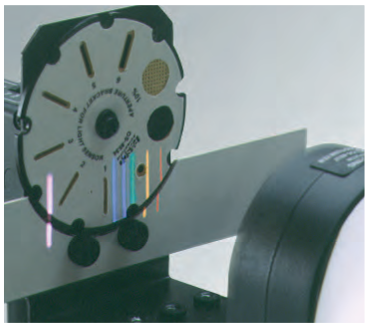
When the Spectrophotometer is used with PASCO's Capstone software, students can explore the relationship between angle, wavelength and intensity and graph the spectral lines from discharge tubes. Lines from mercury, sodium, helium, neon, krypton and argon can be plotted— even the lines of the Balmer series in hydrogen can be detected.

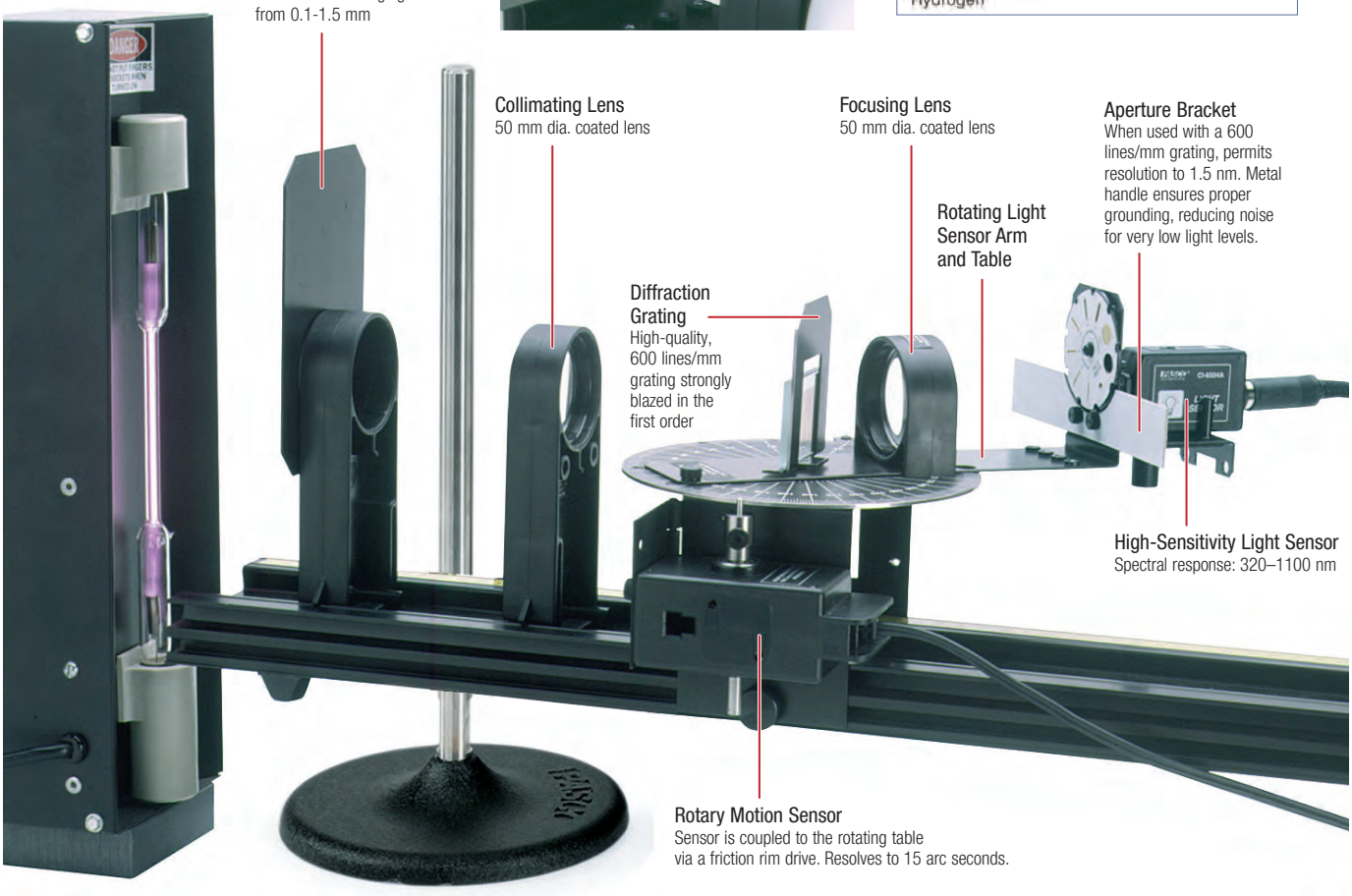




Typical Spectrum Graphs



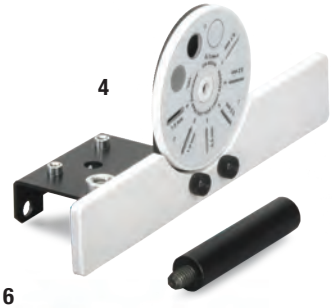




Educational Spectrophotometer Components

Teachers who already own a PASCO Interface and the Basic Optics System OS-8515C should purchase the Accessory Kit OS-8537 and any additional equipment needed from the list below.

The Spectrophotometer System includes:	ScienceWorkshop OS-8539	PASPORT OS-8450
1. Optics Bench (60 cm) OS-8541		
2. Rotary Motion Sensor	CI-6538	PS-2120A
3. High-Sensitivity Light Sensor	CI-6604	PS-2176
4. Aperture Bracket OS-8534A		
5. Spectrophotometer Table		
6. Rotating Arm		
7. Collimating Slits and Lens		
8. Focusing Lens		
9. Diffraction Grating and Holder		
10. Optics Bench Rod Clamps (2) ME-9836		



The Spectrophotometer Accessory Kit (OS-8537) includes:

5. Spectrophotometer Table
6. Rotating Arm
7. Collimating Slits and Lens
8. Focusing Lens
9. Diffraction Grating and Holder
10. Optics Bench Rod Clamps (2) ME-9836

Note: The open design of this spectrophotometer accessory is ideal for education. It is not intended for industrial or research applications.

Order Information

PASPORT Educational Spectrophotometer OS-8450
Educational Spectrophotometer System OS-8539
Educational Spectrophotometer Accessory Kit OS-8537
For use with PASPORT Sensors, see the Atomic Spectra experiment EX-5546B on page 378.
For adjusting height of optics bench to your light source:
Round Base with Rod ..... ME-8270 p. 197

High-Quality Gratings 600 lines per mm

SE-9358

The 600 lines/mm grating is strongly blazed in the first order. It has excellent resolving power and produces bright, sharp spectral lines for spectrometer labs or for projecting spectra in lecture demonstrations.

Order Information

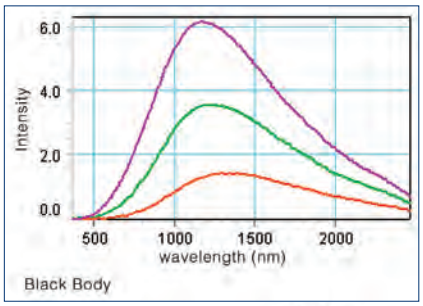
High-Quality Gratings 600 lines per mm SE-9358

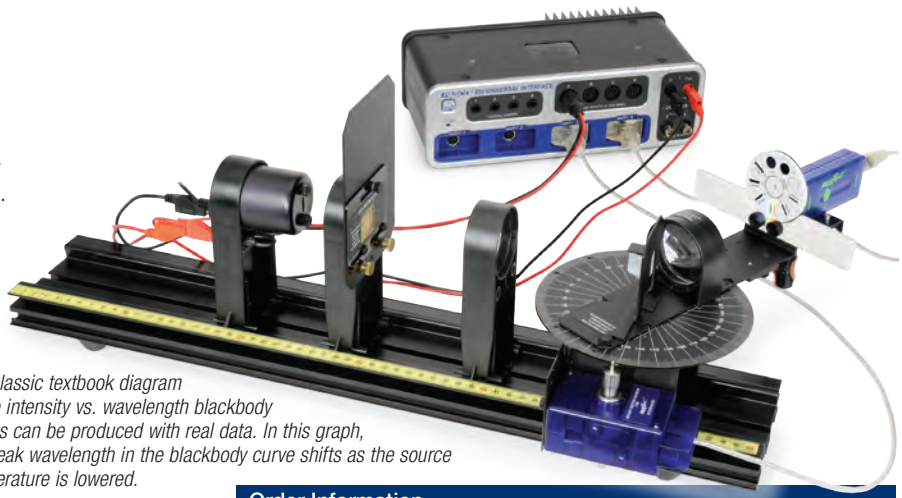
Prism Spectrophotometer Kit

OS-8544

- High-quality prism
- Blackbody light source

Add this kit to the Educational Spectrophotometer System (pages 304-305) to plot blackbody curves. A prism is used to disperse the light (instead of a diffraction grating) so the infrared doesn't overlap the second order visible spectrum.





The classic textbook diagram of the intensity vs. wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is lowered.

Includes:

- Mounted Prism
- IR Filter
- Blackbody Light Source

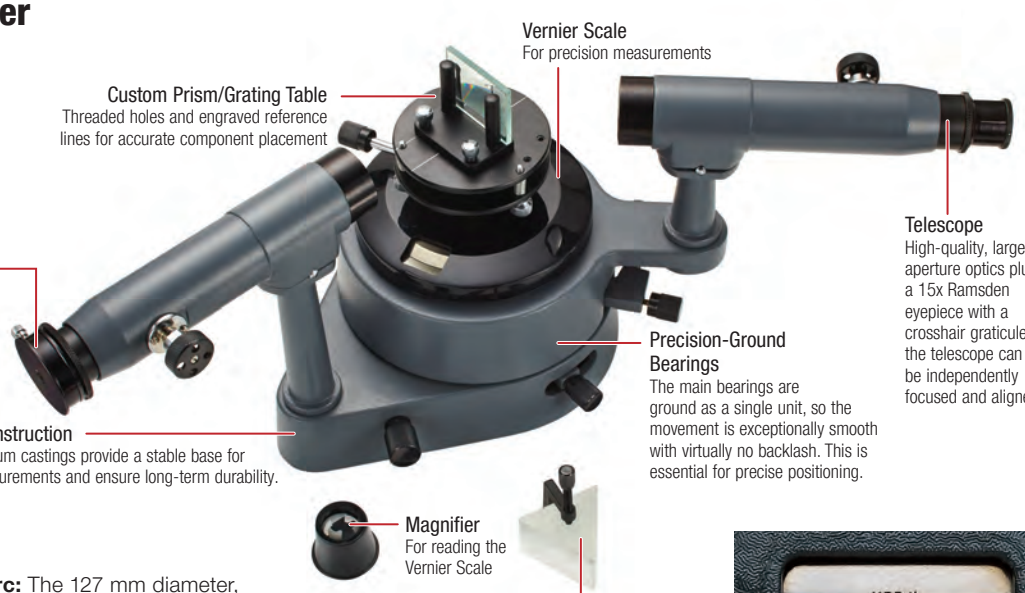
Order Information

Prism Spectrophotometer Kit	OS-8544	
Required for experiment:		
PASPORT Broad Spectrum Light Sensor	PS-2150	p. 48
PASPORT Educational Spectrophotometer	OS-8450	
850 Universal Interface	UI-5000	p. 26
PASCO Capstone		pp. 84-87
Replacement Supplies:		
Replacement Light Bulbs (10)	SE-8509	
OR components of the system may be ordered separately		
Black Body Light Source	OS-8542	
Prism Mount	OS-8543	

Student Spectrometer

SP-9268A

- Wide aperture optics
- Precision vernier: resolves one minute of arc
- Durable and precise



Vernier Scale
For precision measurements

Custom Prism/Grating Table
Threaded holes and engraved reference lines for accurate component placement

Telescope
High-quality, large-aperture optics plus a 15x Ramsden eyepiece with a crosshair graticule; the telescope can be independently focused and aligned.

Collimator
High-quality, large-aperture optics with a 6 mm long slit of adjustable width; the collimator can be independently focused, leveled, and aligned.

Precision-Ground Bearings
The main bearings are ground as a single unit, so the movement is exceptionally smooth with virtually no backlash. This is essential for precise positioning.

Durable Construction
Heavy aluminum castings provide a stable base for delicate measurements and ensure long-term durability.

Magnifier
For reading the Vernier Scale

Dense Flint Glass Prism with Holder

The Vernier Scale resolves angle measurements within 1 minute of arc.

Features:

- **Resolution to 1 Minute of Arc:** The 127 mm diameter, precision-engraved degree plate is complemented by 2 precision-engraved verniers, one on each side of the instrument for convenient reading.
- **Wider Aperture Optics:** 32 mm wide apertures on the telescope and collimator provide more light for brighter and sharper images.
- **Rack and Pinion Focusing:** On both the telescope and the collimator. Focusing is easier and more precise.
- **Rotatable Table:** For greater flexibility in measurements. Turn the table by hand for coarse adjustments. Use the fine lead screw for delicate adjustments.

Order Information

Student Spectrometer	SP-9268A	
Recommended:		
Spectral Light Sources		p. 308

UV Beads (1000)

SE-7729

Shining an ultraviolet flashlight on UV-sensitive beads causes them to change color.

UV-sensitive beads are white when indoors but change color instantly when exposed to UV radiation. These beads make students aware of UV radiation. Students can explore how much UV there is on a cloudy day and how much UV is blocked by car windows.

Each bead is created with a pigment that changes color as the ultraviolet energy is absorbed. When the UV radiation is removed, the beads will return to their pale white color. This process can be repeated many thousands of times. Each package includes 1000 beads.

Order Information

UV Beads (1000) SE-7729

UV Flashlight

SE-7730

This ultraviolet flashlight with 51 UV LEDs is great for illuminating UV beads and activating fluorescent materials. The wavelength is centered on 385 nm. Powered by three AA batteries (not included).

Specifications:

Wavelength: 385 nm
Length: 14 cm
Bulb Type: 51x UV LED
Bulb Life: 50,000 hours
Battery Requirement: 3 AA (not included)
Battery Life: Approx. 20 hrs on new batteries
Body Material: Machined aluminum with rubber O-rings

Order Information

UV Flashlight SE-7730

Spectral Light Sources

Mercury Light Source

SE-6608

This bright Mercury Light Source is perfect for studying spectra with the Educational Spectrophotometer (OS-8539). It is also used with the Photoelectric Effect experiment (SE-6609 and EX-5549A) and mounts on the extruded track in that experiment.

Includes:

- Mercury Light Source Housing
- Power Supply
- Replacement Hg Bulb: SE-6597

Order Information

Mercury Light Source SE-6608
Replacement Supplies:
Replacement Hg Bulb SE-6597

Spectral Tube Power Supply and Mount

SE-9460

This system is easy-to-use and inexpensive, with a variety of safety features that make it suitable for beginning labs. Mount any of the eight different spectral tubes into the Power Supply and turn it on. The 26 cm long tubes are capillary-thin over the middle 10 cm, providing sharp, bright spectra.

Features:

- **Student Safety:** The tubes mount from the front of the supply and snap into molded sockets that fully enclose the conductive ends. The all-metal case is electrically grounded.
- **Spectral Tube Safety:** A current limiting transformer protects the tubes. A protective shield also helps safeguard the tubes, while blocking unwanted ambient light for clear viewing. The glass does not transmit UV light.
- **Power Requirements:** 115 OR 220 VAC, 50/60 Hz.
- Emission tubes sold separately.

Power Supply and Mount

Order Information

Spectral Tube Power Supply and Mount SE-9460

Spectral Tubes

- Argon
- Carbon Dioxide
- Helium
- Hydrogen
- Krypton
- Mercury
- Neon
- Water Vapor

These spectral tubes are designed for use in the Spectral Tube Power Supply and Mount (at left).

Order Information

Spectral Tubes:

Argon	SE-9463
Carbon Dioxide	SE-9464
Helium	SE-9462
Hydrogen	SE-9461
Krypton	SE-9465
Mercury	SE-9466
Neon	SE-9467
Water Vapor	SE-9468

Diode Laser – Basic Optics

OS-8525A (Red) OS-8458B (Green)

These diode lasers fit on the Basic Optics Benches (OS-8505 and OS-8541) and the Dynamics Track Optics Carriage (OS-8472).

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM

Specifications:

Output Power: <1 mW

Wavelength: 650 nm (OS-8525); 515 nm (OS-8458B)

Power Supply: 9 V adapter (included)

Order Information

Red Diode Laser	OS-8525A
Green Diode Laser	OS-8458B

X-Y Adjustable Diode Laser

OS-8526A

This versatile, inexpensive diode laser is designed to mount on a rod stand. The laser can be rotated through 360 degrees. There are x- and y-adjustment screws to align the laser beam. Easy set-up makes it perfect for refraction investigations and tracking the oscillation of the Cavendish Gravitational Balance (AP-8215A).

Two knobs allow independent adjustment of horizontal and vertical alignment of the laser beam.

Specifications:

Output Power: <1 mW

Wavelength: 650 nm

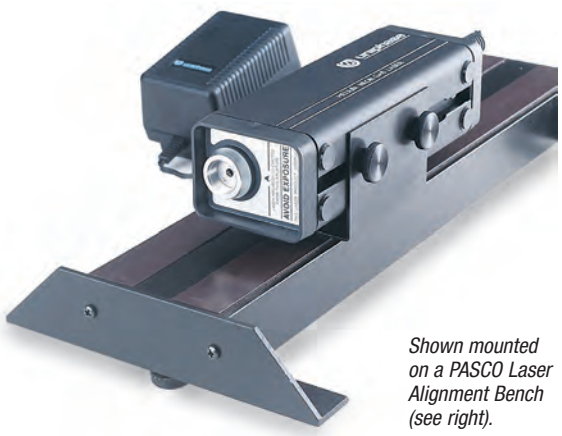
Power Supply: 9 VDC, 500 mA adapter (included)

Order Information

X-Y Adjustable Diode Laser OS-8526A

Mini Laser with Bracket

OS-8514



Shown mounted on a PASCO Laser Alignment Bench (see right).

CLASS II LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

This 0.5 mW Helium Neon Laser is ideal for use with the PASCO Advanced Optics System. It includes a mounting bracket that attaches to the PASCO Magnetic Optics Bench and permits adjustment of the laser beam in the x and y axes.

The aperture has a 15.8 mm (5/8") receptacle for mounting beam spreaders or spatial filters. An AC adapter is included, but the unit can be powered with any power source providing 0.7 A at 12 VDC.

Specifications:

Output: 0.5 mW min

Wavelength: 632.8 nm

Polarization: Random

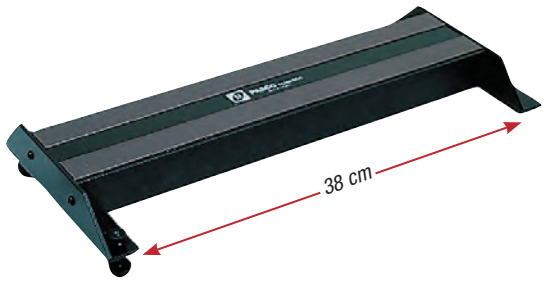
Power: 115/220 VAC, 50/60 Hz

Order Information

Mini Laser with Bracket OS-8514

Laser Alignment Bench

OS-9172



This Laser Alignment Bench connects to the Optics Bench with the included couplers, which leaves the full 1 m length of the Optics Bench free for experimental work.

Order Information

Laser Alignment Bench OS-9172

Laser Pointers

SE-9716C (Red)

SE-8805A (Green)

- Push-button switch
- Inexpensive

CLASS II LASER PRODUCT
LASER RADIATION – AVOID DIRECT EYE EXPOSURE

Specifications:

Source: Laser diode

Power: 5 mW max. (class II)

Wavelength: 645 nm (red pointer)
532 nm (green pointer)

Battery: Alkaline AAA (2 included)

Dimensions: 143 mm x 12.7 mm (red pointer);
151 mm x 13.5 mm (green pointer)

Order Information

Red Diode Laser Pointer SE-9716C
Laser Pointer, Green SE-8805A

Wireless Light Sensor

PS-3213

- Four sensors in one
- Ambient lux
- Ultraviolet and infrared
- Detect RGB colors separately
- Bluetooth 4.0 wireless
- New enhanced features measure PAR and irradiant light!

The Wireless Light Sensor features two separate apertures - one for ambient light measurements and one for directional light measurements. The ambient sensor measures illuminance and UV Index, while the spot (directional) aperture measures light level and color intensity. Our software displays the relative intensities of Red, Green, and Blue light, compared to the total amount of unfiltered White light. PAR and irradiance are also available as calculated measurements within PASCO Capstone (version 1.8 or later) and SPARKvue software (version 2.6 or later).

Use the ultraviolet sensor on the back side to measure the amount of UVA and UVB radiation that makes it through sunglasses.

Specifications:

Spectral Response: 300 nm to 1100 nm

Illuminance Range: 0 to 131,000 lux

Irradiance Range: 0 to 1362 W/m^2

PAR Range: 0 to 2400 µmol/m^2/s

UV Index Range: 0 to 12 (typical in daylight)

RGB and White Light Range: 0 to 100%

Maximum Sample Rate: 2 Hz (ambient); 20 Hz (spot)

Battery: Coin cell

Bluetooth 4.0: Yes

Order Information

Wireless Light Sensor PS-3213

PASPORT Infrared Light Sensor

PS-2148

- For heat studies

The Infrared Light Sensor is sensitive in the infrared portion (up to 40,000 nm) of the spectrum, but also detects the visible spectrum. It can detect the radiation from a person's hand. The response is linear over its entire frequency range.

Applications:

- Measure blackbody radiance
- Perform Leslie's Cube experiments
- Measure solar radiance
- Evaluate heat flow into or out of the sensor
- Simulate a non-contact temperature sensor

Specifications:

Intensity Units: Watts/Meter

Maximum Sample Rate: 100 Hz

Spectral Response: 580 to 40,000 nm

Built-in Thermistor: to measure temperature of the "cold" side of the thermopile in °C, °F or K.

Order Information

PASPORT Infrared Light Sensor PS-2148

PASPORT Broad Spectrum Light Sensor

PS-2150

- For use with Spectrophotometer
- Ideal for Black Body Spectrum

The Broad Spectrum Light Sensor is designed specifically for use with our Educational Spectrophotometer System OS-8539 and Prism Spectrophotometer Accessory OS-8543 for Blackbody experiments. The Broad Spectrum Light Sensor uses a thermopile and window combination that respond to both the near infrared and visible light necessary for the Black Body experiment.

Applications:

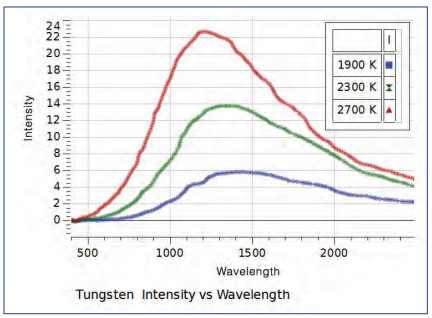
- Blackbody Experiment

Specifications:

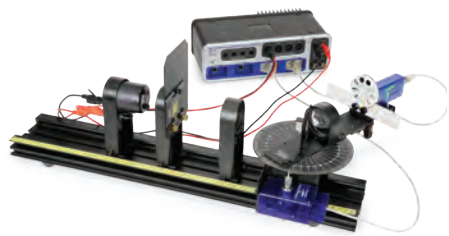
Sensing Element: BaF_2 window, xenon gas-filled thermopile

Spectral Response: 300 to 10,000 nm

Maximum Sample Rate: 100 Hz



The classic textbook diagram of the Intensity versus Wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is lowered.



Order Information

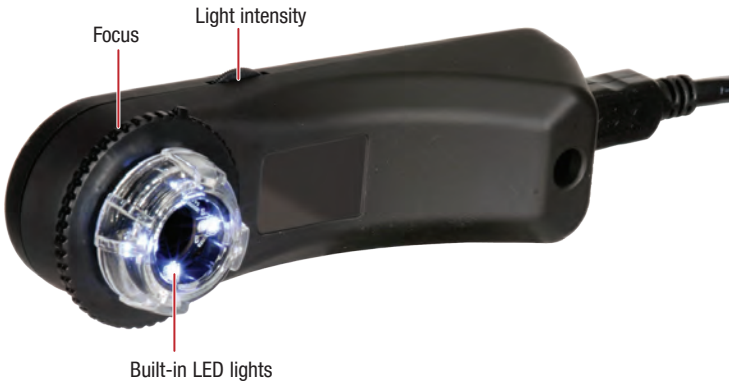
PASPORT Broad Spectrum Light Sensor PS-2150

USB Camera Microscope

PS-2343

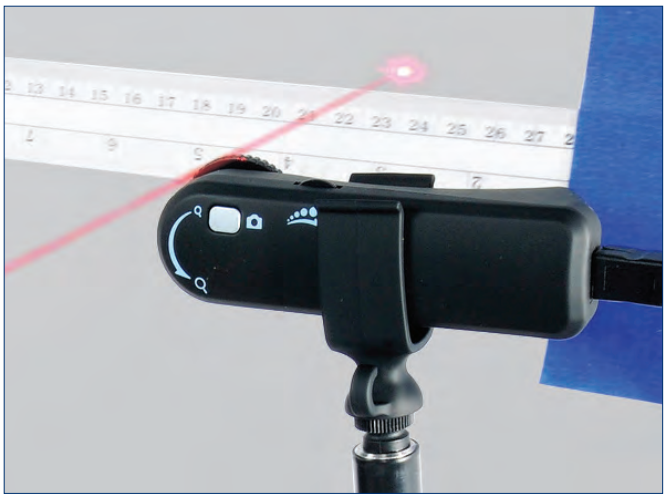
- Optical zoom from 1x to 60x
- Includes four white LED lights as a light source
- Can be used as a web camera
- Works with PASCO's SPARKvue and Capstone software
- Comes with 4" stand

The versatile USB Camera Microscope is ideal for a variety of applications in the science classroom. Its dual functionality means it can take pictures just like a digital camera, but it can also magnify like a microscope when it's up close to a specimen. It is especially useful for studying topics such as crystalline structures. You can also use it to capture lab setups, such as what materials look like before and after an experiment has been performed.



How It Works

When used with the video and image-capture features in PASCO Capstone, magnification of specimens can be magnified by adjusting the dial located on the front of the camera.



The USB Camera Microscope records the oscillation of the laser beam.

Specifications:

Magnification: 1x to 80x, 320x on 22" monitor

Lens & CMOS Sensor: 2M pixels

Still Image Resolution: 1600x1200 pixels

Formats: JPEG, BMP

Video Resolution: 1600x1200 pixels

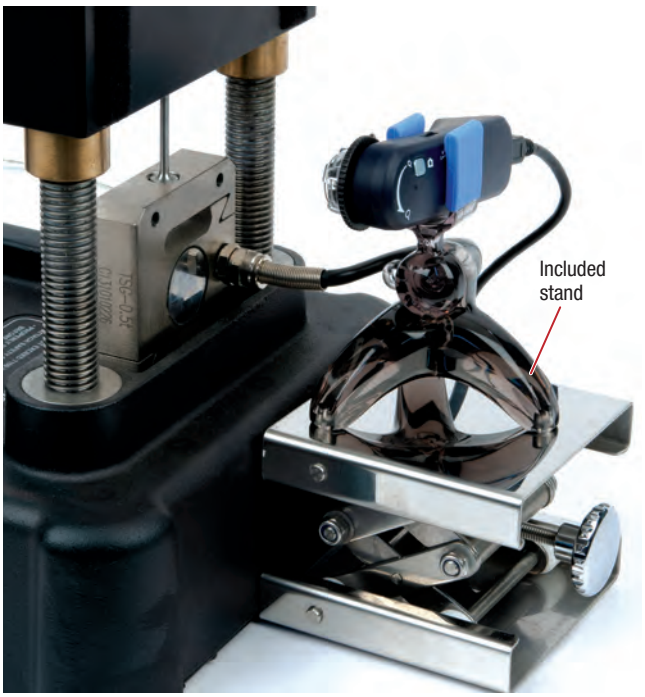
Formats: AVI

Frame Rate: 30FPS on 640x480 pixels: AVI

Interface: USB 2.0; works on Windows, Mac, and Android phones with OTG functions

Light Source: 4 white LED lights

See the USB Camera Microscope in use with the Universal Gravitational Constant Experiment (EX-5550) on page 340.



Shown in use with ME-8236 Materials Testing Machine (see page 170). As the tensile sample is being stretched, a real-time Force versus Time graph is displayed alongside video from the camera.

Includes:

- Camera Microscope
- Stand

Order Information

USB Camera Microscope	PS-2343	
Suggested Base Supports:		
Flex Rod	ME-8978A	p. 197
Small "A" Base	ME-8976	p. 196
Aluminum Table Clamp	ME-8995	p. 199

Introductory Michelson Interferometer

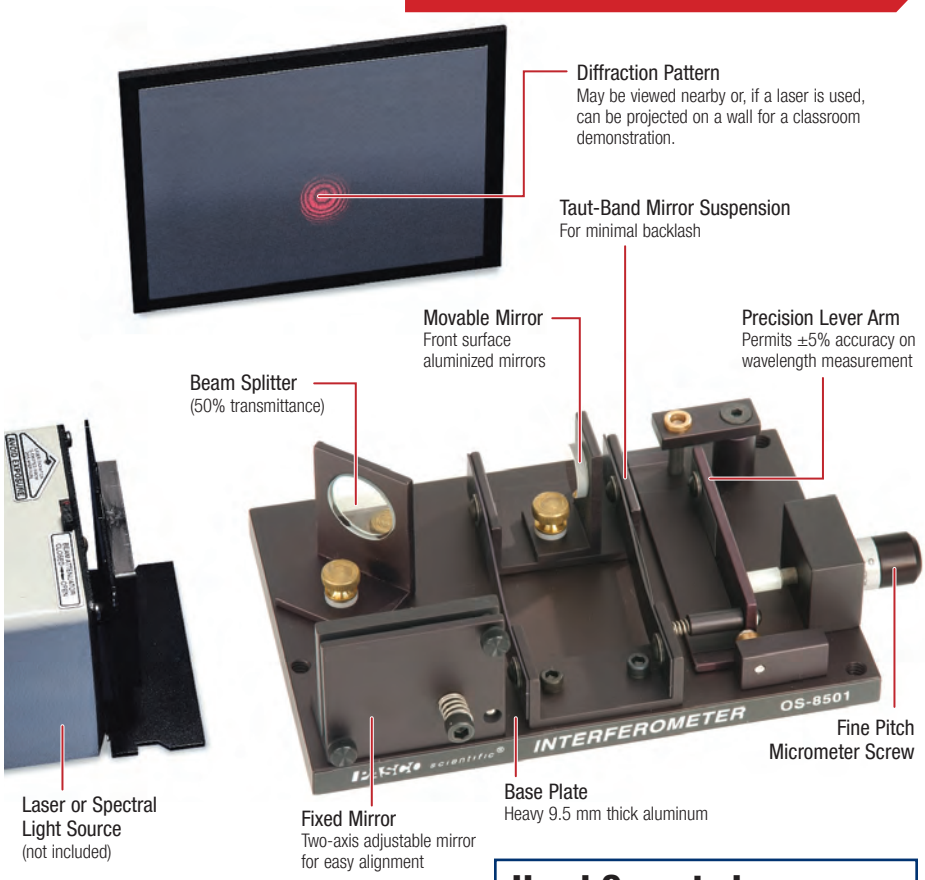
OS-8501

- Micrometer-controlled mirror movement
- Precision, front-surface optics
- Good quality, low price

This interferometer is a precision instrument for the introductory lab. It's easier to use, more compact, and less expensive than PASCO's Advanced Interferometer (see page 313).

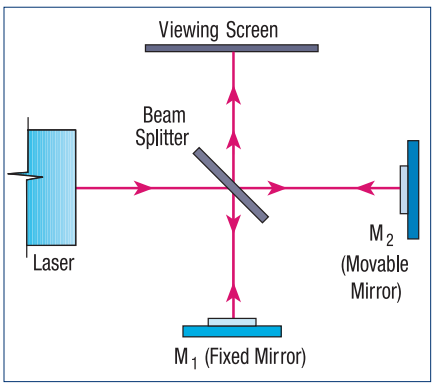
It's capable of measuring the wavelength of monochromatic light with an accuracy of better than 5%. The Michelson Interferometer can also be used for making precise measurements of the index of refraction of air.

The Introductory Michelson Interferometer provides precision interferometry at an economical price (laser and screen not included).



Features:

- **Smooth Mirror Movement:** Uses a taut-band mirror movement similar to PASCO's more advanced interferometer, providing smooth movement with minimal backlash.
- **Built-in Micrometer:** Measures mirror movement to a fraction of a micron.
- **Easy Setup:** Especially easy with a laser and a PASCO Optics Bench. If a laser is unavailable, a spectral light source can be used.
- **Complete Manual:** Manual includes illustrated setup instructions, a detailed discussion of basic Michelson interferometry plus two copy-ready experiments (measure the wavelength of monochromatic light and measure the index of refraction of air).
- The Introductory Michelson Interferometer provides precision interferometry at an economical price (laser and screen not included). Manual included.



Beam-splitting schematic for a basic Michelson Interferometer

Optics Bench

Note: While the interferometer is designed to be used with the Optics Bench of the Advanced Optics System OS-9103, it can also be used without the PASCO Optics Bench.

Includes:

- Michelson Interferometer
- Gas Cell
- Collimating Lens (18.4 mm focal length)
- Lens Holder
- Storage Case
- Manual

Order Information

Introductory Michelson Interferometer..... OS-8501
Recommended:
Mini Laser with Bracket ..... OS-8514 p. 309
Hand Operated Vacuum Pump OS-8502

Hand Operated Vacuum Pump

OS-8502

This Hand-Operated Vacuum Pump with Gauge is required to measure the index of refraction of air using the Introductory Michelson Interferometer.

Order Information

Hand Operated Vacuum Pump OS-8502

Complete Interferometer System

OS-9258B

- Three modes: Michelson, Fabry-Perot, Twyman-Green
- Large precision optics
- 5 kg machined aluminum base

No study of interferometry should overlook the historical importance of the Michelson interferometer. Yet in the laboratory, the Fabry-Perot and Twyman-Green interferometers can be more important tools: the first for high-resolution spectroscopy; the second for testing and producing optical components with aberrations that can be measured in fractions of a wavelength.

The PASCO Interferometer is a high-precision, movable-mirror interferometer that can be used to perform Michelson, Fabry-Perot, and Twyman-Green interferometry. The mirrors are attached with thumbscrews, so it's easy to set up and change configurations.

The PASCO Interferometer can be ordered in a variety of systems. The Precision Interferometer can be operated in either the Michelson or Fabry-Perot modes. The Complete Interferometer Systems also contain components for the Twyman-Green mode and a vacuum pump for the refractive index of air experiment. The Systems Component List shows the contents of each system.

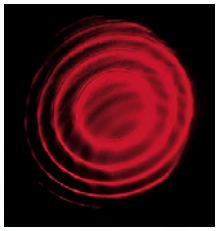
Features:

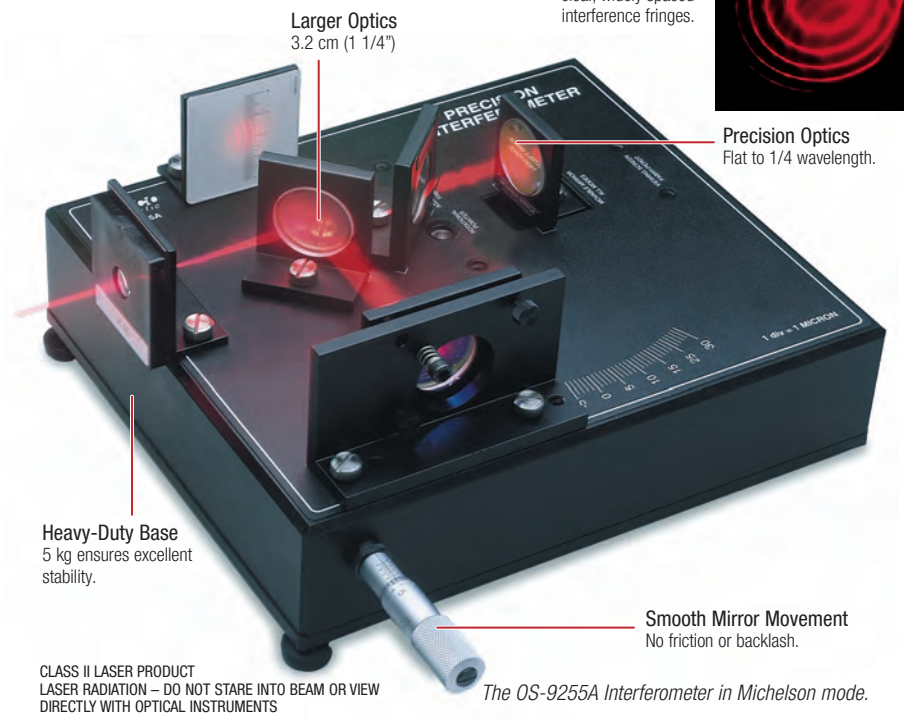
- **Stable:** The massive (5 kg) base is machined from a single block of aluminum ensuring extremely stable optics.
- **Smooth Mirror Movement:** With the taut-band suspension system, there's no starting or stopping friction and virtually no backlash (less than 0.5 micron).
- **Precise Measurements:** Mirror control is extremely fine: one micron per division of the micrometer head. The mirrors and beam-splitter are flat to 1/4 wavelength to ensure uniform interference patterns.
- **Larger Optics:** The 3.2 cm (1-1/4") diameter optics in the PASCO Interferometer produce larger and sharper interference patterns for better experimental results.
- **Complete:** The Basic Interferometer includes everything necessary to perform basic Michelson and Fabry-Perot interferometry.

Order Information

Complete Interferometer System OS-9258B
Precision Interferometer OS-9255A
Interferometer Accessories Kit OS-9256A

Fabry-Perot Interferometry: Two parallel, partially reflecting mirrors create clear, widely spaced interference fringes.





The OS-9255A Interferometer in Michelson mode.

Add the Accessories Kit (OS-9256A) (included in the Complete Interferometer System) to:

- Demonstrate that cross-polarized beams will not interfere
- Measure lens irregularities in Twyman-Green Mode
- Measure the indices of refraction for air and glass. The indices of refraction for user-supplied materials can also be measured.

Note: The fitted case will hold all components and accessories except the 5 kg base, which must be stored separately.

A. OS-9258B: Complete Interferometer System with Laser
B. OS-9255A: Precision Interferometer
C. OS-9256A: Interferometer Accessories Kit

Systems Component List	A	B	C
Machined base—5 kg	1	1	
Three-point adjustable mirror	1	1	
Mounted beam-splitter	1	1	
Mounted movable mirror	1	1	
Accessory mounts	3	2	1
Viewing Screen OS-9138	1	1	
Diffuser OS-9120	1	1	
Double Convex Lens (18 Mm) OS-9132	1	1	
Compensator lens	1	1	
Fitted case	1	1	
Vacuum Pump with Gauge OS-8502	1		1
Gas cell	1		1
Calibrated Polarizer OS-9109	2		2
Glass Plate OS-9128	1		1
Rotating component holder	1		1
Twyman-Green Lenses OS-9133, OS-9132	2		2
Mini Laser with Bracket OS-8514	1		
Laser Alignment Bench OS-9172	1		
Instruction manual	1	1	

Microwave Optics

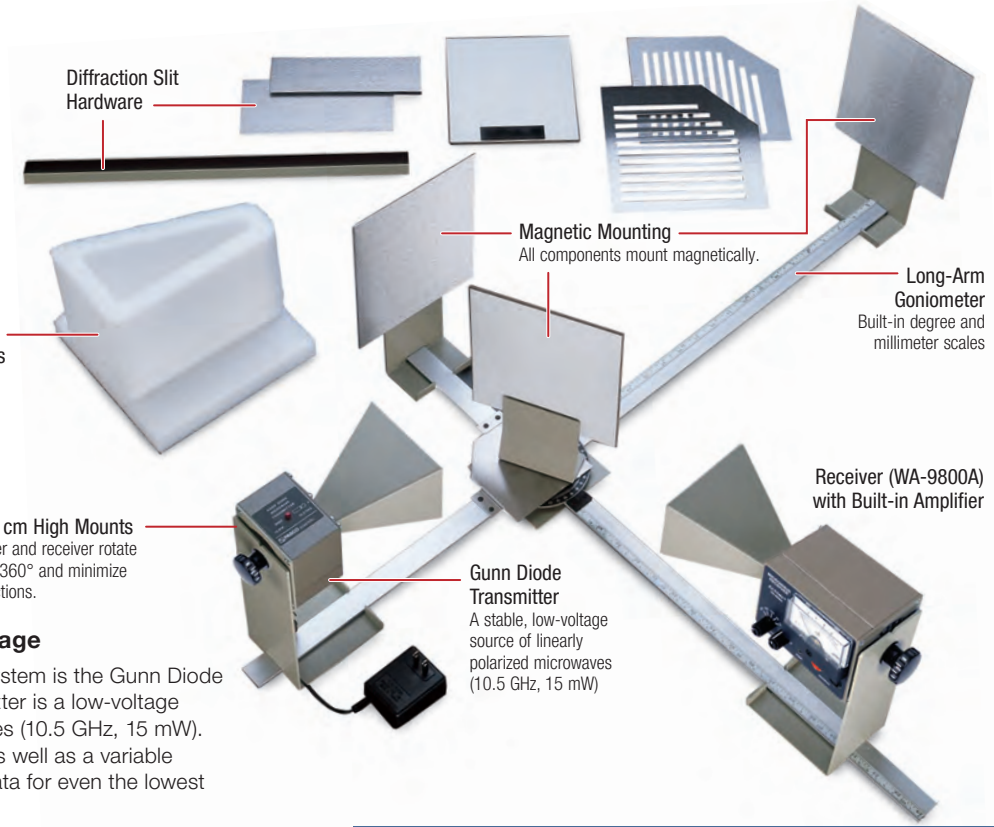
Basic System

WA-9314C

Advanced System

WA-9316A

- Durable construction
- Parts are made of stainless steel or die-cast aluminum.



The Microwave Optics Advantage

The heart of the Microwave Optics System is the Gunn Diode Transmitter and receiver. The transmitter is a low-voltage source of linearly polarized microwaves (10.5 GHz, 15 mW). The receiver has a built-in amplifier, as well as a variable sensitivity scale, ensuring accurate data for even the lowest intensity measurements.

The large 3 cm wavelength makes it easy to understand and visualize electromagnetic wave interactions. The interference and diffraction slits are several centimeters wide, and the polarizers are slotted sheets of stainless steel.

The WA-9314C Basic Microwave Optics System Includes:

- Gunn Diode Transmitter with mounting stand
- Receiver with built-in amplifier and mounting stand
- Goniometer with fixed and rotatable arms and degree scale
- Fixed-arm assembly for interferometer experiments
- Component holders: two standard, one rotating
- Rotating table
- Reflectors: two full reflectors (metal), two partial reflectors (wood)
- Polarizers
- Diffraction slit hardware
- Prism (Ethafoam) with styrene pellets
- AC adapter
- Laboratory manual with 12 experiments

The WA-9316A Advanced Microwave Optics System Includes:

- Microwave Optics: Basic System: WA-9314C
- Microwave Accessory Package: WA-9315

Order Information

Microwave Optics: Basic System	WA-9314C
Advanced Microwave Optics System	WA-9316A

Recommended:
The microwave transmitter and receiver assemblies may be purchased separately:

Microwave Transmitter	WA-9801
Microwave Receiver	WA-9800A
Microwave Mounting Stand	WA-9802

Microwave Detector Probe

WA-9319A

Investigate the nodes and antinodes in standing wave patterns with this microwave probe. It plugs directly into the (WA-9800A) receiver.

Not compatible with older versions of the receiver.

Order Information

Microwave Detector Probe	WA-9319A

Microwave Accessory Package

WA-9315

(included in the WA-9316A Advanced System)

Includes a polyethylene panel for measuring Brewster's angle and a simulated crystal for Bragg diffraction experiments.
The crystal is a cubic lattice of 100 metal spheres in a 5 x 5 x 4 array, mounted in plastic foam.

Includes:

- Simulated Crystal Lattice
- Polyethylene Panel

Order Information

Microwave Accessory Package	WA-9315

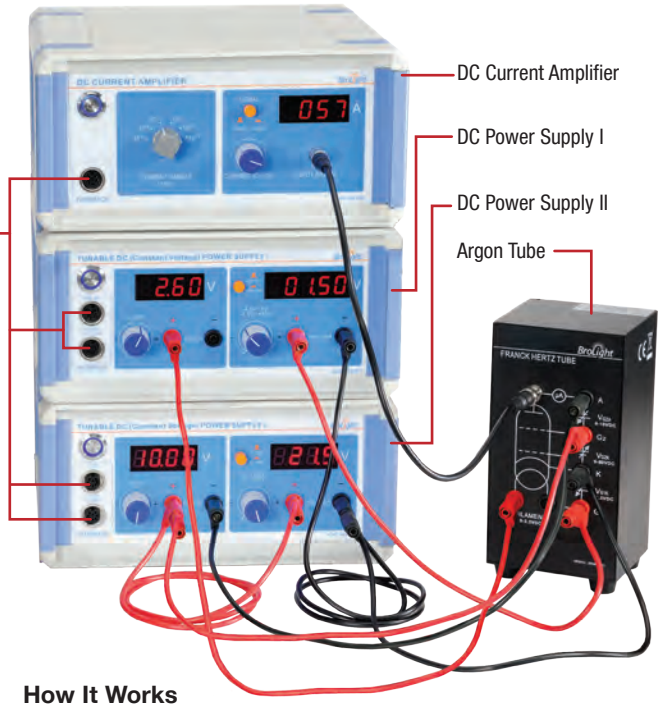
Franck-Hertz System

SE-9639

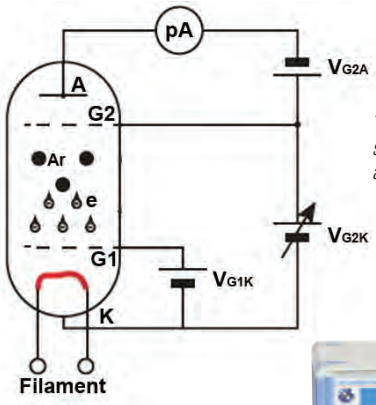
See complete experiment on page 381.

- Uses argon gas, so no heating is required
- Digital displays for standalone use
- Can be used with the 850 Interface and PASCO Capstone

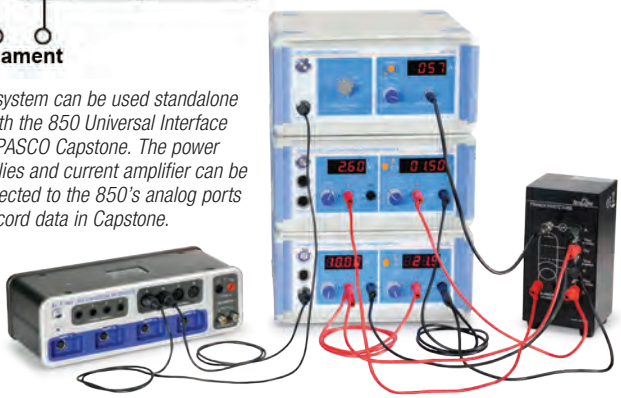
850 Universal Interface Connections
for Instrument Readout



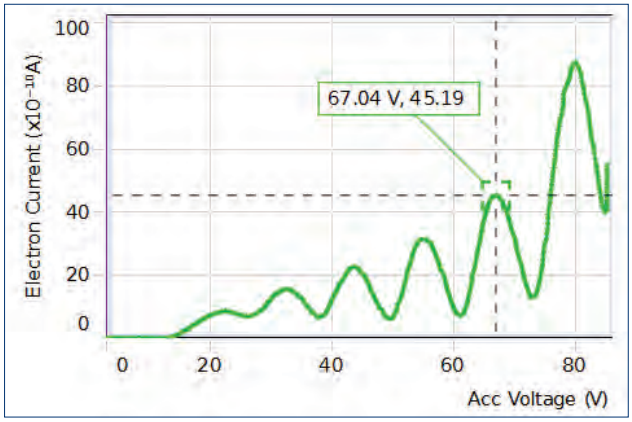
As early as 1914, James Franck and Gustav Hertz discovered in the course of their investigations an energy loss in distinct steps for electrons passing through mercury vapor and a corresponding emission at the ultraviolet line (λ= 254 nm) of mercury. They performed this experiment that has become one of the classic demonstrations of the quantization of atomic energy levels. They were awarded the Nobel Prize for this work in 1925.



This diagram shows the internal structure of the Franck-Hertz tube and the wiring diagram.



The system can be used standalone or with the 850 Universal Interface and PASCO Capstone. The power supplies and current amplifier can be connected to the 850's analog ports to record data in Capstone.



Capstone lets students collect many more data points compared to manually taking readings from the digital readouts. The peaks and troughs are easily measured using the coordinate tool.

How It Works

Electrons are accelerated by applying a known potential between two grids inside the argon tube. When an electron has sufficient kinetic energy to excite one of argon's outer orbital electrons and has an inelastic collision with an argon atom, the electron loses a specific amount of kinetic energy. This loss of electron kinetic energy causes a decrease in the electron current in the argon tube. Within a very short time, the excited argon electron will fall from the excited state back into the ground state level, emitting energy in the form of photons.

As the accelerating voltage is increased, the electrons undergo multiple collisions and the excitation energy of the argon atom can be determined by the differences between the accelerating voltages that cause a decrease in the current. Planck's Constant can be determined.

Specifications:

Filling Gas: Argon
Filament Voltage: ≤6.3 VDC
Accelerating Voltage: ≤100 VDC
Wave Crest (or Trough) Number: 6
Argon Tube Life Span: ≤3000 hrs

Power supply and current amplifier specs: See page 260.

Includes:

- Franck-Hertz Tube Enclosure with Argon Tube: SE-9650
- DC Power Supply I (Constant Voltage): SE-6615
- DC Power Supply II (Constant Voltage): SE-9644
- DC Current Amplifier: SE-6621
- Red and Black Patch Cords

Order Information

Franck-Hertz System SE-9639
Power supplies and amplifier can be purchased separately. See page 260. if you already have power supplies, you will need:
Franck-Hertz Tube Enclosure with Argon Tube SE-9650A
Replacement Parts:
Franck-Hertz Argon Tube SE-9645A

Millikan Oil Drop Apparatus

AP-8210A

- Nobel Prize-quality physics in the student lab
- Ionization source for changing droplet charge
- Measures the charge of an electron to within ±3%

The Millikan Oil Drop Experiment is one of the most popular experiments in undergraduate physics for several reasons:

- The experimental principle is straightforward and easy to understand.
- It measures a fundamental atomic constant using a method that won its originator, Robert Millikan, the Nobel Prize.
- The observation of the effects of one or more electrons upon oil drops in an electric field provides a striking demonstration of the quantized nature of electricity.

See complete experiment on page 360.

The Millikan Oil Drop Apparatus mounted on a rod stand for easy, eye-level viewing

Thermistor Connectors
Attach an ohmmeter to monitor chamber temperature. A thermistor is embedded in the bottom plate of the chamber.

Plate Voltage Connectors
Connect a power supply to charge the plates inside the chamber.

Plate Charging Switch
Allows the operator to ground the plates or charge them to either polarity. The switch box is separate to minimize vibration.

3 Chamber Level Positions

Ionization ON
Introduces a thorium source into the chamber to change droplet charge

Spray
Allows air to be displaced when oil droplets are sprayed into chamber.

Ionization OFF
Prevents ionization source from affecting the droplets.

Bright LED Light Source
User adjustable variable light output.

Bubble Level
Bull's-eye level makes sure apparatus is level.

Rod Stand Mounts and Screws
Designed to mount on PASCO's Large Rod Stand. Allows the apparatus to be reduced to eye level.

Droplet Viewing Chamber
Unique design minimizes droplet drift due to heat from droplet illumination and outside air currents.

Viewing Scope
30X, bright-field, erect-image microscope with focusing ring.

Thermistor Resistance Table
A convenient table provided for quick conversion of resistance values to Celsius.

Reticle Focus
Separate reticle focus and precision etching provide sharp, easy-to-view grid lines with 0.5 mm major and 0.1 mm minor divisions.

Focusing Wire
When placed in the chamber, the focusing wire allows the lamp to be aligned so that both the light and the eyepiece focus on the center of the chamber.

Clear droplet observation and low droplet drift are essential for success with Millikan's classic experiment. PASCO's apparatus uses a pre-aligned optical system and special condenser to achieve these conditions.

Accuracy in the Oil Drop Experiment depends on the student's ability to precisely measure all the variables involved: plate voltage, plate separation, time and distance of droplet rise and fall, temperature, oil density, etc. Extreme care taken in the design and manufacturing of this unit ensures that the student's best efforts will be rewarded with more accurate results. Typically, a careful student can achieve results within 3% or less of the accepted value.

Specifications:

Maximum Plate Voltage: 500 VDC
Light Source: Cool LED
Reticle Line Separation:
0.5 mm major divisions
0.1 mm minor divisions
Plate Spacing: 7.62 mm
Plate Diameter: 60 mm

Includes:

- Millikan Oil Drop Apparatus with Switch
- Non-volatile Oil and Atomizer
- 12 VDC Lamp Power Adapter

Order Information

Millikan Oil Drop Apparatus	AP-8210A	
Required:		
Basic Digital Multimeter	SE-9786A	p. 240
High Voltage Power Supply	SF-9585A	p. 263
Recommended for mounting unit at eye level on a standard lab table:		
Large Rod Base	ME-8735	p. 196
45 cm Stainless Steel Rod	ME-8736	p. 196
Replacement Parts:		
4 oz Bottles of Mineral Oil (Qty 4)	AP-8211	
Millikan LED Light Source	AP-8212	

e/m Apparatus

SE-9629

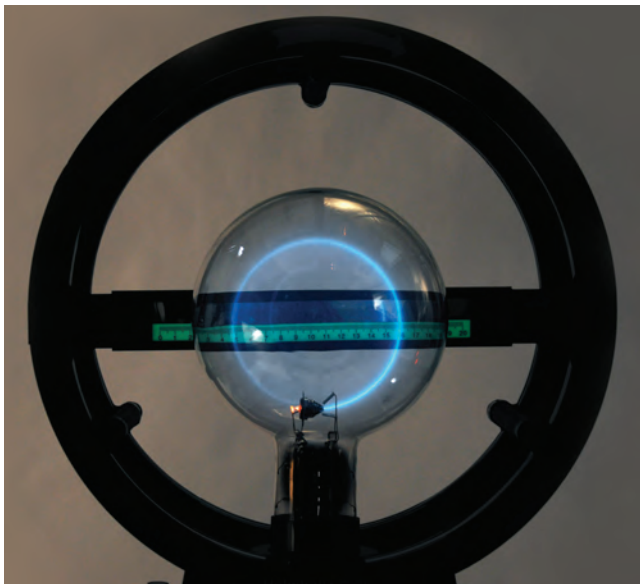
- Sharp, clearly visible electron beam
- Phosphorescent mirrored scale eliminates parallax errors
- Tube rotates for general study of electrons in a magnetic field

In 1897, J. J. Thomson showed that the mysterious cathode rays were actually negatively charged particles—he had discovered the electron. In the same year he measured the charge-to-mass ratio of the electron, providing the first measurement of one of the fundamental constants of the universe.

The Charge-to-Mass Ratio System reproduces one version of Thomson's landmark experiment, providing an accurate measurement of the charge-to-mass ratio of the electron. And, since the electron tube can be rotated through 90°, students can also make a more general study of the behavior of electrons in a magnetic field.

This apparatus also has deflection plates, so students can study the effect of an electric field on moving electrons.

The complete Charge-to-Mass Ratio System includes the power supplies, which can also be used in other experiments (such as the Franck-Hertz experiment, see page 381).



Fluorescent scale shows behind the electron beam in a dark room.

How It Works

A large, helium-filled electron tube is mounted between a pair of Helmholtz coils. The tube contains an electron gun, which generates a focused beam of electrons. A measured current is applied to the Helmholtz coils so that the magnitude of the magnetic field within the electron tube can be calculated. A measured accelerating potential (V) is then applied to the electron gun. The magnetic field (B) deflects the electron beam in a circular path with a radius (r) that is measured using the illuminated mm scale. From these measured values, the charge-to-mass ratio of the electron is calculated:

$$e/m = 2V/B^2r^2.$$

(The details of the calculations are fully described in the manual.)

Specifications:

Hemholtz Coil Radius: 16 cm
Number of Turns: 130
Maximum Current: 3.5 A
Filament Voltage: 6.3 VAC
Acceleration Voltage: 0 - 200 V
Tube Diameter: 15.5 cm

Includes:

- Helmholtz coils for e/m: SE-9626
- Replacement e/m Tube: SE-9651
- Tunable DC Power Supply (Constant Current): SE-9622
- DC Power Supply II (Constant Voltage): SE-9644
- Red and Black Patch Cords

For more information about power supplies, see page 260.

Order Information

e/m Apparatus	SE-9629
If you already have power supplies, you will need:	
Helmholtz coils for e/m	SE-9626
Replacement e/m Tube	SE-9651A
Replacement Parts:	
Replacement Mirror Scale for e/m Apparatus	SE-9649

Photoelectric Effect System

SE-6609

- Experimentally determine Planck's Constant within 5%
- Verify that stopping potential is independent of light intensity
- Find characteristics of the material(s) inside the vacuum photodiode

The Photoelectric Effect System uses the conventional method to determine Planck's Constant within 5%. First, the metal plate in the photodiode is illuminated by various light frequencies, selected from a mercury lamp with filters. Then, the voltage is adjusted to stop the photoelectric current. The stopping voltage is then plotted against the frequency, and Planck's Constant is determined using the slope. Students can test whether the stopping voltage changes with light intensity using the various apertures and corresponding light intensities.

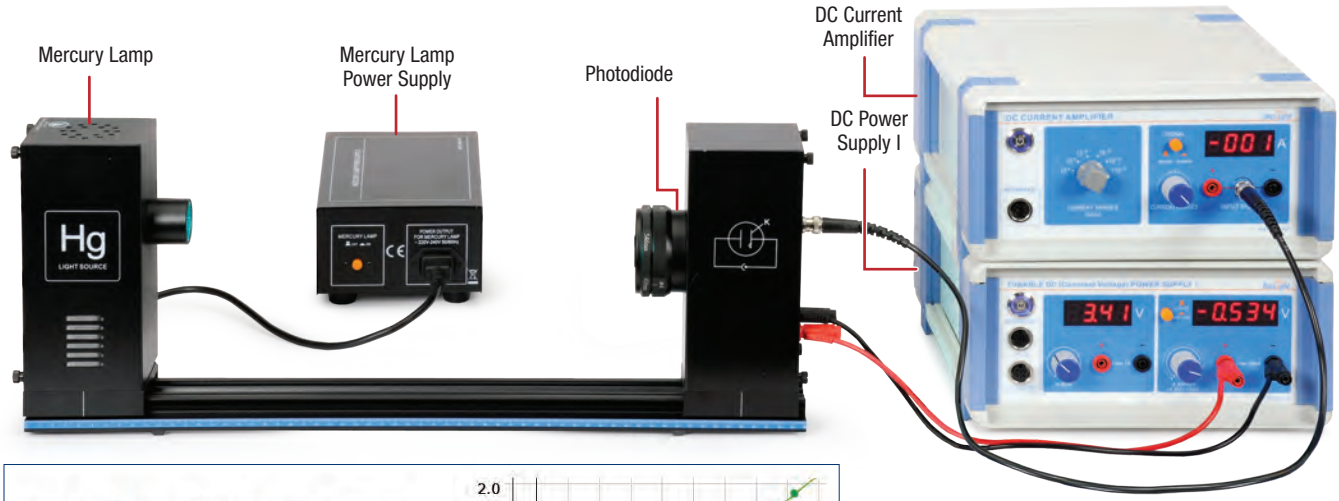
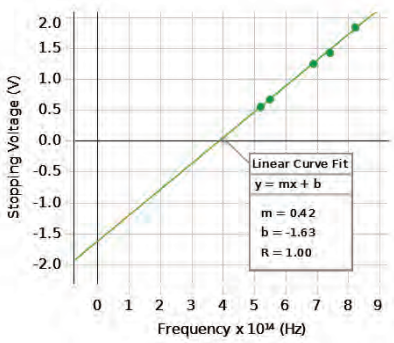


Table I: Photoelectric Effect with 4 mm Aperture

	Run #1 Frequency x 10^{14} (Hz)	Run #1 Stopping Voltage (V)
1	8.214	1.835
2	7.408	1.428
3	6.879	1.248
4	5.490	0.671
5	5.196	0.551



In the sample data above, the graph of Stopping Voltage vs. Frequency gives a slope of 4.2 x 10^{-15} V·s. This results in a value for Planck's Constant of 6.7 x 10^{-34} J·s, which is 1.3% above the accepted value. This graph was generated using PASCO Capstone™ software and the 850 Interface.

Compatible with the 850 Interface (UI-5000, see p. 26) and PASCO Capstone

See the complete experiment on page 379.

For Power Supply and Current Amplifier specs, see page 260.

The filters and the apertures are built into the front of the photodiode case, making it easy to clean and eliminating the need for a separate storage box. To change the aperture size, simply pull outward on the aperture ring and rotate it to a different aperture. The filter wheel rotates independently of the aperture ring to select different frequencies of light. The wheel clicks into place, assuring that the filter is aligned with the aperture.

Specifications:

Current Amplifier Measuring Range: 10^{-8} to 10^{-13} A in six ranges

Photoelectric Tube Voltage Adjustment: –4.5 V to 0 V and –4.5 V to +30 V (two ranges)

Photoelectric Tube Spectral Response Range: 300 nm – 700 nm

Photoelectric Tube Anode: nickel ring

Five Optical Filters with Central Wavelengths: 365.0, 404.7, 435.8, 546.1, and 578.0 nm

Order Information

Photoelectric Effect System SE-6609
If you already have the Power Supply and Amplifier, you will need:
Basic Photoelectric Effect Apparatus SE-6614
Replacement Parts:
Photoelectric Tube with Box Plate.....SE-6612

SE-6609 Includes:

- Basic Photoelectric Effect Apparatus: SE-6614
- DC Current Amplifier: SE-6621
- DC Power Supply I (Constant Voltage): SE-6615

SE-6614 Includes:

- Photodiode Enclosure with Tube
- Track, 60 cm and required cables
- Mercury Light Source (SE-6608)

Save!

Share Instruments in Three Experiments

These three experiments require the same power supplies and amplifiers. Save storage and equip your lab for less, by sharing these instruments between all three experiments asynchronously.

1. Photoelectric Effect

Complete Setup:
Photoelectric Effect System SE-6609

2. Franck-Hertz

Complete Setup:
Franck-Hertz System SE-9639

3. Electron Charge-to-Mass Ratio (e/m)

Complete Setup:
e/m Apparatus.....SE-9629

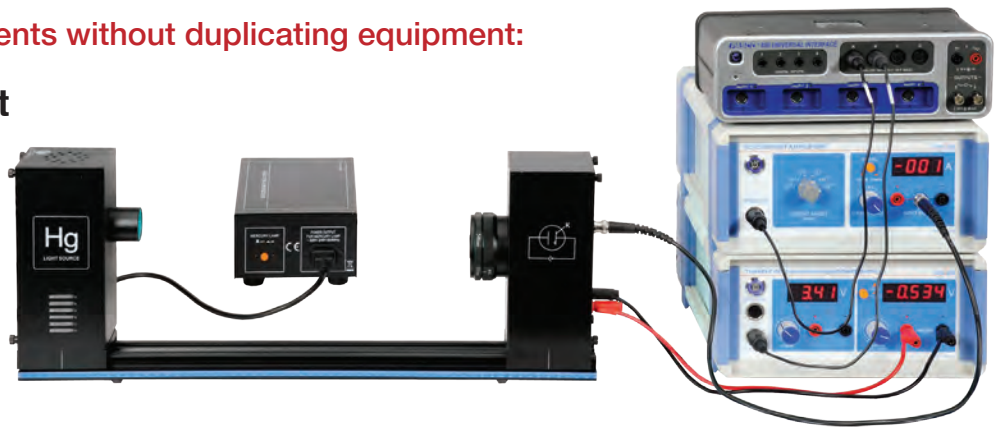
EXPERIMENT	DC Power Supply I	DC Power Supply II	DC (Constant Current) Supply	DC Current Amplifier
Photoelectric Effect	✔			✔
Frank-Hertz	✔	✔		✔
e/m		✔	✔	

Perform these experiments without duplicating equipment:

1. Photoelectric Effect

Photoelectric Effect System
SE-6609

This complete setup includes two instruments that can be used in the Frank-Hertz and e/m experiments.



2. Franck-Hertz

Add

Franck-Hertz Tube Enclosure with Argon Tube
SE-9650A

Add

DC Power Supply II (Constant Voltage)
SE-9644

3. Electron Charge-to-Mass Ratio (e/m)

Add

Helmholtz Coils for e/m
SE-9626

Add

Tunable DC Power Supply (Constant Current)
SE-9622

Add

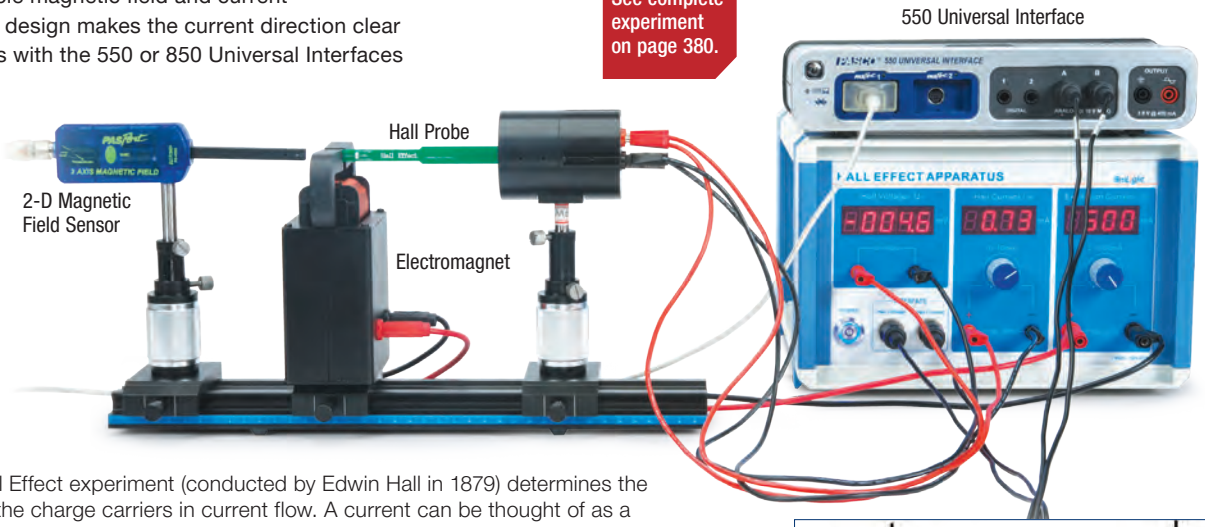
Replacement e/m Tube
SE-9651A

Hall Effect n-Doped Semiconductor

SE-7260

- Variable magnetic field and current
- Open design makes the current direction clear
- Works with the 550 or 850 Universal Interfaces

See complete experiment on page 380.



The Hall Effect experiment (conducted by Edwin Hall in 1879) determines the sign of the charge carriers in current flow. A current can be thought of as a negative charge moving in one direction or as a positive charge moving in the opposite direction. To determine which it actually is, the semiconductor is immersed in the magnetic field transverse to the direction of flow of current. The moving charge experiences a force, causing a charge build-up on one side of the semiconductor (creating an electric field), which in turn leads to a force. The direction of the electric field will depend on the sign of the charge carriers, which is revealed by the polarity of the Hall voltage across the semiconductor.

The magnitude of the Hall voltage is dependent on the current, the charge carrier density, and the magnitude of the magnetic field. In modern day electronics, the Hall Effect is used to measure the magnitude and direction of magnetic fields.

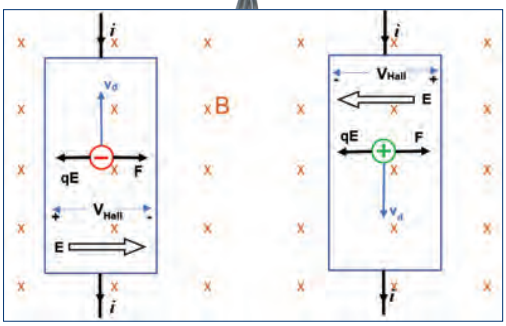


Figure 1 Figure 2

PASCO Advantage

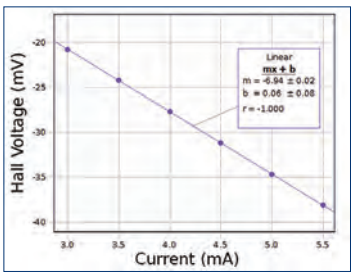
The open design of this Hall Effect apparatus makes it possible for students to see the direction of the current and the magnetic field, enabling them to use the sign of the Hall voltage to deduce the sign of the charge carriers.

The directions of the current and the voltage probe are clearly marked on the probe that holds the semiconductor.

Specifications:

n-Doped Semiconductor Material: GaAs
Hall Sensitivity: ≥150 mV/(mA·T)
Magnet Space: 10 mm
U-core Electromagnetic Coil: 1000 Turns
Magnet Field: 0 to 0.065 T (at 1A)
Excitation Current: 0 to 1 A DC
Hall Voltage: 0 to 1.9999 V
Power Supply Digital Readout for Current, Hall Voltage, and Magnet Current

Using the 550 Universal Interface to record data, this plot of the Hall Voltage vs. the Current was made in PASCO Capstone software. In this case, the magnetic field was held constant and the current through the semiconductor was varied.



Includes:

- Hall Probe Unit, n-Semiconductor (GaAs)
- Hall Effect Power Supply
- U-Core Electromagnetic Coil
- Track, Length 40 cm
- Optical Carrier (2)
- Adjustable Post Holder with 9 cm Post (2)
- Banana Cords (6)
- Connecting Cables for 550/850 Interface (2)
- Manual

Order Information

Hall Effect n-Doped Semiconductor.....SE-7260

Note: This apparatus can be used manually by reading the digital displays. Measuring the magnetic field requires a sensor or other Tesla meter. This apparatus includes connector cables for an 850 or 550 Interface so data collection can be automated.

Required:

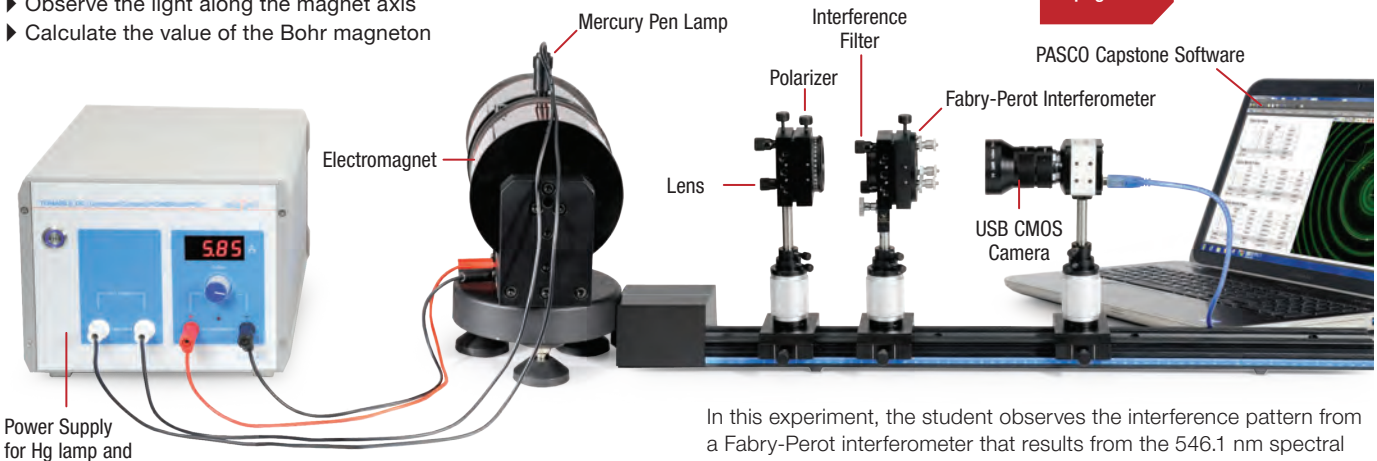
PASPORT 2-Axis Magnetic Field Sensor	PS-2162	p. 51
850 or 550 Universal Interface	UI-5000 or UI-5001	pp. 26-29
PASCO Capstone Software		pp. 84-87

Zeeman Effect

SE-9654

- Measure the Zeeman Effect with polarization perpendicular and parallel to the field
- Observe the light along the magnet axis
- Calculate the value of the Bohr magneton

See complete experiment on page 382.

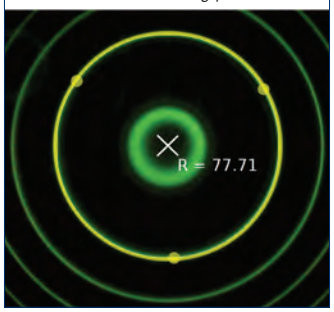


In this experiment, the student observes the interference pattern from a Fabry-Perot interferometer that results from the 546.1 nm spectral line of a mercury lamp immersed in a uniform magnetic field. The magnetic field is varied from zero to nearly 1 Tesla.

Initially, the light is viewed along an axis perpendicular to the magnetic field axis. A polarizer is used to show the three lines due to light that is polarized parallel to the field axis and to show the six lines that are polarized perpendicular to the field axis. The pattern may also be viewed along the field axis where the light is circularly polarized.

Finally, the pattern that is polarized perpendicular to the field axis is used to calculate the Bohr magneton. All atomic magnetic moments are integral or half-integral multiples of the Bohr magneton.

Zeeman Effect ring pattern



Electromagnet produces over one Tesla.

The vertical position can be adjusted precisely with the fine-adjustment mechanism.

Lens and polarizer mount can be adjusted vertically and horizontally.

The optics and track come in an aluminum hard case with foam cutouts for each component.

Specifications:

CMOS Camera and Lens: 1/3", 2M pixels, f = 50 mm, RA = 1:4
Fabry-Perot Interferometer: λ = 546.1 nm
Collimating Lens: f = 125 mm
Mercury Lamp: 10A, 3W
Electromagnet: 5A, 1.2T, ~7.4 mm gap
Tunable DC Power Supply: 110V/220V, 6A
Precision Adjustable Optical Mount: Φ45 mm, 2D
Horizontal Optical Mount: Φ45 mm, travel = 36 mm, 2D
Track Length: 600 mm

Includes:

- Electromagnet
- Optics
- Power supply
- PASCO Capstone Single User License

Order Information

Zeeman Effect	SE-9654	
May be purchased separately:		
Electromagnet	SE-9655	p. 248
Tunable DC Power Supply 6A	SE-9656	p. 261
Replacement Part:		
Pen-Type Mercury Lamp 10A, 3W	SE-9658	
Optional:		
Magnetic Field Meter	SE-7579B	p. 256

Field strength as a function of the current supplied to the magnet is included in a chart. To directly measure field strength, order the optional Magnetic Field Meter (SE-7579B).

Gravitational Torsion Balance

AP-8215A

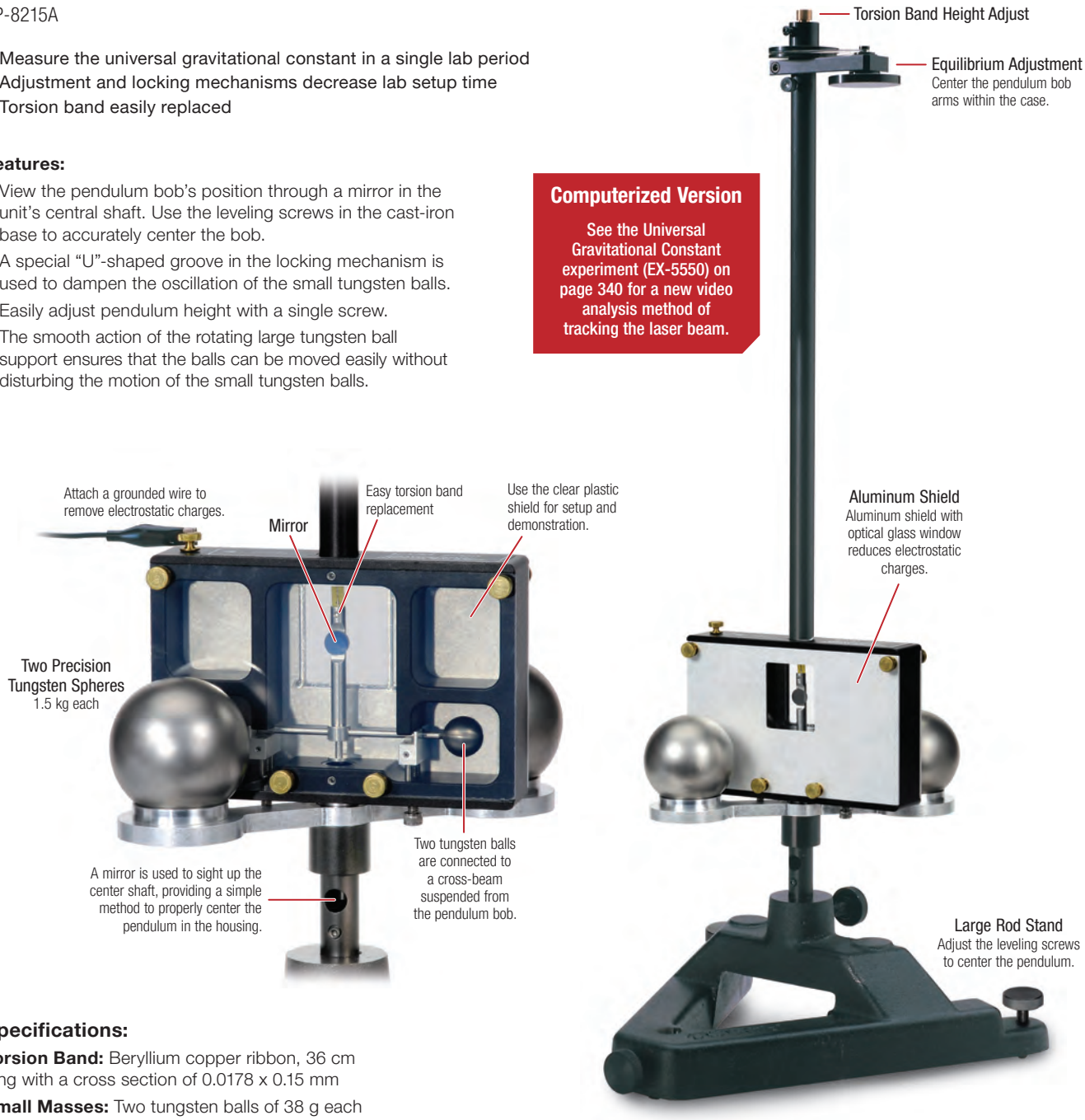
- Measure the universal gravitational constant in a single lab period
- Adjustment and locking mechanisms decrease lab setup time
- Torsion band easily replaced

Features:

- View the pendulum bob's position through a mirror in the unit's central shaft. Use the leveling screws in the cast-iron base to accurately center the bob.
- A special "U"-shaped groove in the locking mechanism is used to dampen the oscillation of the small tungsten balls.
- Easily adjust pendulum height with a single screw.
- The smooth action of the rotating large tungsten ball support ensures that the balls can be moved easily without disturbing the motion of the small tungsten balls.

Computerized Version

See the Universal Gravitational Constant experiment (EX-5550) on page 340 for a new video analysis method of tracking the laser beam.



Specifications:

Torsion Band: Beryllium copper ribbon, 36 cm long with a cross section of 0.0178 x 0.15 mm

Small Masses: Two tungsten balls of 38 g each

Large Masses: Two tungsten balls of 1.5 kg each

Period of Oscillation: Eight minutes (approx.)

Accuracy: 5% (approx.)

Includes:

- Torsion Balance Assembly
- Large Rod Base ME-8735
- Extra Torsion Band
- Manual

Order Information

Gravitational Torsion Balance	AP-8215A	
Required:		
X-Y Adjustable Diode Laser	OS-8526A	p. 308
45 cm Stainless Steel Rod	ME-8736	p. 196
Large Table Clamp	ME-9472	p. 199
Replacement Supplies:		
Torsion Bands (2 Pack) – Gravitational Torsion Balance	AP-8218	
Gravitational Torsion Balance Replacement Spheres	AP-8219	

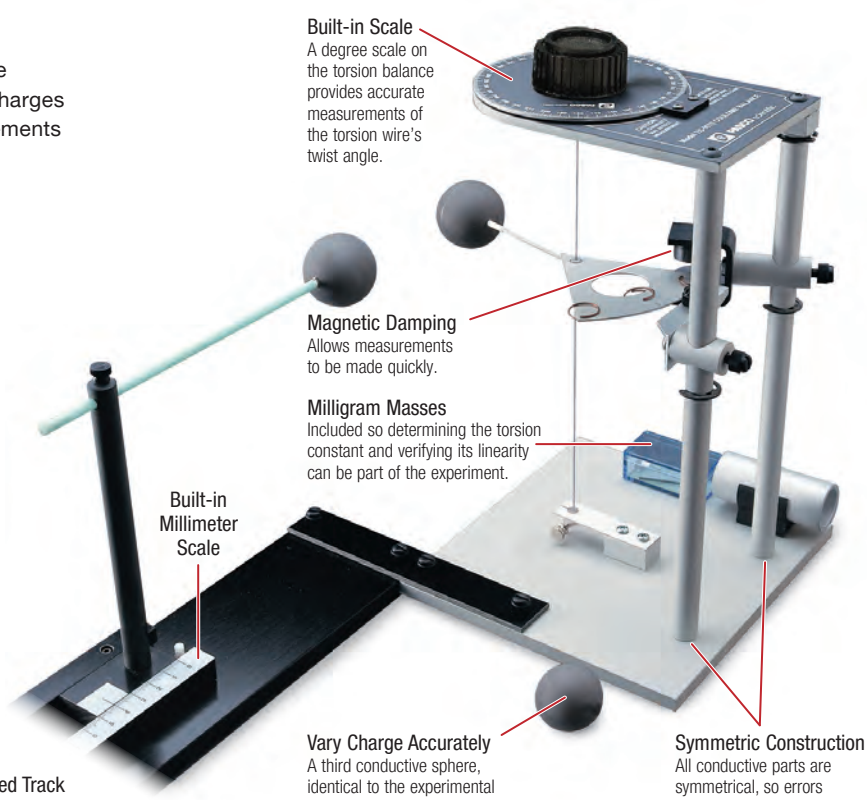
Coulomb's Law Apparatus

ES-9070

- Accurately measure charge, force, and distance
- Symmetric design minimizes stray and mirror charges
- Magnetic damping for quick, accurate measurements

How It Works:

A conductive sphere is mounted on the end of an insulating, counterbalanced rod and suspended from a thin torsion wire. An identical sphere is mounted on a calibrated linear track. This second sphere can be positioned at various distances from the first. When the conductive spheres are charged, the force between them is proportional to the twist of the torsion wire that is required to bring the balance back to its equilibrium position. Beginning students can determine the Inverse Square Law in a simple experiment. Advanced students can perform a more sophisticated investigation into all the variables of electrostatic repulsion.



Specifications:

Torsion Balance:

Torsion Assembly: 38 mm dia. conductive sphere on 12 cm rod with counterbalance vane

Torsion Wire: equals 10-6 Newtons/degree

Degree Plate: 1° increments

Magnetic Damping: dampens oscillations for quick measurements

Calibrated Linear Track:

Sphere: 38 mm dia. conductive sphere

Range of Movement: 350 mm in 1 mm increments

Material: phenolic (to minimize mirror charges)

Miscellaneous Equipment:

Charging Probe: 17 cm long plus 1.5 m cable; banana plug connector; 200 μΩ internal resistance

Calibration Masses: 50 mg (1), 20 mg (2)

Conductive Sphere on Insulating Thread: for reducing charge by fixed ratios

Spare Torsion Wire: 3 m

Shipping Information:

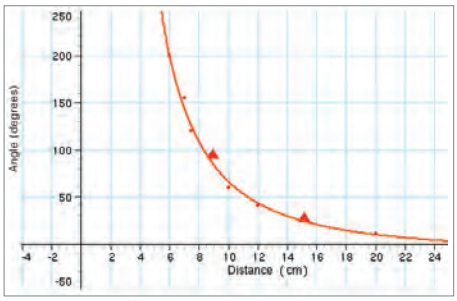
Size: 28 x 38 x 61 cm (11 x 15 x 24 in.)

Weight: 9.5 kg, 21 lbs

Additional Equipment

To perform a basic experiment, the conductive spheres can be charged with a piezoelectric gun or by contact with a charged rod. This allows the Inverse Square Law to be verified with reasonable accuracy. However, for more accurate and thorough investigations, we strongly recommend the following additional equipment (see ordering information):

- **Kilovolt Power Supply,** which provides a fixed and repeatable charge. The charge can be refreshed before each measurement, which practically eliminates errors due to leakage currents.
- **Basic Electrometer and a Faraday Ice Pail,** for accurate measurement of the charge on the spheres (required only if you wish to measure the Coulomb Constant).



Actual data of the Angle (force) vs. Distance

Order Information

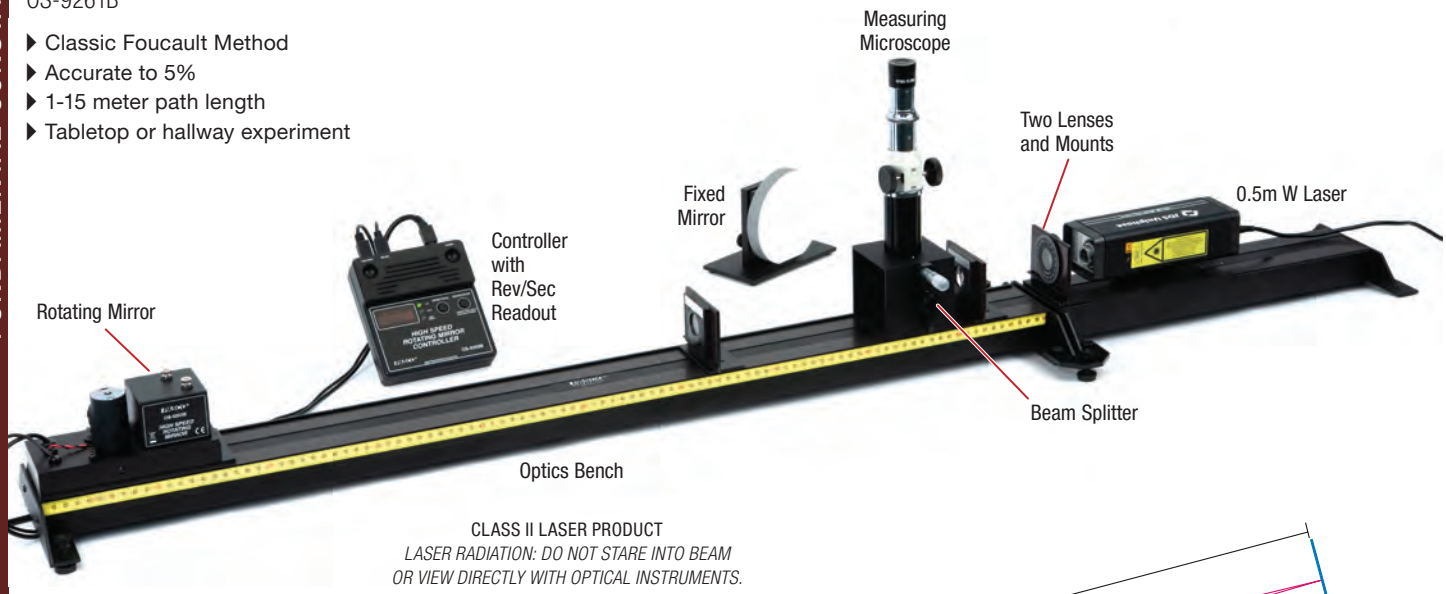
Coulomb's Law Apparatus	ES-9070	
Recommended:		
Kilovolt Power Supply	SF-9586B	p. 263
Basic Electrometer	ES-9078A	p. 224
Faraday Ice Pail	ES-9042A	p. 225
Charge Producers and Proof Plane	ES-9057C	p. 225
Coulomb's Law Experiment	EX-9930B	p. 359

Speed of Light

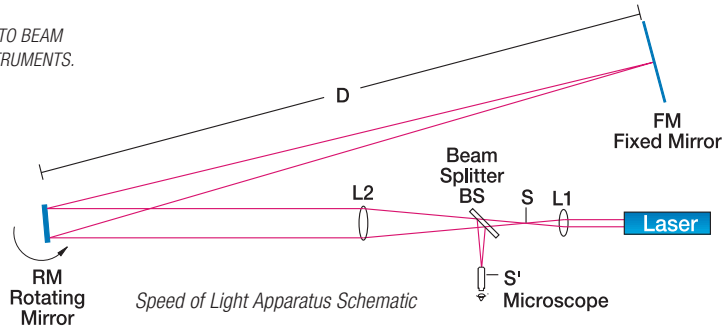
Complete Speed of Light Apparatus

OS-9261B

- Classic Foucault Method
- Accurate to 5%
- 1-15 meter path length
- Tabletop or hallway experiment



CLASS II LASER PRODUCT
LASER RADIATION: DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS.



Speed of Light Apparatus Schematic

How It Works – The Foucault Method

1. The first observation is made when the rotating mirror is not rotating. Light from a He-Ne laser is reflected from the rotating mirror and focused onto the fixed mirror. The fixed mirror reflects the image back onto the rotating mirror, which in turn reflects the light back through the lenses to reform the image, where it can be observed with the microscope.
2. The second observation is made when the rotating mirror is rotating. Since it takes a finite amount of time for the light to traverse the distance between the fixed and rotating mirrors, the rotating mirror is in a slightly different position when the light returns after reflecting off the fixed mirror. This produces a displacement, which can be measured with the microscope.
3. The displacement between the first and second observations is proportional to the transit time of the light and the angular velocity of the rotating mirror. With a very straightforward calculation, the speed of light can be calculated.

OS-9261B Includes:

- 1 m Optics Bench
- Laser Alignment Bench
- Mini Laser with Bracket
- Double Convex Lens, 48 mm F.L.
- Plano Convex Lens, 252 mm F.L.
- Calibrated Polarizer
- Component Carrier

Order Information

Complete Speed of Light Apparatus	OS-9261B	
Parts Available Separately:		
Laser Alignment Bench	OS-9172	p. 309
Mini Laser with Bracket	OS-8514	p. 309
Speed of Light Experiment	EX-9932A	p. 377

High Speed Rotating Mirror with Controller

OS-9263B

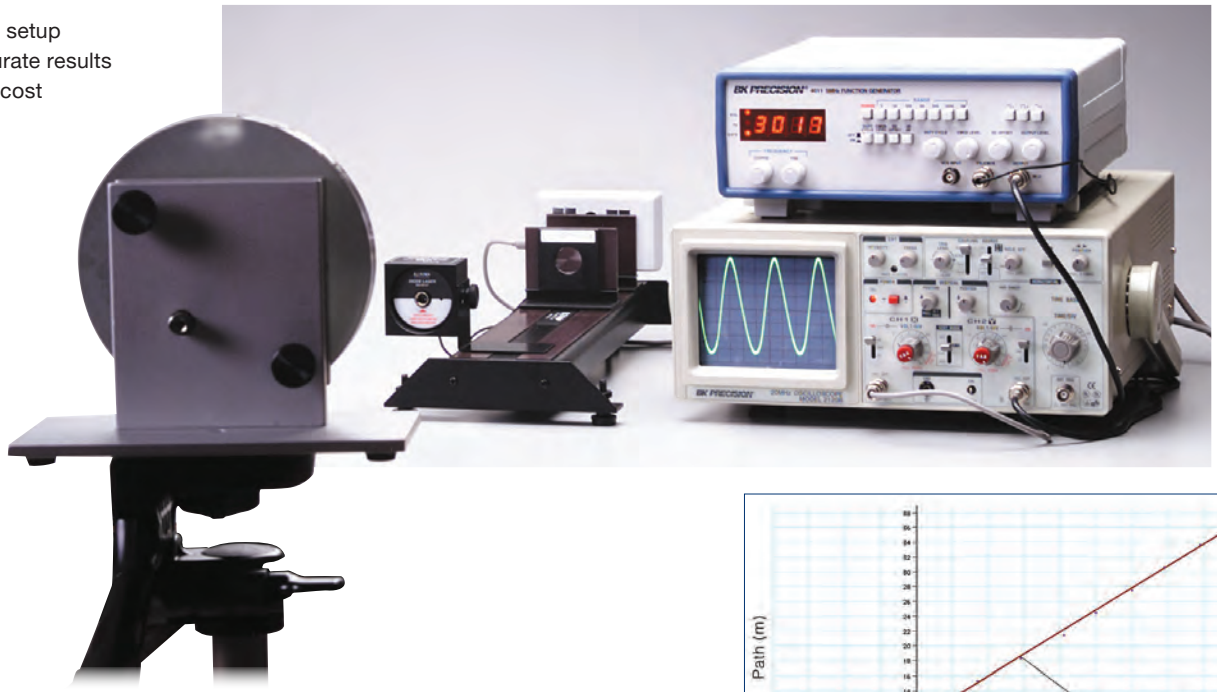
Order Information

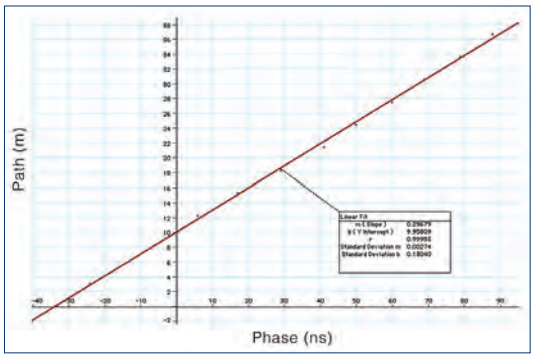
High Speed Rotating Mirror	OS-9263B

Laser Speed of Light System

AP-8586

- Easy setup
- Accurate results
- Low cost





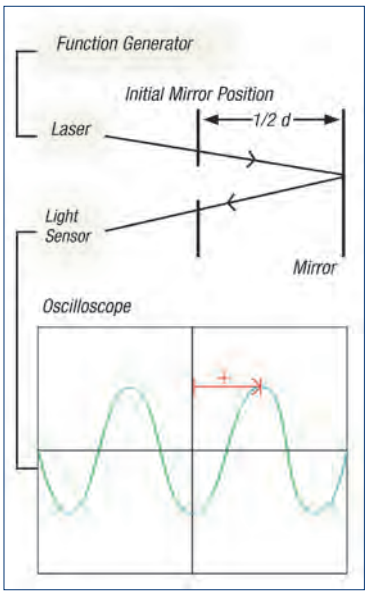
A linear fit is applied to the data, and the slope of the fit represents Δd/Δt, or the speed of light.

The Laser Speed of Light System is a low cost, yet effective method of measuring the speed of light. While it does not duplicate the classic Foucault Method, its ease of use gives every student the opportunity to perform the experiment.

How It Works:

A function generator is used to modulate the light from the laser at 3 MHz. This light is then reflected from a mirror and focused onto a light receiver. An oscilloscope is used to observe the modulated light, and the phase of the signal is noted as the baseline value for phase.

The mirror is moved back, increasing the distance that the light travels. Since it takes more time for the light to travel from the laser to the sensor, the phase of the signal on the oscilloscope increases. The phase at each successive mirror position is recorded and compared to the baseline value. The mirror is moved back several more times to get a reasonable number of data points. For each mirror position, the additional path length (d) is graphed versus the phase difference (t).



Includes:

- Diode Laser, Component Carrier (2)
- Laser Alignment Bench
- +127 mm Lens
- Light Receiver
- Stainless Steel Mounting Pads (4)
- Concave Mirror
- Coaxial Cable – RCA male to BNC male
- Coaxial Cable – 3.5 mm phone plug to BNC male
- Coaxial Cable – BNC male to male

Order Information

Laser Speed of Light System	AP-8586	
Required:		
Wide Range Function Generator	SB-9549A	p. 265
30 Meter Measuring Tape	SE-8712A	p. 202
Standard Photo Tripod		
Digital Storage Oscilloscope (100 MHz)	SB-9621B	p. 267
Replacement Part:		
Speed of Light Diode Laser	OS-8475	

Multi-Channel Analyzer

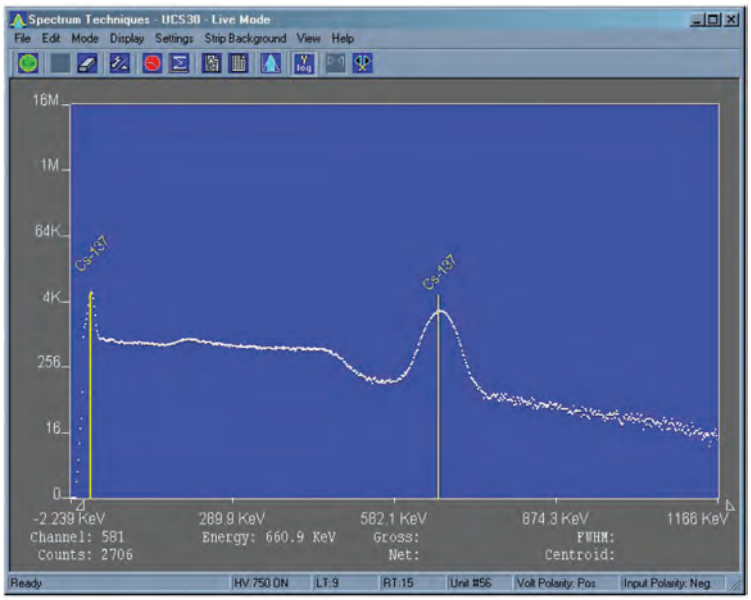
Advanced Nuclear Spectroscopy System, (Win/Mac) USB

SN-7901B

- Sophisticated spectroscopy system
- Multi-channel analysis

Designed for spectroscopy applications, the Universal Computer Spectrometer offers complete support for standard scintillation detectors as well as multi-channel scaling for decay and time-related studies. The multi-channel analyzer contains many advanced features, including a computer-controlled amplifier and high voltage for G-M tubes, upper- and lower-level discriminators, data memory, and a comprehensive software package.

The sources are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations.



Main screen display for Universal Computer Spectrometer

Features:

- **Variable Voltage:** A regulated high voltage of 0 to 1280 V is supplied with computer control (1 mA maximum, 5 V increments).
- **Amplifier:** On-board combination preamplifier/amplifier for use with scintillation detectors and PMTs.
- **Complete Computer Control:** When used in MCA mode, the software provides complete computer control of all features including preset live/real-time, preset count, unlimited regions-of-interest and centroid, gross and net area calculations.
- **Multiple Memory Buffers:** In addition to on-board hardware data memory, the spectrometer provides three software memory buffers for holding spectra. A background spectrum may be collected over a long counting period and stored in the background buffer.
- **Peak Labeling:** With ISOMATCH, an isotope library file, users can quickly identify peaks by superimposing characteristic isotope emission lines over their spectrum. Isotope and energy information are also provided.

Specifications:

Physical Hardware: Interface card or box includes pre-amplifier, amplifier, detector high voltage, 1024 channel analyzer with data memory, LLD and ULD

ADC: Wilkinson-type with 80 MHz clock and computer selected conversion gain of 256, 512, or 1024 channels

High Voltage: 0-1280 V, 1 mA maximum Amplifier: Preamplifier/amplifier combination; computer controlled coarse/fine gain from 2x to 1000x

Modes: MCA for pulse height analysis, or MCS for half-life decay or other time-related studies

Software Energy Calibration: 2-point linear or 3-point quadratic converts cursor position reading directly to energy units

Computer Software Display: Vertical scale adjusts from 32 to 16 M and LOG display; horizontal 1024 channels with expansion down to 128 channels

ISOMATCH Software: Isotope library text file with peak markers and labeling for overlaying on spectrum for quick isotope identification; library may be edited and expanded.

Includes:

- Universal Computer Spectrometer, USB
- NaI (Tl) Scintillation Probe
- Gamma Sources (8)
- Connection Cables
- Installation, Instruction, and Experiment CDs (2)

***Note:** Purchased Sources are "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 400.

Order Information

Advanced Nuclear Spectroscopy System, (Win/Mac) USB.....SN-7901B

Intermediate Nuclear Laboratory System (Win/Mac)

SN-7900B

- Macintosh®, Windows®, or standalone option
- Complete system

PASCO's most sophisticated, standalone G-M System supports a wide range of experiments with alpha, beta and gamma radiation. Includes a versatile scaler, a G-M Tube with a mount and trays, and a full set of radioactive sources and absorbers.

The Sources are USNRC License Exempt (US only).
Outside the US, consult local laws and regulations.

Features:

- **Preset Timing and Counting Intervals:** (in seconds) 1-9, 10-90, 100-900, 1K-9K, 10K-90K, 100K- 900K. Intervals are selected using the Preset switch.
- **Digital Display:** A bright 6-digit digital readout uses extra-large LEDs for clear readout in most ambient light conditions.
- **Built-in Power Supply:** 0 to 1200 volts for the G-M Probe.
- USB and serial interface to Mac and PC

Advanced Scaler/Timer

The Radiation Counter SN-7907 is a versatile, general purpose Scaler/Timer.

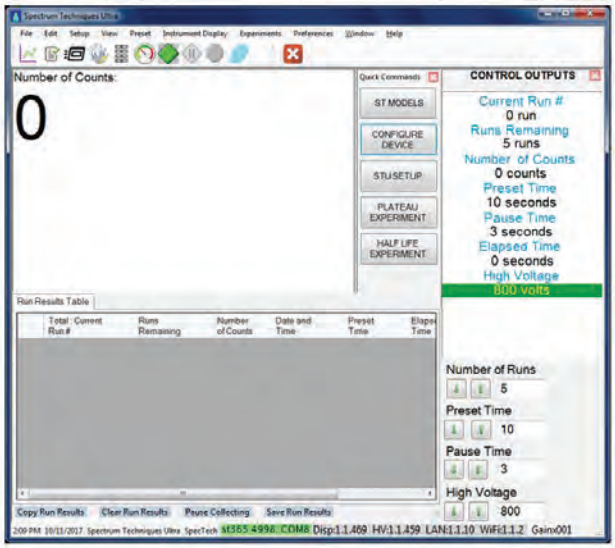
Sensitive G-M Probe

- Suitable for alpha, beta, and gamma radiation detection
- The rugged and versatile mount is made of sturdy plastic for years of rugged use. It comes with one sample holder and 10 shelf positions.

Large Variety of Absorbers

The Absorber Set SN-8111A includes four lead, ten aluminum sheets, two polyethylene, two plastic, and two aluminum foil absorbers, ranging from 5 mg/cm^2 to 7200 mg/cm^2.

***Note:** Purchased Sources are "Non-Cancellable" and "Non-Returnable".
See Radioactive Source Disclaimer on the Order Information page 400.



Main screen display from Spectrum Techniques Ultra software

Computer Compatibility

The bi-directional STU software allows full control of the Radiation Counter from the computer. STU provides real-time display of a simulated analog rate-meter with auto-ranging, digital ratemeter in CPM or CPS, count, elapsed time, preset count, preset time, acquisition time, and run number. Data is loaded into spreadsheet-compatible files.

Five Radioactive Sources

1.	Po-210:	0.1	µCi,	138 days,	α
2.	Sr-90:	0.1	µCi,	28.6 years,	β
3.	Co-60:	1	µCi,	5.27 years,	β,γ
4.	Tl-204:	0.25	µCi,	3.78 years,	β,γ
5.	Cs-137:	0.25	µCi,	30.2 years,	β,γ

The five sources are USNRC License Exempt (US only).
Outside the US, consult your local laws and regulations.

Includes

1. SN-7907 Radiation Counter with STU software and manual
2. SN-7970A G-M Probe (35 mm) and stand
3. USB Cable
4. SN-8111A Calibrated Absorber Set (20)
5. SN-7972A Radioactive Sources (5)
6. Two CDs with installation instructions and nuclear science experiments

Order Information

Intermediate Nuclear Laboratory System (Win/Mac) SN-7900B
Required:
Isotope Generator Kit (Barium-137 m) ..... SN-7995A p. 329

Radiation Counters

Radiation Counter

SN-7907

- Available only for 110 VAC (See SN-7902 for 220 VAC version)

Wireless Radiation Counter has LCD display.

This Radiation Counter supports G-M detectors, as well as scintillation detectors. It can be used standalone or connected to a computer through USB, Ethernet, or Wi-Fi. The control software stores data in a format that can easily be transferred directly to common spreadsheet programs.

Specifications:

Power: 110 VAC Adapter 9 VDC at 1200 mA
Variable High Voltage: 0 to 1200 V, in 10 V increments
Display: 16 character LCD
Housing: Plastic housing with metal face plate
Dimensions: 21.6 cm W x 15.2 cm D x 6.4 cm H
Computer Connectivity: USB, Ethernet, or Wi-Fi for Mac and Windows
Mobile Device Connectivity: Wi-Fi
Detector Connectors: BNC and MHV
Supported Detectors: G-M and scintillation

Includes:

- Spectrum Techniques Ultra Software for Windows and Mac
- 110 VAC to 9 VDC Power Adapter

Order Information

Radiation Counter SN-7907

G-M Probe with Sample Holder

SN-7970A

Similar to the Student G-M Tube except that the larger, 35 mm diameter window provides excellent photon efficiency for detecting low activity samples. The SN-7970A G-M Probe has a 200 µs dead time, contains 10 shelf positions and is designed to accommodate the larger G-M Probe. The probe can be removed from the holder and comes with a standard BNC connector cable.

Specifications:

Mica Window: ≤2 mg/cm^2
Probe Dimensions: 11.25 x 3.5 cm (4.5 x 1.4 in.) OD, excluding connector
Operating Voltage: 900 V, 150 V plateau

Order Information

G-M Probe with Sample Holder SN-7970A

Wireless Geiger Counter

PS-3238

The PASCO Wireless Geiger Counter counts beta, gamma and alpha radiation particles as they enter the Geiger–Müller detector tube inside the counter. Designed for easy mounting, the Geiger Counter provides superior position control in inverse square law labs, as well as an audible beep to indicate the detection of ionizing radiation. The front plastic snout fits conveniently inside the NU-3344 Sample Holder stand (available separately), which stabilizes the front of the counter's detector tube exactly 1 cm from the first slot in the holder.

With the Wireless Geiger Counter, students can wirelessly control the high voltage supplied to the Geiger–Müller tube inside the counter, enabling them to make measurements of counts/interval for different tube voltages. They can also plot counts/interval versus tube voltages to experimentally observe the Geiger plateau characteristics of the tube.

Specifications:

Sensitivity: Alpha, Beta, Gamma
Count Detection: Switchable audio signal
Gas Filling: Ne +Halogen
Effective Tube Diameter: 9.1 mm
Window Thickness: 1.5 to 2.0 mg/cm^2
High Voltage Control Range: 150 VDC to 650 VDC
Standard Operating Voltage: 500 VDC

Includes:

- Wireless Geiger Counter
- Micro USB Cable (PS-3584)
- Threaded handle for mounting the sensor to a ring stand

Order Information

Wireless Geiger Counter PS-3238

Geiger Counter Sample Holder

NU-3344

The PASCO Geiger Counter Sample Holder is designed for easy mounting and superior position control of the PS-3238 Wireless Geiger Counter for inverse square law labs, radiation shielding labs, and other radiation labs. The front plastic snout on the Wireless Geiger Counter is designed to fit conveniently inside the Sample Holder stand, which stabilizes the front of the counter's detector tube exactly 1 cm from the first slot in the holder.

The stand includes a radioactive sample holder tray and 5 pieces of 7 cm x 7 cm aluminum shielding material. The stand has eight slots designed to hold the included radioactive sample holder tray or shielding material. Each slot in the holder is spaced 1 cm apart to make changing the spacing between the Geiger Counter, radioactive sample, or shielding materials quick and easy.

Includes:

- Stand with 8 slots
- Radioactive sample tray
- 7cm x 7cm aluminum shielding material (5)

Order Information

Geiger Counter Sample Holder NU-3344

The following sources are mounted in 2.5 cm diameter sealed plastic disks. All sources and isotopes on this page are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations. Shown below are the isotopes, activity, half-life, and types of radiation (alpha-α, beta-β, gamma-γ).

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 400.

Radioactive Sources (set of 3)

SN-8110

1. Po-210	0.1	µCi	138 days	α
2. Sr-90	0.1	µCi	28.6 years	β
3. Co-60	1	µCi	5.27 years	β,γ

Order Information

Radioactive Sources (set of 3) SN-8110

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 400.

Radioactive Sources (set of 5)

SN-7972A

1. Po-210	0.1	µCi	138 days	α
2. Sr-90	0.1	µCi	28.6 years	β
3. Tl-204	0.25	µCi	3.78 years	β
4. Co-60	1	µCi	5.27 years	β,γ
5. Cs-137	0.25	µCi	30.2 years	β,γ

Order Information

Radioactive Sources (set of 5) SN-7972A

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 400.

Individual Sources

Order Information

Po-210*	0.1 µCi	138 days	α	SN-9085
Sr-90*	0.1 µCi	28.6 years	β	SN-9796
Tl-204*	1 µCi	3.78 years	β	SN-9797
Co-60*	1 µCi	5.27 years	β,γ	SN-9794
Cs-137*	10 µCi	30.08 years	β,γ	SN-7938
Cs-137*	5 µCi	30.2 years	β,γ	SN-9795
Cs-137*	0.25 µCi	30.2 years	β,γ	SN-7942
Tl-204*	0.25 µCi	3.78 years	β	SN-7941

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 400.

Gamma Sources (set of 8)

SN-7949A

1. Co-60	1	µCi	5.27 years	β,γ
2. Na-22	1	µCi	2.60 years	β+,γ
3. Mn-54	1	µCi	313 days	γ
4. Cs-137	0.25	µCi	30.2 years	β,γ
5. Ba-133	1	µCi	10.5 years	γ
6. Cd-109	1	µCi	464 days	γ
7. Co-57	1	µCi	270 days	γ

8. "UNKNOWN": mixture of Cs-137 and Zn-65 for student testing. Cs-137 is 0.25 µCi or lower.

Order Information

Gamma Sources (set of 8) SN-7949A

Absorbers (set of 20)

SN-8111A

This set of 20 calibrated absorbers includes 4 lead, 2 plastic, 10 aluminum, 2 polyethylene, and 2 aluminum foil absorbers. Absorbers vary in density from 5 mg/cm^2 to 7200 mg/cm^2.

Order Information

Absorbers (set of 20) SN-8111A

WARNING! This product can expose you to Lead, which is known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Isotope Generator Kit (Barium-137 m)

SN-7995A

This Cs-137/Ba-137m Isotope Generator is used to demonstrate the properties of radioactive decay. Based on the original Union Carbide patented design, it offers exceptional performance, ease-of-use, and safe operation.

Each generator contains 10 µCi of Cs-137. The generator can produce up to 1000 small aliquots of the short-lived Ba-137m isotope with a half-life of 2.6 minutes.

Each generator is supplied with 250 mL of eluting solution (0.9% NaCl in 0.04M HCl). The parent isotope Cs-137 with a half-life of 30.1 years beta decays (94.6%) to the metastable state of Ba-137m. This further decays by gamma emission (662 keV) with a half-life of 2.6 min. to the stable Ba-137 element. During elution, the Ba-137m is selectively "milked" from the generator, leaving behind the Cs-137 parent. Regeneration of the Ba-137m occurs as the Cs-137 continues to decay, re-establishing equilibrium in less than 1 hour.

Approximately 30 minutes after elution, the residual activity of the Ba-137m sample has decayed to less than one thousandth of its initial activity, making it safe for disposal. When used with the eluting solution supplied, bleed-through of the parent Cs-137 is less than 50 Bq/mL, affording a long working life. Each kit is supplied with the generator, syringe, tube, 250 mL of solution, and a storage case.

Order Information

Isotope Generator Kit (Barium-137 m) SN-7995A

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 400.

Diffusion Cloud Chamber

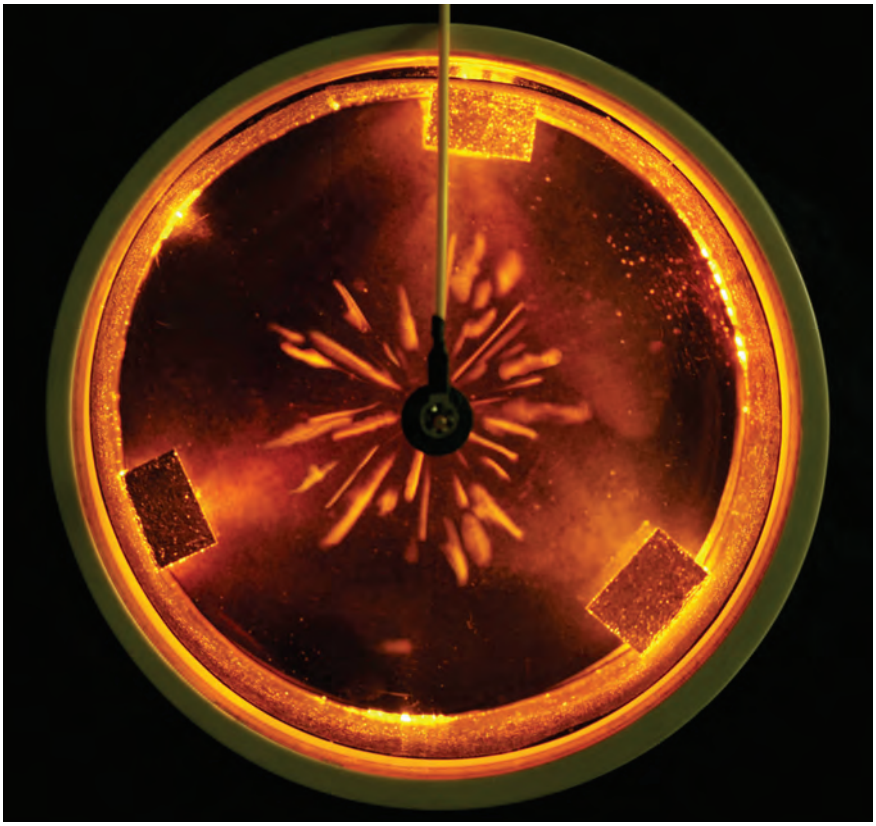
SE-7943

- No dry ice required
- View cosmic rays
- Built-in illumination

How It Works

The bottom of the chamber is cooled by circulating ice water through the base and further cooling it to -35°C with a Peltier device. Alcohol placed in the chamber wicks up the inside chamber lining where it evaporates in the warmer region of the chamber and diffuses downward. The alcohol vapor is then cooled near the chamber bottom and becomes super saturated.

As energetic alpha and beta particles from a radioactive source pass through the alcohol vapor, the vapor condenses, forming droplets that appear as tracks in the strong chamber cross-lighting.



Particle tracks are visible from radioactive particles given off by the Pb-210 source at the center. The dense straight tracks are produced by alpha particles and the fainter, crooked tracks are produced by beta particles.

Includes:

- Cloud Chamber
- 12 VDC Power Adapter (6 A)
- Water Circulation Pump
- Two Rubber Hoses
- Extraction Pipette
- Source Holder and Stopper
- High Voltage Connection Cable
- SpecTech™ Coupon for Pb-210 Source Needle

***Note:** Purchased Sources are "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 400.

Features:

- Powered by 12V DC power adapter
- Built-in LED lamps for illuminating the particle trails
- Uses ice water instead of dry ice
- Water circulation pump
- Built-in high voltage (~800V) power supply for clearing the chamber of unwanted ions

Specifications:

Diameter: 15 cm 12 VDC Power Adapter (6 A)

Water Circulation Pump: 120 V/60 Hz, 3 W, 180 liter/hr

Built-in High Voltage Source: ~800 VDC with 108 Ω protection resistor

Rubber Hoses: 0.25" ID (6.4 mm ID), 60 cm long

High Voltage Connection Cable:
22 cm long, Banana plug to ring lug eight amber LEDs

Order Information

Diffusion Cloud Chamber (15 cm diameter)..... SE-7943
Diffusion Cloud Chamber (15 cm diameter) - No Source SE-7940
Required:
Ice Water
Recommended:
Pb-210 Source Needle..... SE-7945
The Needle Source is USNRC License Exempt (US only).

Download FREE PASCO Capstone Experiments

Over 60 classic physics experiments for use with PASCO equipment and software

The following pages present classic experiments in physics performed with PASCO apparatus. Manuals can be downloaded at www.pasco.com. Interfaces and software, where indicated, should be ordered separately. Everything else is included in the experiment: apparatus, sensors (when needed), and accessories.

Download This Experiment

Each experiment manual and the PASCO Capstone™ workbook files may be downloaded for free at

www.pasco.com/CapstoneExperiments

- Experiment Manual: A detailed experiment manual helps ensure student success. An electronic Word® version is included for modification by the teacher.
- PASCO Capstone Workbook File: PASCO Capstone workbook files are included for each experiment. These files contain workbooks with step-by-step instructions and embedded live data displays to support students through the lab. A file with sample data is also included.

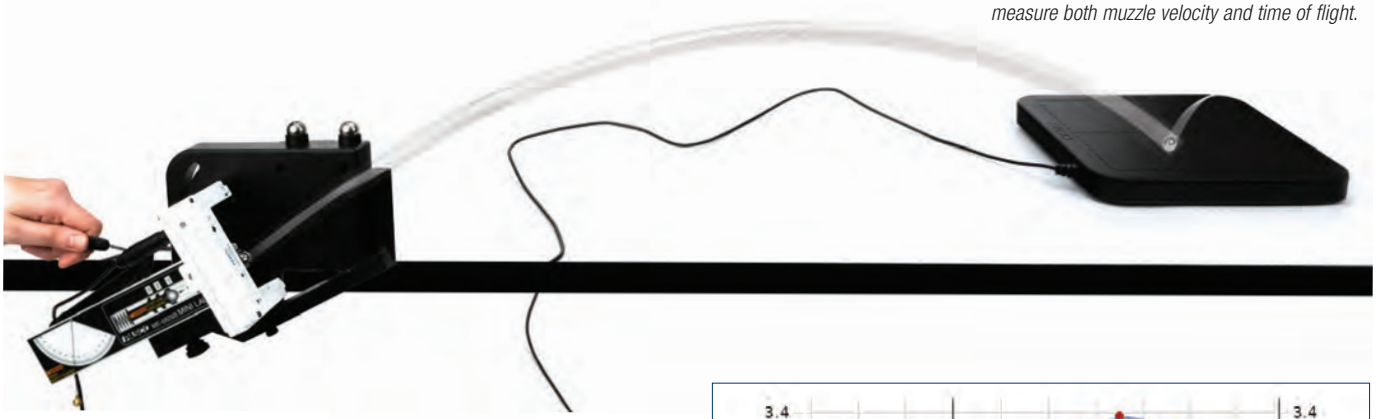
Projectile Motion Experiment

EX-5602

NEW EXPERIMENT!

Concepts:

- Independence of x- and y-motion
- Muzzle velocity vs. time of flight
- Angle vs. horizontal range



The Wireless Smart Gate and Time-of-Flight Accessory are used with the Mini Launcher to measure both muzzle velocity and time of flight.

Muzzle Velocity vs. Time of Flight

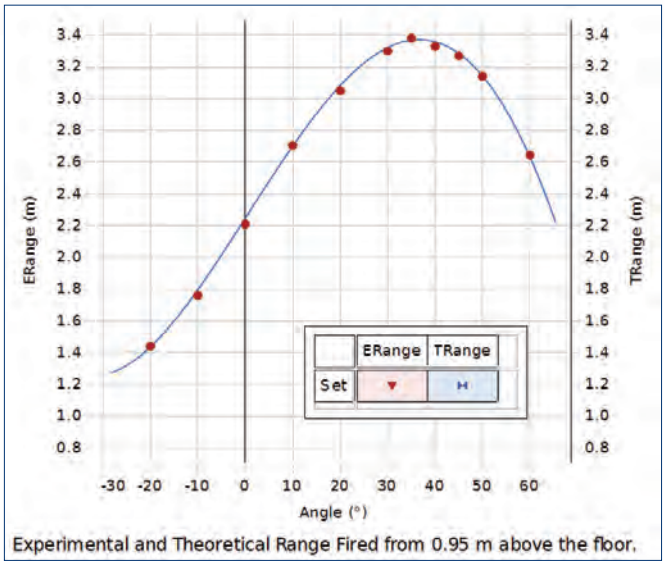
Students fire the projectile at three different velocities from the same height. The Photogate and Time-of-Flight Accessory are used to measure the time of flight at each muzzle velocity. Students are surprised to find that the time of flight is not related to the muzzle velocity at 0˚ launch angle.

Angle vs. Horizontal Range

The angle of launch is varied and the horizontal range is measured for each angle. Students produce a graph of angle vs. horizontal range, and use its equation to find the angle of maximum range. This experiment is conducted in two variations:

- Projectile is fired from a higher vertical position than its landing position
- Projectile is fired from the same vertical position as its landing position

Students are asked to use the kinematic equations to predict the horizontal range, given a launch angle and muzzle velocity. Carbon paper and a bullseye can be used to test their hypotheses.



Experimental and Theoretical Range Fired from 0.95 m above the floor.

Students can use their data to determine which launch angle produces the maximum horizontal range.

PASCO Advantage:

PASCO Projectile Launchers are designed for repeatable and accurate launches. In addition, photogates and other accessories are designed to work seamlessly with our Projectile Launchers. These features allow student predictions and calculations from the kinematic equations to be empirically verified.

Includes:

• Mini Launcher	ME-6825B
• Time-of-Flight Accessory	ME-6810A
• Phone Jack Extender Cable	PI-8117
• Wireless Smart Gate	PS-3225
• Photogate Mounting Bracket	ME-6821A
• Carbon Paper (100 Sheets)	SE-8693
• Large C Clamp (6 Pack)	SE-7285
• Plumb Bobs (10 Pack)	SE-8728
• 30 Meter Measuring Tape	SE-8712A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Projectile Motion Experiment.....EX-5602

Required:

PASCO Capstone Software.....pp. 84-87

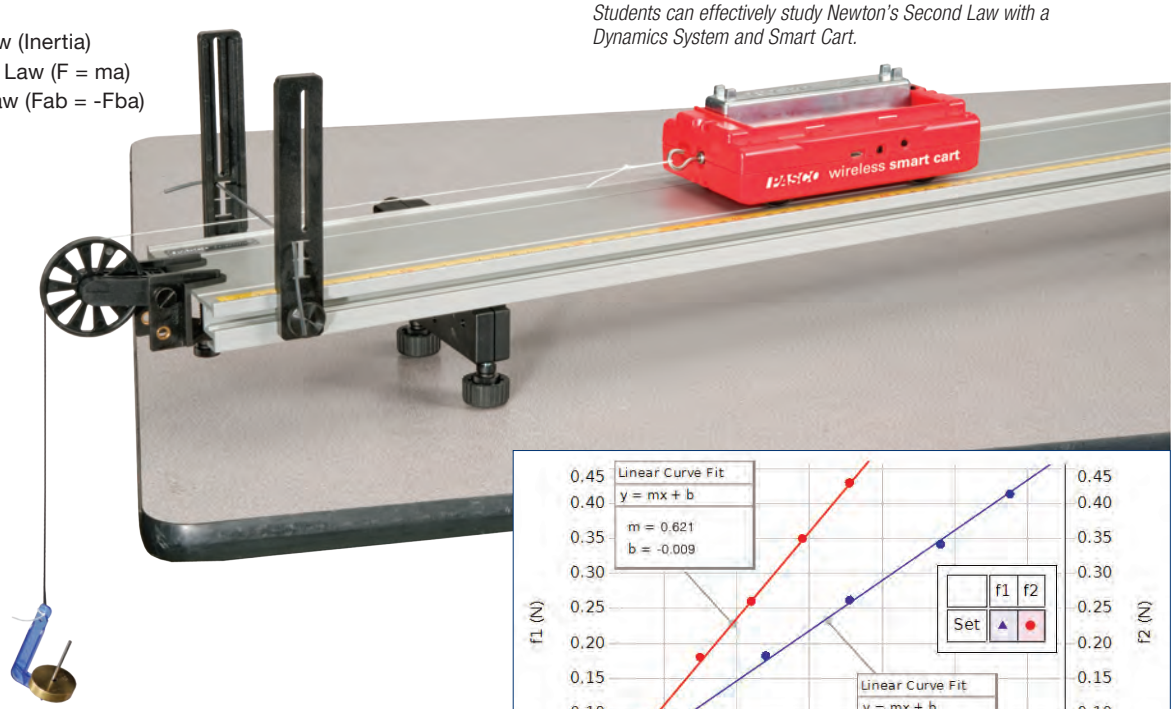
View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5502) online at pasco.com/capstoneexperiments

Newton's Laws Experiment

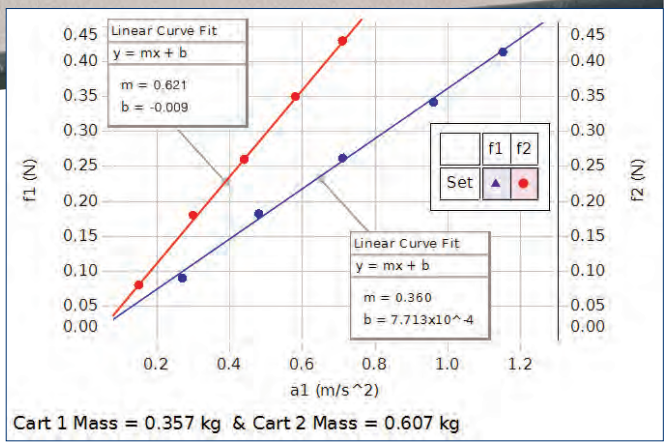
EX-5503B

Concepts:

- Newton's First Law (Inertia)
- Newton's Second Law (F = ma)
- Newton's Third Law (Fab = -Fba)



Students can effectively study Newton's Second Law with a Dynamics System and Smart Cart.



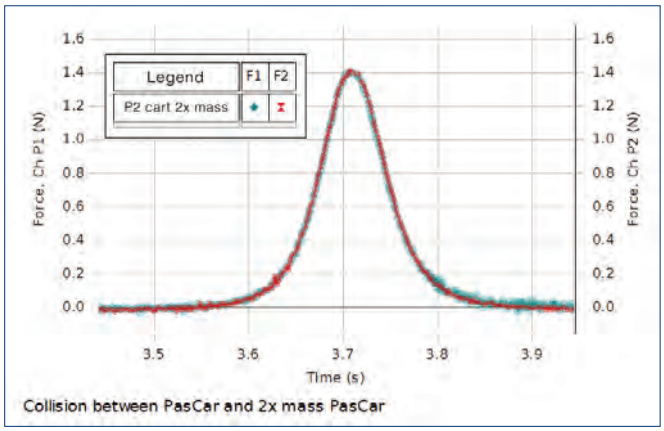
Force vs. acceleration data for the cart as it experiences changing net force

This collection of equipment lets students discover or experimentally determine all three of Newton's Laws.

- **Newton's First Law –** Students examine an object's motion to see if it changes when forces are applied or not.
- **Newton's Second Law –** Students use the Smart Cart to discover the relationships between force, mass, and acceleration.
- **Newton's Third Law –** Using two Smart Cart Force Sensors, students prove that forces between objects are equal in magnitude yet opposite in direction. These experiments include both tug-of-war exercises and collisions between cars.

PASCO Advantage:

The Smart Cart has all the sensors required, which makes setup very quick and easy. The integration between the probeware and equipment helps students focus on the physics of each experiment.



Includes:

• Smart Cart (Red)	ME-1240
• Smart Cart (Blue)	ME-1241
• PAScar Cart Mass (set of 2)	ME-6757A
• Dynamics Track Feet (Pair)	ME-8972
• Mass and Hanger Set	ME-8979
• Elastic Bumper	ME-8998
• Super Pulley with Clamp	ME-9448B
• 1.2 m Aluminum Dynamics Track	ME-9493
• Friction Block - IDS	ME-9807
• Braided Physics String	SE-8050
• Smart Cart Rod Stand Adapter	ME-1244

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Newton's Laws Experiment.....EX-5503B
Required:
Bluetooth 4.0 enabled computer
PASCO Capstone Software.....pp. 84-87

Atwood's Machine Experiment

EX-5501

Concepts:

- Newton's 2nd Law of Motion
- Newton's 2nd Law of Rotational Motion
- Rotational Inertia

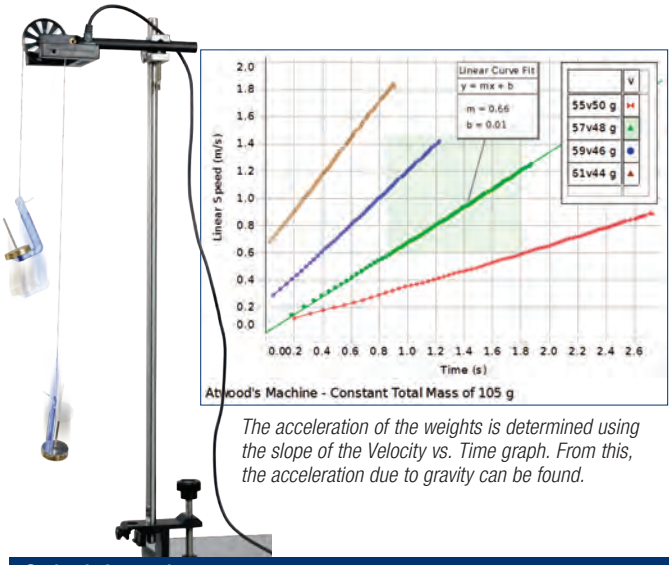
In this classic experiment, students use a very low mass, low friction pulley to measure the changing velocity of the unbalanced mass system. Students interpret the slope of the velocity graph as acceleration. They examine the effect of the pulley's rotational inertia and estimate the friction forces based on experimental data.

PASCO Advantage:

The Super Pulley/Photogate System makes it easy for students to set up the apparatus and take data. Analysis includes accounting for friction and the rotational inertia of the pulley.

Includes:

• Photogate & Pulley System	ME-6838A
• Mass and Hanger Set	ME-8979
• Universal Table Clamp	ME-9376B
• Stainless Steel Rod, 60 cm Threaded	ME-8977
• Multi-Clamp	ME-9507
• Braided Physics String	SE-8050



The acceleration of the weights is determined using the slope of the Velocity vs. Time graph. From this, the acceleration due to gravity can be found.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Atwood's Machine Experiment EX-5501
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87
Balance or Scale ..... p. 206
Digital Calipers ..... SE-8710 p. 202
* This experiment can be performed using the 550 or 850 Universal Interface or AirLink with Digital Adapter.

Hooke's Law and Spring Potential Experiment

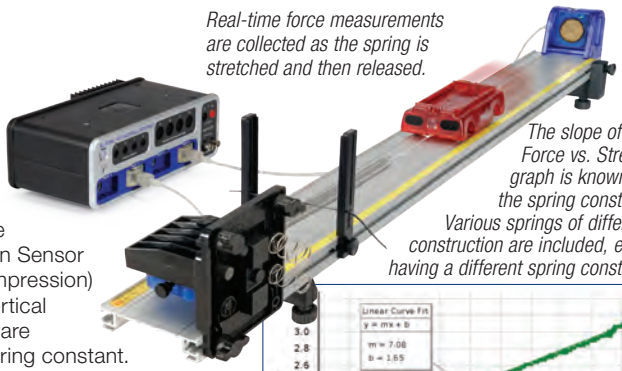
EX-5504A

Concepts:

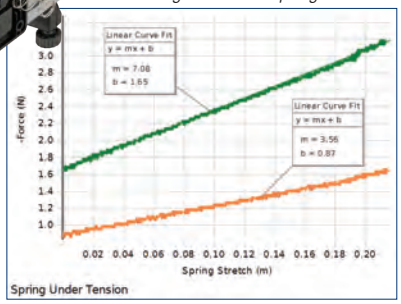
- Relationship between force and spring deformation
- Investigate both spring compression and extension
- Amount of energy stored in a spring

In this experiment, students use a High Resolution Force Sensor to measure the force exerted to either compress or extend various springs, and a Motion Sensor to measure position and speed. Students create a Force vs. Stretch (or Compression) graph. The slope of this graph is known as the spring constant, while the vertical intercept is the initial loading force. Various springs of different construction are included, so students can better understand the physical meaning of the spring constant. The spring is then compressed (or stretched) and released. The kinetic energy transferred to a PAScar is measured and compared to the potential energy lost by the spring.

Real-time force measurements are collected as the spring is stretched and then released.



The slope of the Force vs. Stretch graph is known as the spring constant. Various springs of different construction are included, each having a different spring constant.



PASCO Advantage:

The High Resolution Force Sensor allows students to take direct measurements of force for each compression or elongation of the spring. This is superior to using a hanging mass to apply a force, since students don't have to convert from mass to force. In addition, students apply the forces to the springs, giving them a better kinesthetic feel for the amount of force being applied in each case. Energy changes are easily measured and very visual.

Includes:

• PASPORT Motion Sensor	PS-2103A
• IDS Spring Kit	ME-8999
• PASPORT High Resolution Force Sensor	PS-2189
• Force Sensor Track Bracket	ME-6622
• Spring Cart Launcher	ME-6843
• Elastic Bumper	ME-8998
• Braided Physics String	SE-8050

Download This Experiment

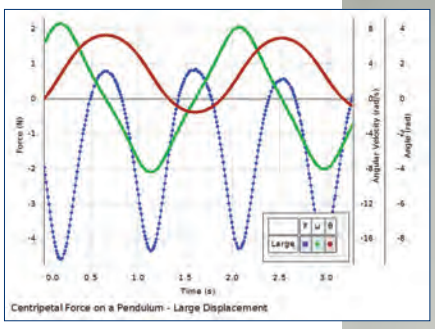
The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Hooke's Law and Spring Potential Experiment EX-5504A
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Centripetal Force on a Pendulum Experiment

EX-5605



Concepts:

- Centripetal force
- Angular velocity
- Periodic motion

In this experiment, students explore the relationship between mass, radius of rotation, angular velocity, and centripetal force. The force and angular velocity are continuously measured, allowing students to see not only peak values, but also how these change during the entire motion of the pendulum. Students also explore sources of error and magnitude of error.

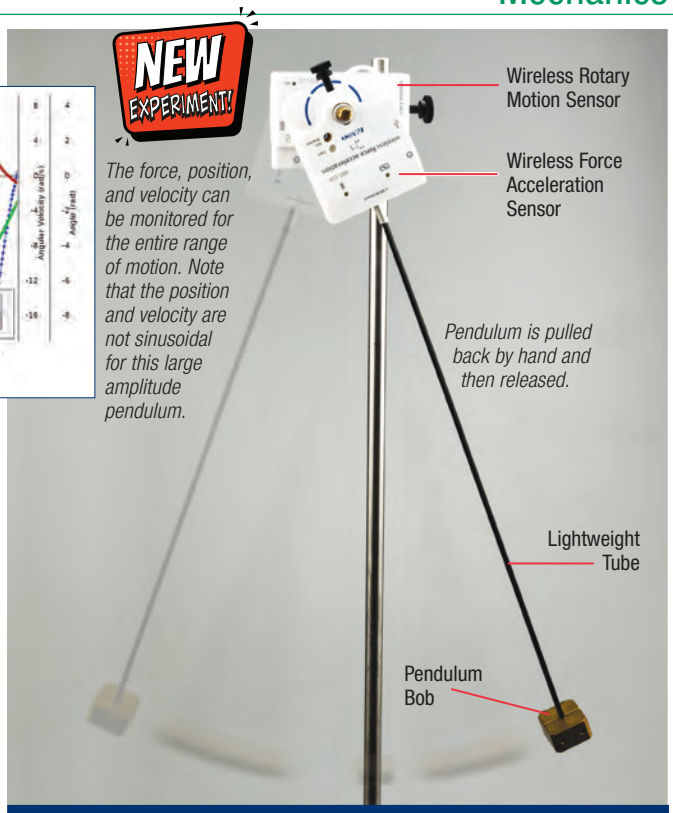
Includes:

• Wireless Force Acceleration Sensor	PS-3202
• Wireless Rotary Motion Sensor	PS-3220
• Centripetal Force Pendulum	ME-9821
• Aluminum Table Clamp	ME-8995
• 45 cm Stainless Steel Rod	ME-8736

Order Information

Centripetal Force on a Pendulum Experiment EX-5605
Required:
PASCO Capstone Software ..... pp. 84-87
Balance or Scale ..... p. 206

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5505A) online at pasco.com/capstoneexperiments



Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Centripetal Force Experiment

EX-5506

Concepts:

- Centripetal force depends on radius, mass, and speed

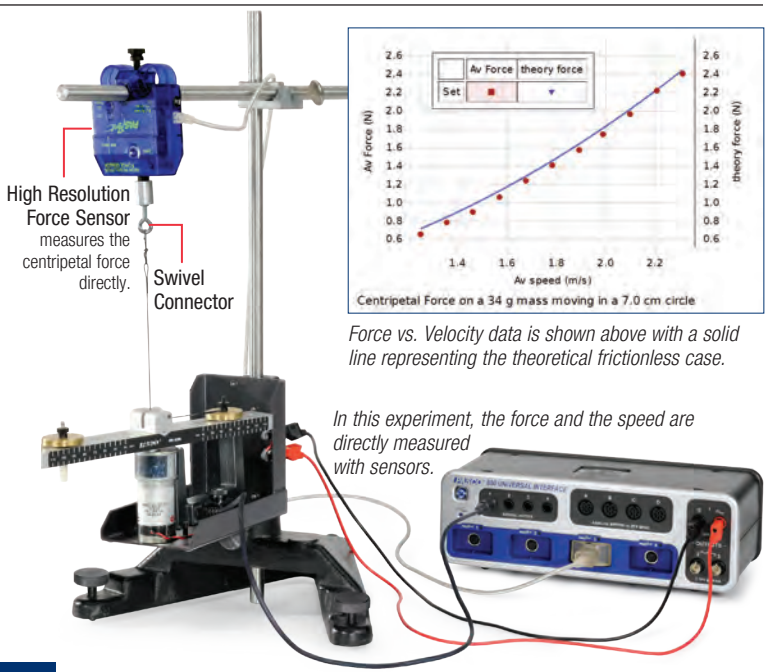
Students explore the relationship between mass, radius of rotation, tangential speed, and centripetal force. By continuously measuring the force as the speed is varied, students clearly see the effect of speed on the centripetal force. The effect of changing the mass or radius is also investigated.

Includes:

• Centripetal Force Apparatus	ME-8088
• PASPORT High Resolution Force Sensor	PS-2189
• Photogate Head	ME-9498A
• Large Rod Base	ME-8735
• 90 cm Stainless Steel Rod	ME-8738
• Multi-Clamp	ME-9507
• 45 cm Stainless Steel Rod	ME-8736
• Banana Plug Cord-Red (5 Pack)	SE-9750

Order Information

Centripetal Force Experiment EX-5506
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87



Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Impulse Experiment

EX-5509B

Concepts:

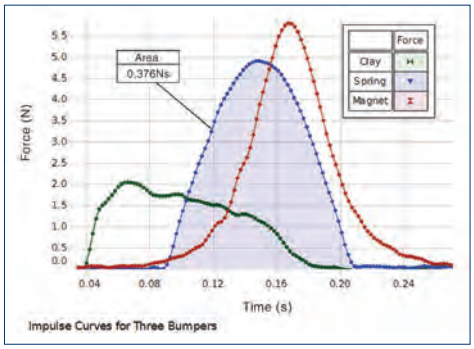
- **Impulse:** Change in momentum
- **Impulse:** Area under a Force vs. Time curve
- Different shaped force curves for elastic and inelastic collisions

In this experiment, the impulse on a cart is determined in two ways: by measuring the change in velocity and by finding the area under a Force vs. Time curve.

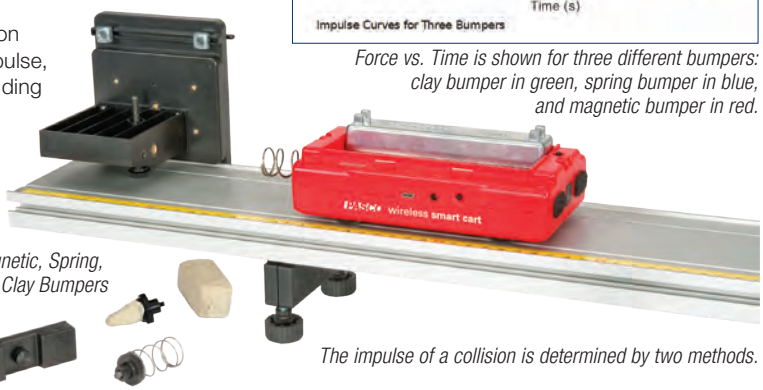
A Smart Cart runs down a slightly inclined track with its Force Sensor equipped with either a clay bumper, spring bumper, or magnetic bumper. The cart collides with the endstop. To determine the change in momentum (impulse), the velocities before and after the collision are recorded using the Smart Cart's encoder. To confirm the impulse, the force vs. time is plotted, and the impulse is determined by finding the area under the curve.

Features:

- Designed for use with the Smart Cart



Force vs. Time is shown for three different bumpers: clay bumper in green, spring bumper in blue, and magnetic bumper in red.



Magnetic, Spring, and Clay Bumpers

The impulse of a collision is determined by two methods.

Includes:

• Force Sensor Track Bracket	ME-6622
• PAScar Cart Mass (Set of 2)	ME-6757A
• Smart Cart (Red)	ME-1240
• Dynamics Track End Stop (2 Pack)	ME-8971
• Dynamics Track Feet (Pair)	ME-8972
• 1.2 m Aluminum Dynamics Track	ME-9493
• Smart Cart Rod Stand Adapter	ME-1244

Order Information

Impulse Experiment EX-5509B
Required:
Bluetooth 4.0 enabled computer
PASCO Capstone Software ..... pp. 84-87
Balance or Scale ..... p. 206

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Conservation of Momentum Experiment

EX-5510C

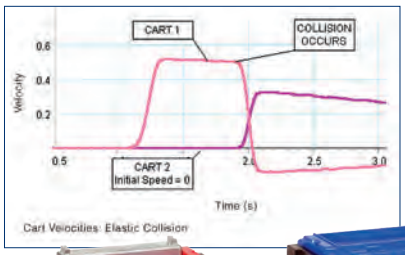
Concepts:

- Conservation of momentum in elastic and inelastic collisions
- Kinetic energy is not conserved in inelastic collisions
- Kinetic energy can be temporarily stored as magnetic potential energy during elastic collisions using magnetic bumpers

The total momentum and total energy of carts undergoing elastic and inelastic collisions are measured. The values before and after the collisions are compared to verify that momentum is conserved in all collisions, while energy is only conserved in elastic collisions.

Elastic and inelastic collisions are performed with two dynamics carts of different masses. Magnetic bumpers are used in the elastic collision and Velcro bumpers are used in the completely inelastic collision. In both cases, momentum is conserved.

Cart velocities are recorded using the encoders inside the Smart Carts. A real-time graph of Velocity vs. Time is obtained for each cart, clearly showing when the collision occurred. This enables the student to determine the cart velocities immediately before and after the collision.



Features:

- Designed for use with 2 Smart Carts

A real-time graph of Velocity vs. Time is obtained for each cart, clearly showing when the elastic collision occurred.

Includes:

• PAScar Cart Mass (set of 2)	ME-6757A
• Smart Cart (Red)	ME-1240
• Smart Cart (Blue)	ME-1241
• Dynamics Track End Stop (2 Pack)	ME-8971
• Dynamics Track Feet (Pair)	ME-8972
• 1.2 m Aluminum Dynamics Track	ME-9493
• Smart Cart Rod Stand Adapter	ME-1244

Order Information

Conservation of Momentum Experiment EX-5510C
Required:
Bluetooth 4.0 enabled computer
PASCO Capstone Software ..... pp. 84-87
Balance or Scale ..... p. 206

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Ballistic Pendulum Experiment

EX-5611

Concepts:

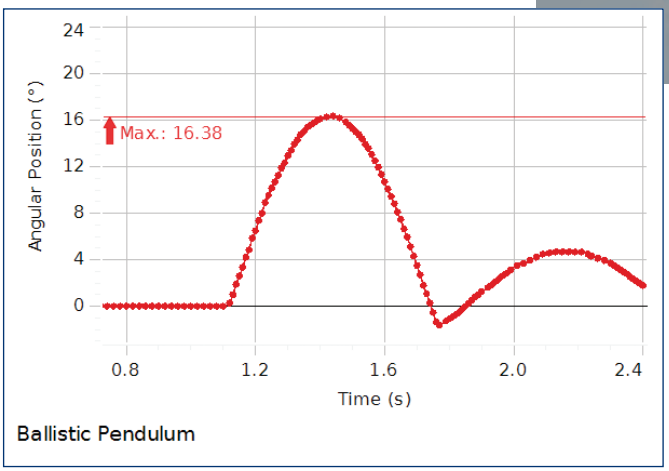
- Conservation of momentum
- Conservation of energy

PASCO's Wireless Rotary Motion Sensor is the heart of this modern approach to a classic physics experiment. The Mini Launcher (ME-6825B) fires a steel ball into the foam catcher of the Ballistic Pendulum Accessory (ME-6829) mounted on the Wireless Rotary Motion Sensor. The Wireless Rotary Motion Sensor measures the angular displacement of the pendulum and plots it in real-time in PASCO Capstone.

There is no need to catch the pendulum at its maximum height because the angle is continuously measured. Students can use the analysis tools in PASCO Capstone, to find the maximum angle.

Using Conservation of Momentum and Conservation of Energy, students can determine the initial speed of the ball as it leaves the projectile launcher. The initial speed of the ball is confirmed by using two photogates to time the flight of the ball for a short distance.

The ball is shot into a foam catcher at the end of a pendulum. The pendulum is mounted on a Wireless Rotary Motion Sensor to record the entire swing.



This graph of the angle of the pendulum vs. time is plotted in real time in PASCO Capstone. The maximum angle is displayed on the graph.

Includes:

• Wireless Rotary Motion Sensor	PS-3220
• Mini Launcher	ME-6825B
• Wireless Smart Gate	PS-3225
• Photogate Mounting Bracket	ME-6821A
• Mini Ballistic Pendulum Accessory	ME-6829
• Large C Clamp	
• 45 cm Stainless Steel Rod	ME-8736

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Ballistic Pendulum Experiment EX-5611
Required:
PASCO Capstone Software ..... pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5511A) online at pasco.com/capstoneexperiments

Conservation of Energy Experiment

EX-9935

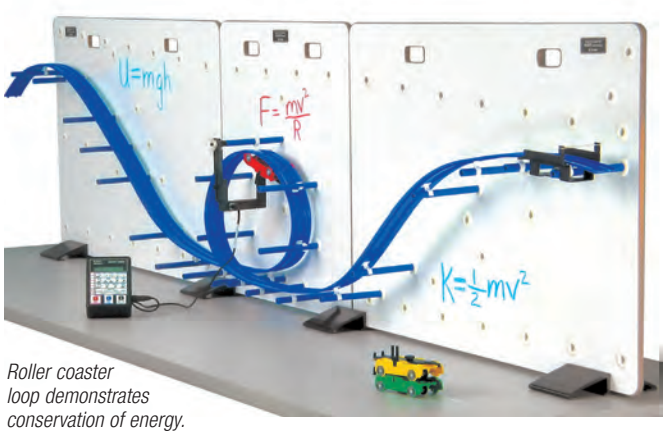
Concepts:

- Conservation of energy
- Centripetal acceleration
- Apparent weight

In this experiment, the Law of Conservation of Energy is verified by measuring the potential and kinetic energies of a car traveling over hills and loops on a curved track.

A car is started from rest on a variety of tracks (hills, valleys, loops, straight track). The speed of the car is measured at various points along the track using a photogate connected to a Smart Timer. The potential energy is calculated from the measured height and the kinetic energy is calculated from the speed. The total energy is calculated for two points on the track and compared.

The height from which the car must be released from rest to just make it over the loop can be predicted from conservation of energy and the centripetal acceleration. Then the prediction can be tested on the roller coaster. If the car is released from the top of the hill and easily makes it over the top of the loop, the speed of the car can be measured at the top of the loop and the centripetal acceleration as well as the apparent weight (normal force) on the car can be calculated.



Roller coaster loop demonstrates conservation of energy.

PASCO Advantage:

The Roller Coaster can be configured in many ways. The whiteboard background is convenient for writing calculations or making marks for measuring heights. The PASCO Roller Coaster differs from conventional roller coaster toys in three ways:

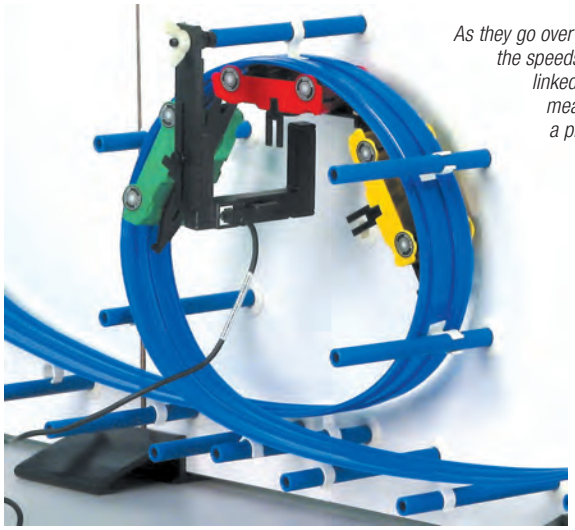
- Speed and height of the Roller Coaster car can be easily measured
- Loss of energy due to friction is generally only about 5%
- Cars will withstand repeated drops to the floor

Includes:

• Roller Coaster Complete System	ME-9812
• Photogate Head (2)	ME-9498A
• Smart Timer	ME-8930

Conservation of energy for a car going over hills

Conservation of energy shows that the final speeds of these two cars are the same even though the red car takes much less time than the yellow car to reach the end of the track.



As they go over the loop, the speeds of three linked cars are measured by a photogate.

Download This Experiment

Search for EX-9935 at **www.pasco.com**

Order Information

Conservation of Energy Experiment.....EX-9935

Conservation of Energy II Experiment

EX-5612

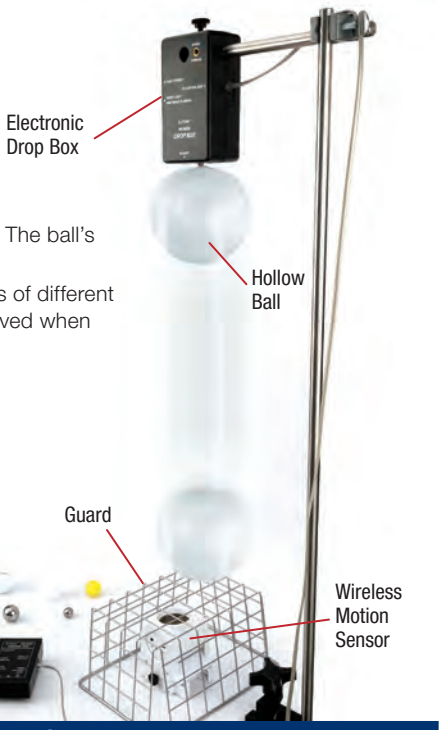
NEW EXPERIMENT!

Concepts:

- Potential energy of a falling ball
- Kinetic energy of a falling ball
- Use different size balls to change friction

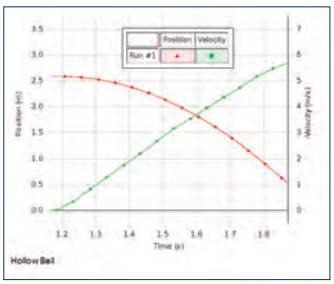
A ball is dropped from rest and its height and speed are recorded using a Wireless Motion Sensor. The ball's potential energy and kinetic energy are calculated at various points during the ball's fall.

The total energy of the ball is examined throughout the fall to determine if there is any change. Balls of different sizes are used to vary the amount of air friction, so that students can see that energy is not conserved when friction is appreciable.



Includes:

• Wireless Motion Sensor	PS-3219
• Discover Freefall System	ME-9889
• Large Rod Base	ME-8735
• 120 cm Stainless Steel Rod	ME-8741
• Multi-Clamp	ME-9507
• 45 cm Stainless Steel Rod	ME-8736
• Motion Sensor Guard	SE-7256



As the ball falls, its height and speed are recorded and displayed in PASCO Capstone software.

Order Information

Conservation of Energy II Experiment EX-5612
Required:
PASCO Capstone Software ..... pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5512) online at pasco.com/capstoneexperiments

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Work Energy Theorem Experiment

EX-5513A

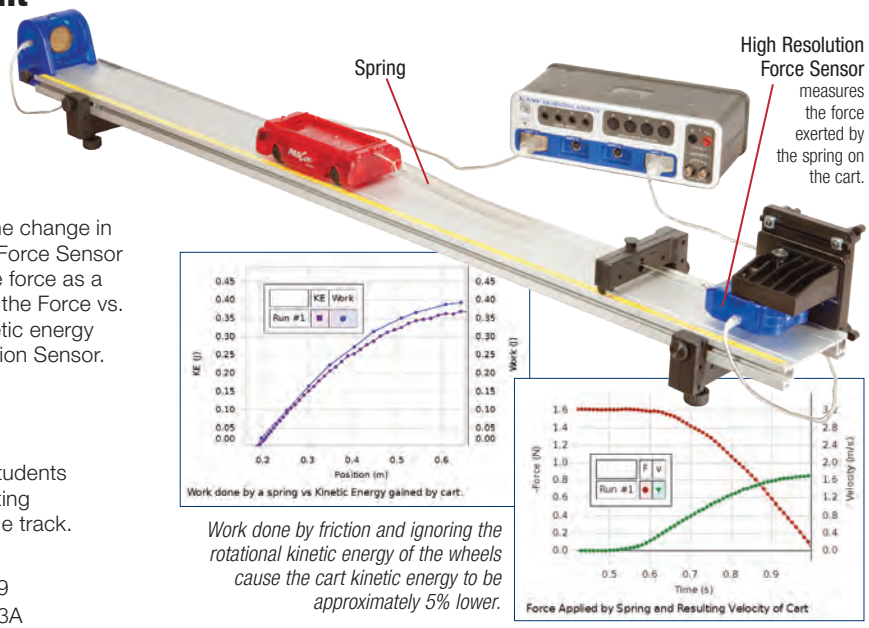
Concepts:

- Kinetic energy
- Potential energy
- Work energy theorem
- Conservation of mechanical energy

The total work done on an object is compared with the change in kinetic energy of the object. Using a High Resolution Force Sensor and a Motion Sensor, students record and display the force as a function of position. The work done is the area under the Force vs. Position plot. At any point during the experiment, kinetic energy is calculated from the velocity measured with the Motion Sensor. Students explore the meaning of dissipative forces.

PASCO Advantage:

Instead of just focusing on the end points, real-time measurements of force, position, and velocity allow students to continuously examine the work done and the resulting kinetic energy of the cart during its entire trip down the track.



Work done by friction and ignoring the rotational kinetic energy of the wheels cause the cart kinetic energy to be approximately 5% lower.

Includes:

• PASPORT High Resolution Force Sensor	PS-2189
• PASPORT Motion Sensor	PS-2103A
• Force Sensor Track Bracket	ME-6622
• IDS Spring Kit	ME-8999
• Braided Physics String	SE-8050

Download This Experiment

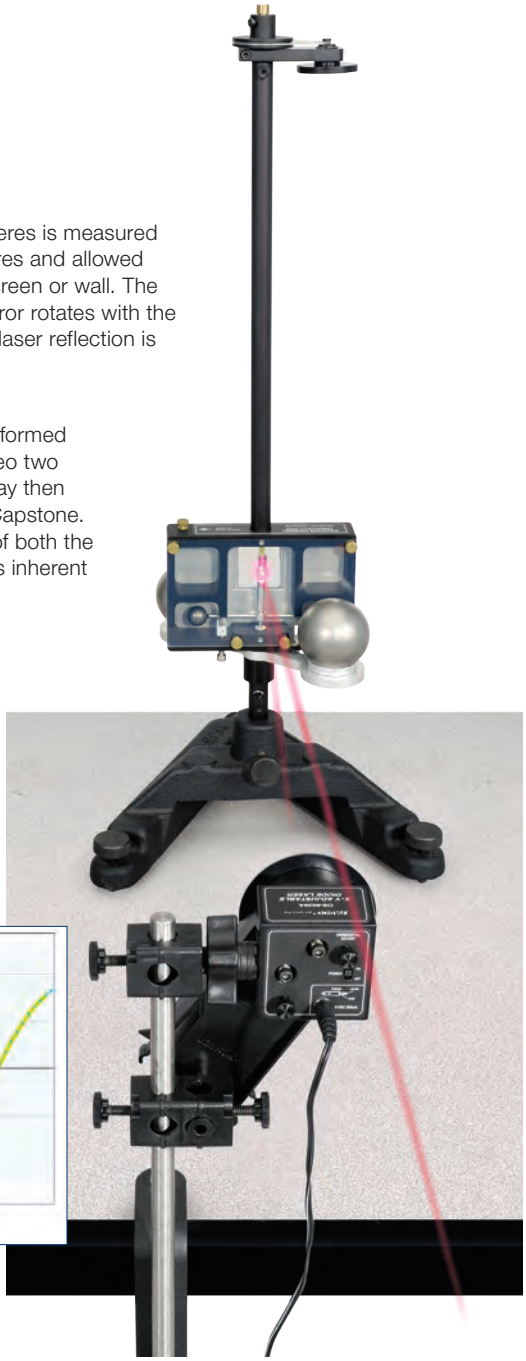
The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Work Energy Theorem Experiment EX-5513A
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87
Balance or Scale ..... p. 206
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Universal Gravitational Constant Experiment

EX-5550



Concepts:

- Measure the Universal Gravitational Constant in less than three hours!
- Recreate Cavendish's historical experiment
- Uses PASCO Capstone Video Analysis

The attraction between a pair of small tungsten spheres and a pair of larger tungsten spheres is measured by the torsion of a beryllium ribbon. The large spheres are placed close to the small spheres and allowed to equilibrate. A laser is reflected from a mirror on the beryllium ribbon and shown on a screen or wall. The large spheres are then rotated through an angle to produce torque on the ribbon. The mirror rotates with the ribbon, so the laser reflection on the screen or wall is displaced. The displacement of the laser reflection is measured to find "G".

PASCO Advantage:

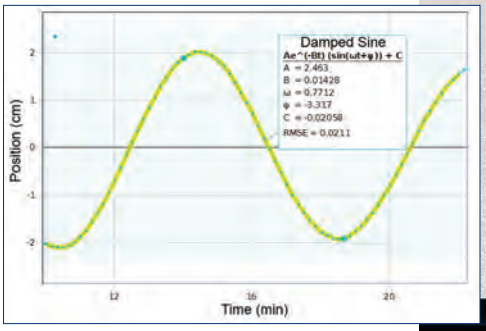
For the first time, the measurement of G using the Cavendish Balance can actually be performed in a three-hour lower division physics laboratory! Data is collected using a webcam to video two periods of the oscillation for both ball positions in less than 45 minutes. The video data may then be transferred to lab groups for analysis using the video analysis features within PASCO Capstone. Fitting a damped sine curve to the video data allows an extremely precise determination of both the period of oscillation and the position of the final equilibrium. When analysis of small effects inherent in the method is included, an accuracy of better than 2% is possible.

Includes:

• Gravitational Torsion Balance	AP-8215A
• X-Y Adjustable Diode Laser	OS-8526A
• USB Camera Microscope	PS-2343
• Polarizer Set	OS-8473

NOTE: No interface is required.

The USB Camera Microscope records the oscillation of the laser beam.



In PASCO Capstone, a damped sine fit is applied to the data to determine the equilibrium point.

This is a screenshot of the video analysis points (red plus signs) in PASCO Capstone.

Download This Experiment

Search for EX-5550 at **www.pasco.com**

Order Information

Universal Gravitational Constant Experiment EX-5550
Required:
PASCO Capstone Software ..... pp. 84-87
Transparent Ruler and Meter Stick

Archimedes' Principle Experiment

EX-9909

Concepts:

- Archimedes' Principle
- Density
- Buoyant force

Archimedes' Principle states that the buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object.

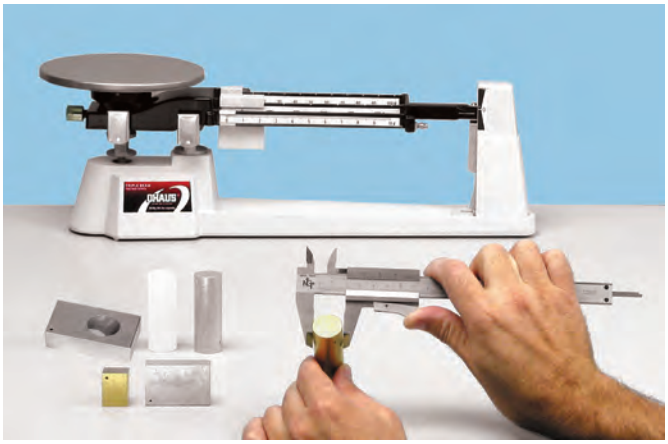
In this experiment, the buoyant force on several objects is measured by weighing the water displaced by a submerged object. The buoyant force is also determined by measuring the difference between the object's weight in air and its apparent weight in water.

Some of the objects have the same density, some have the same volume, and some have the same mass. The density of each object is measured and the dependence of the buoyant force on density, mass, and volume is explored.

PASCO Advantage:

The provided objects have related volumes, masses, and densities to demonstrate that only the volume of water displaced affects the buoyant force.

The buoyant force is measured by weighing the water displaced by the object.



The mass and volume are measured to determine the dependence of the buoyant force on mass, volume, and density.

Includes:

• Density Set	ME-8569A
• Overflow Can	SE-8568
• Large Rod Base	ME-8735
• 45 cm Stainless Steel Rod	ME-8736
• Braided Physics String	SE-8050
• Ohaus Triple-Beam Balance (with Tare)	SE-8707
• Stainless Steel Calipers	SF-8711
• 1000 ml Beaker	
• 100 ml Beaker	
• 50 ml Graduated Cylinder	
• Archimedes' Principle Experiment Manual	

Download This Experiment

Search for EX-9909 at **www.pasco.com**

Order Information

Archimedes' Principle Experiment.....EX-9909
(No interface required.)

Rotational Inertia Experiment

EX-5616

Concepts:

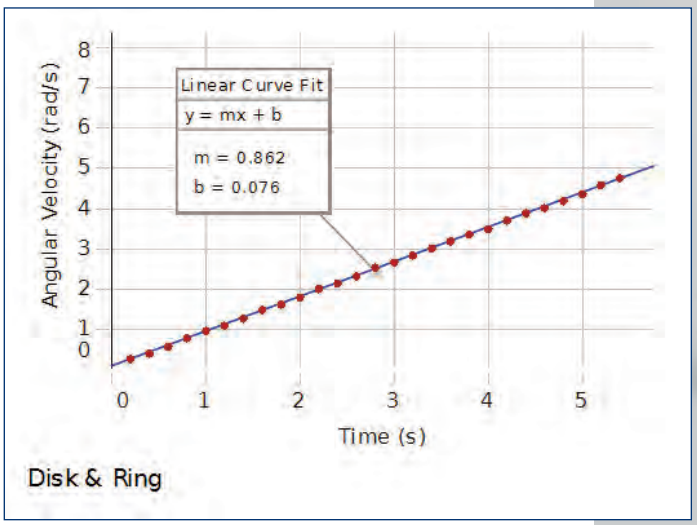
- Rotational inertia of a ring and disk
- Torque

In this experiment, the rotational inertias of a ring and a disk are determined by applying a torque to the object and measuring the resulting angular acceleration.

A known torque is applied to the pulley on the Wireless Rotary Motion Sensor, causing a disk and ring to rotate. The resulting angular acceleration is measured using the slope of a graph of Angular Velocity vs. Time. The rotational inertia of the disk and ring combination is calculated from the torque and the angular acceleration. The procedure is repeated for the disk alone to find the rotational inertias of the ring and disk separately.

PASCO Advantage:

Friction can be neglected in this compact setup. The Wireless Rotary Motion Sensor is a versatile tool that can be used in a variety of other experiments.



The rotational inertia of the ring and disk is calculated from the angular acceleration, which can be obtained from the slope of the Angular Velocity vs. Time graph.

In addition to measuring the resulting angular acceleration, the Wireless Rotary Motion Sensor provides a sturdy, low-friction rotational platform for the Ring and Disk.

A known torque is applied to the ring and disk by the hanging a weight over the pulley. The rotational inertia of the ring and disk are determined from the resulting angular acceleration. The procedure is repeated for the disk alone.

Includes:

• Large Rod Base	ME-8735
• 90 cm Stainless Steel Rod	ME-8738
• Rotational Inertia Accessory	ME-3420
• Mass and Hanger Set	ME-8979
• Wireless Rotary Motion Sensor	PS-3220

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

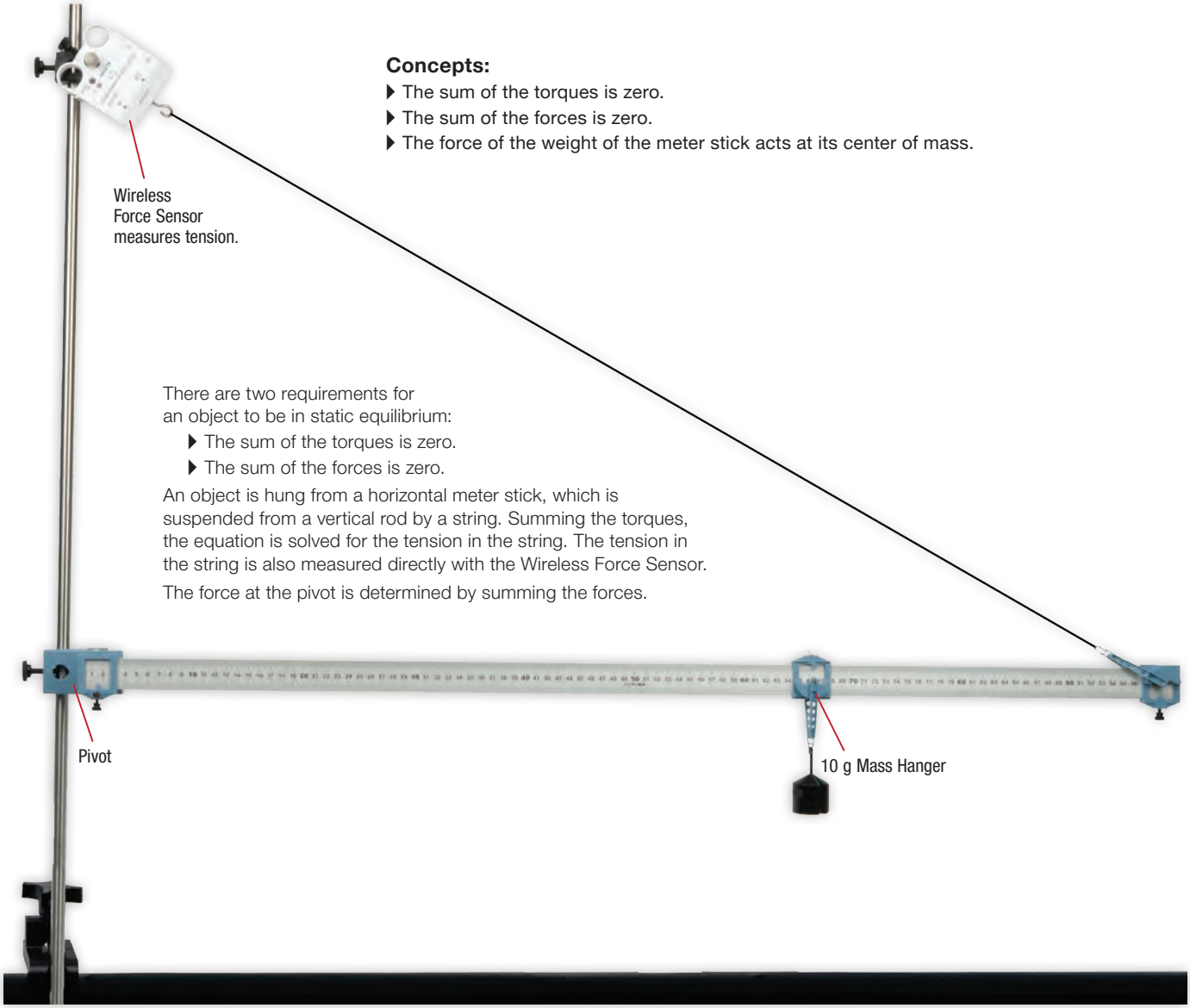
Order Information

Rotational Inertia Experiment	EX-5616	
Required:		
PASCO Capstone Software		pp. 84-87
Balance or Scale		p. 206
Digital Calipers	SE-8710	p. 202

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5516A) online at pasco.com/capstoneexperiments

Static Equilibrium

EX-5564



Concepts:

- The sum of the torques is zero.
- The sum of the forces is zero.
- The force of the weight of the meter stick acts at its center of mass.

There are two requirements for an object to be in static equilibrium:

- The sum of the torques is zero.
- The sum of the forces is zero.

An object is hung from a horizontal meter stick, which is suspended from a vertical rod by a string. Summing the torques, the equation is solved for the tension in the string. The tension in the string is also measured directly with the Wireless Force Sensor.

The force at the pivot is determined by summing the forces.

PASCO Advantage:

The PASCO Pivot has a built-in level to make it easy to tell when the meter stick is horizontal. The Wireless Force Sensor gives a direct reading of the tension in the string.

Includes:

• Meter Stick Torque Set	ME-7033
• Wireless Force Acceleration Sensor	PS-3202
• Hooked Mass Set	SE-8759
• Large Table Clamp	ME-9472
• 90 cm Stainless Steel Rod	ME-8738
• Stainless Steel Rod, 25 cm Threaded	ME-8988
• Multi-Clamp	ME-9507

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Static Equilibrium..... EX-5564
Required:
PASCO Capstone Software..... pp. 84-87
(No interface required.)

Conservation of Angular Momentum Experiment

EX-5517C

Concepts:

- Conservation of angular momentum during collisions
- Easy determination of before and after points
- Calculation of energy lost during collision

Based on the Rotary Motion Sensor, this system makes studies of angular momentum conservation quick and easy. The angular velocity of the spinning disk is graphed in real time as a non-rotating ring is dropped onto it.

PASCO Advantage:

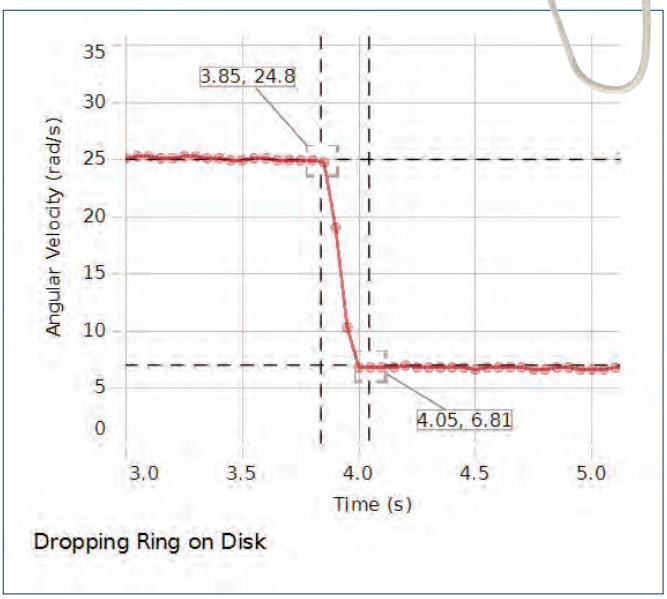
It is easy to measure the rotational speeds just before and after the collision since the entire collision is visible in the graph.

The rotational inertias of the ring and disk are calculated using the mass and dimensions of each. Then the total angular momentum before the collision is compared to the total angular momentum after the collision to show that it does not change.

The total kinetic energy before and after the collision is calculated to show the amount of energy lost during the inelastic collision.

The Rotary Motion Sensor provides a sturdy, low-friction rotational platform for the Ring and Disk, in addition to measuring the resulting change in angular velocity.

As a non-rotating ring is dropped onto a rotating disk, the angular velocity decreases to about 1/6th of its initial value. The ring has a large rotational inertia compared to the disk.



Includes:

• PASPORT Rotary Motion Sensor	PS-2120A
• Mini Rotational Accessory	CI-6691
• Stainless Steel Calipers	SF-8711
• Large Rod Base	ME-8735
• 45 cm Stainless Steel Rod	ME-8736

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Conservation of Angular Momentum Experiment..... EX-5517C
Required:
550 or 850 Universal Interface* .....pp. 26-29
PASCO Capstone Software.....pp. 84-87
* This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Physical Pendulum Experiment

EX-5618

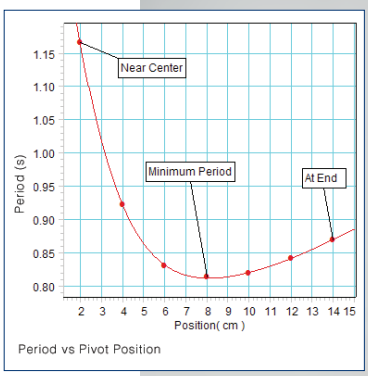
NEW EXPERIMENT!

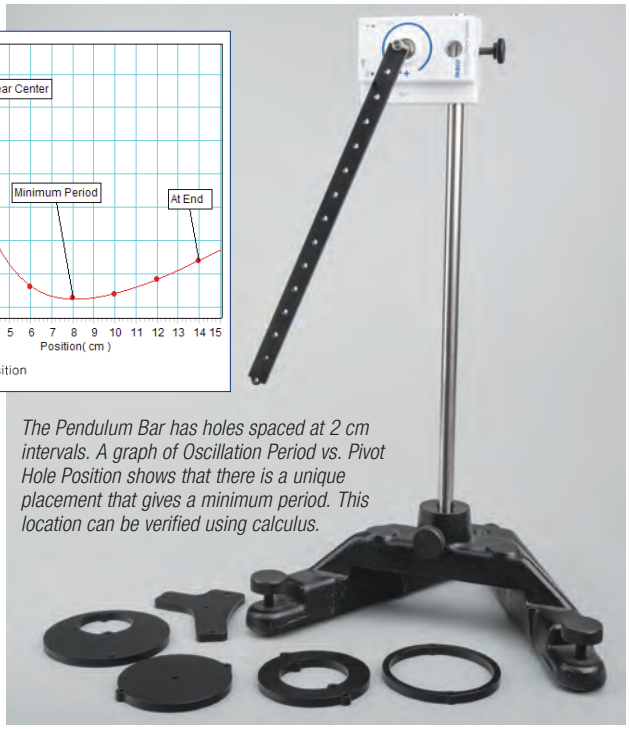
Concepts:

- Parallel Axis Theorem
- Period of a physical pendulum
- Computer modeling of a system
- Rotational inertia

In this experiment, the period of a physical pendulum, a narrow bar, is determined as a function of the distance of the pivot from the center of mass. A computer model of the system is developed, which allows the student to vary the physical parameters of the model (gravity, length, c.m. position) to match the data. This makes it possible to obtain values for the physical parameters without direct measurement.

A second experiment verifies the parallel axis theorem. It also uses superposition to find the rotational inertia of a disk with an off axis circular hole.





The Pendulum Bar has holes spaced at 2 cm intervals. A graph of Oscillation Period vs. Pivot Hole Position shows that there is a unique placement that gives a minimum period. This location can be verified using calculus.

Includes:

• Large Rod Base	ME-8735
• 45 cm Stainless Steel Rod	ME-8736
• Physical Pendulum Set	ME-9833
• Wireless Rotary Motion Sensor	PS-3220
• Super Pulley with Clamp	ME-9448B

Order Information

Physical Pendulum Experiment EX-5618
Required:
PASCO Capstone Software ..... pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5518A) online at pasco.com/capstoneexperiments

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Driven Damped Cart Oscillations

EX-5551A

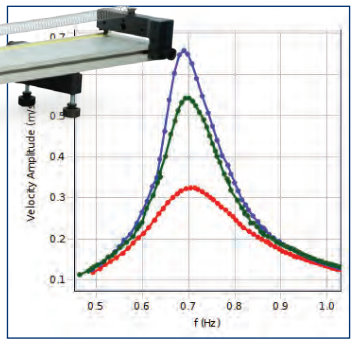
Concepts:

- Resonance curves
- Magnetic drag

Magnets induce currents in the aluminum track and cause a drag force that is proportional to the cart velocity.

PASCO Advantage:

The Smart Cart wirelessly measures the position and velocity of the cart as well as the magnetic drag, since the magnetic drag bumper is attached to the Smart Cart's force sensor.



The amplitude of the cart's velocity is plotted vs. the driving frequency.

The oscillator consists of a Smart Cart attached to two springs. The damping is provided by magnets mounted on the Smart Cart that cause eddy currents in the aluminum track. The amplitude of the oscillation is plotted vs. the driving frequency for different amounts of magnetic damping. The damping can be increased by moving the adjustable magnets closer to the aluminum track.

Includes:

• Smart Cart and Dynamics Track	
• Mechanical Oscillator/Driver	ME-8750
• Dynamics Cart Magnetic Damping	ME-6828
• IDS Spring Kit	ME-8999
• Photogate Head	ME-9498A
• PAScar Cart Mass (Set of 2)	ME-6757A

Order Information

Driven Damped Cart Oscillations EX-5551A
Required:
Ohaus Triple-Beam Balance (with Tare) SE-8707
850 Universal Interface ..... UI-5000 pp. 28-29
PASCO Capstone Software ..... pp. 86-89

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

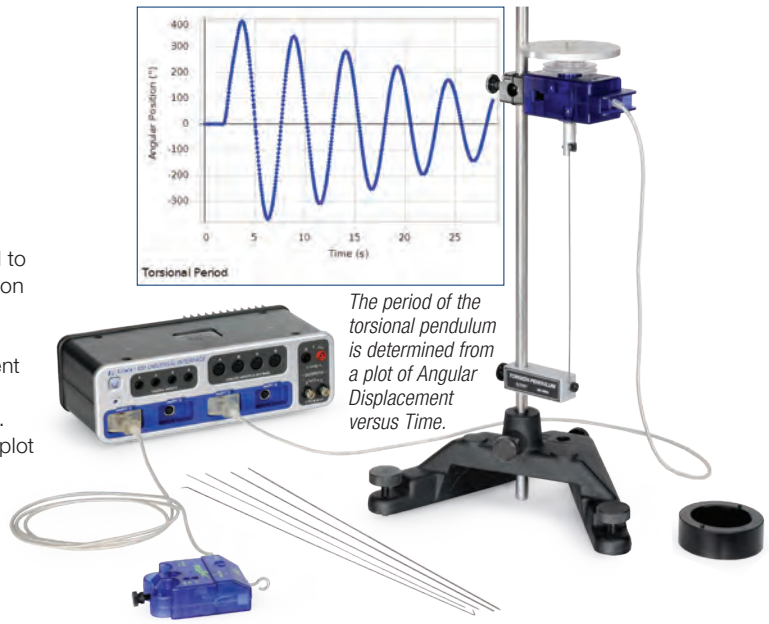
Torsional Pendulum

EX-5521A

Concepts:

- Period of a torsional pendulum
- Rotational inertias of a disk, ring, and point masses
- Torque
- Torsional spring constant

The period of a Torsional Pendulum is measured and compared to the theoretical value. The Torsional Pendulum consists of a torsion wire attached to a Rotary Motion Sensor with an object (a disk, ring, or rod with point masses) mounted on top of it. The period of oscillation is measured from a plot of the Angular Displacement versus Time. To calculate the theoretical period, the rotational inertia is determined by measuring the dimensions of the object. The torsional spring constant is determined from the slope of a plot of Force versus Angular Displacement.



The period of the torsional pendulum is determined from a plot of Angular Displacement versus Time.

Includes

• Rotational Inertia Accessory	ME-3420
• Torsion Pendulum Accessory	ME-6694
• Large Rod Base	ME-8735
• 60 cm Long Stainless Steel Rod	ME-8977
• PASPORT Rotary Motion Sensor	PS-2120A
• PASPORT High-Resolution Force Sensor	PS-2189

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Torsional Pendulum EX-5521A
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Coupled Pendulum

EX-5563

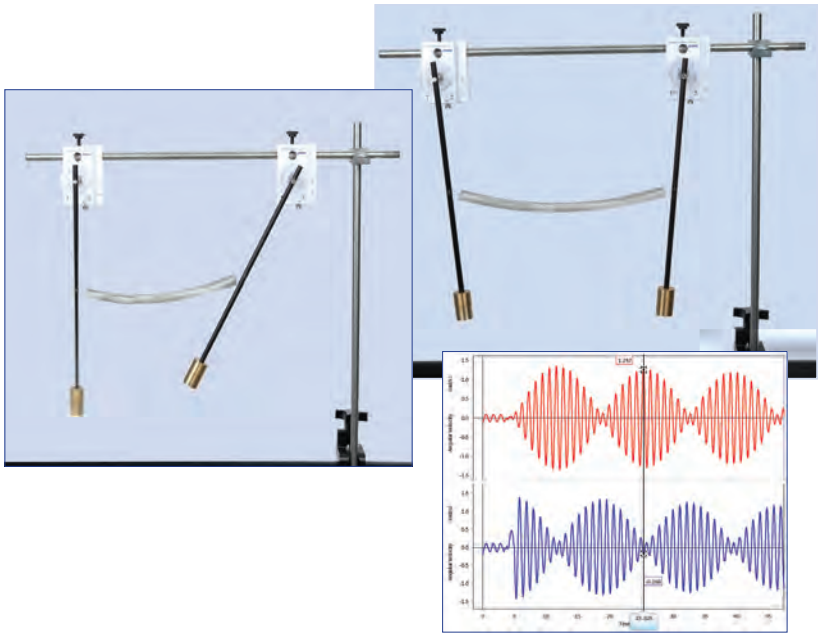
Concepts:

- Resonant Modes of Oscillation
- Period of Transfer of Oscillation Energy between Coupled Pendula

Two pendula are coupled by a spring. This system has two natural modes:

- The two pendula swing in sync.
- The two pendula swing opposite to each other.

When one of the pendula is held at rest and the other is set oscillating, the energy of the oscillating pendulum is transferred to the other pendulum by the spring. The period of the energy transfer can be predicted and verified by experiment.



Includes:

• Wireless Rotary Motion Sensor	PS-3220 (2)
• Pendulum Accessory	ME-8969 (2)
• Longitudinal Wave Spring	WA-9401
• Large Table Clamp	ME-9472
• Stainless Steel Rod, 60 cm Threaded	ME-8977 (2)
• Multi-Clamp	ME-9507

Download This Experiment

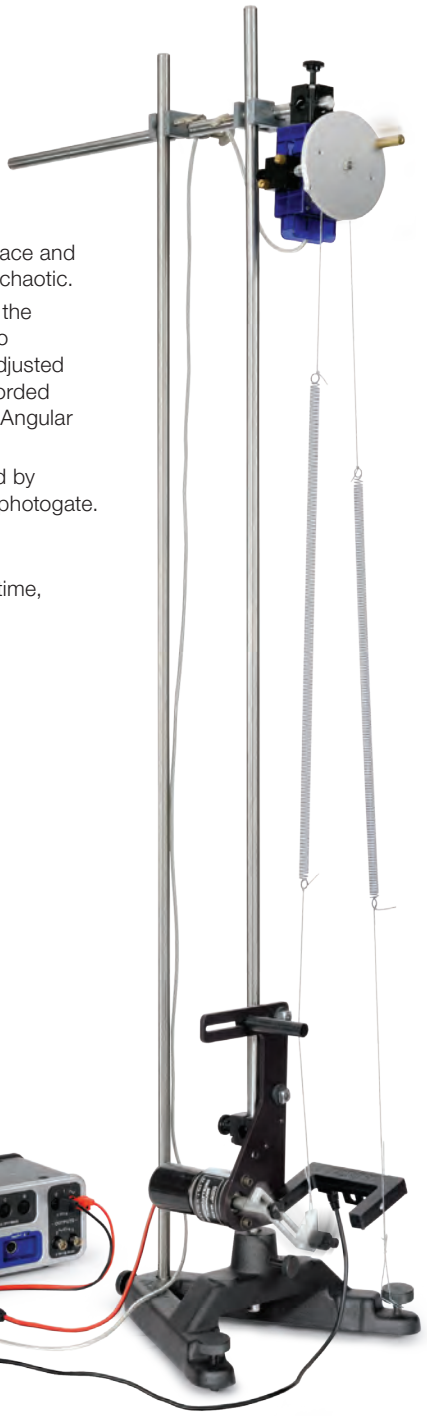
The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Coupled Pendulum EX-5563
Required:
PASCO Capstone Software ..... pp. 84-87
(No interface required.)

Chaos Experiment

EX-5523A



Concepts:

- Nonlinear oscillator
- Chaotic motion
- Phase space
- Poincare plot

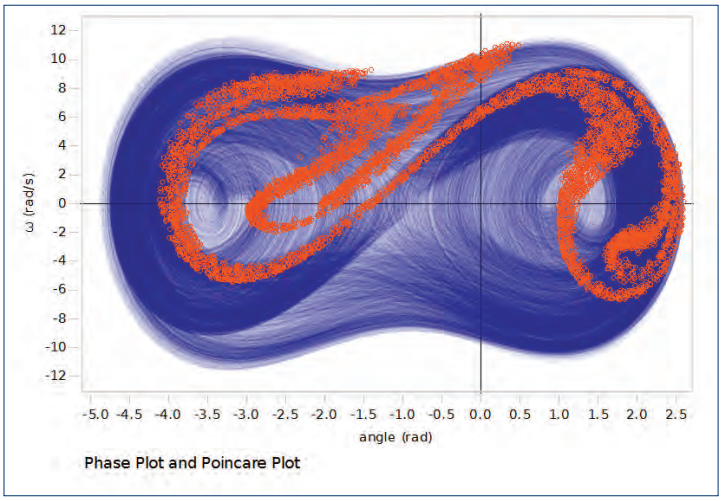
The chaotic behavior of a driven nonlinear pendulum is explored by graphing its motion in phase space and by making a Poincare plot. These plots are compared to the motion of the pendulum when it is not chaotic.

The oscillator consists of an aluminum disk connected to two springs. A point mass on the edge of the aluminum disk makes the oscillator nonlinear. The frequency of the sinusoidal driver can be varied to investigate the progression from predictable motion to chaotic motion. Magnetic damping can be adjusted to change the character of the chaotic motion. The angular position and velocity of the disk are recorded as a function of time using a Rotary Motion Sensor. A real-time phase plot is made by graphing the Angular Velocity vs. the Displacement Angle of the Oscillation.

The Poincare plot is also graphed in real time and superimposed on the phase plot. This is achieved by recording the point on the phase plot once every cycle of the driver arm as the driver arm blocks a photogate.

PASCO Advantage:

PASCO Capstone can graph the motion in phase space and superimpose the Poincare plot in real time, showing students how the motion in phase space relates to the actual motion of the oscillator.



The Poincare plot (in orange) shows the pendulum's Velocity vs. Position once per revolution of the driver. The purple background is the phase plot.

This phase plot (Angular Velocity vs. Angle) is graphed in PASCO Capstone using partial opacity, so the trace gets darker as it traces back over itself.

A graph in phase space and a Poincare plot are obtained to study the chaotic motion of this nonlinear oscillator.

Includes:

• Large Rod Base	ME-8735
• 120 cm Stainless Steel Rod	ME-8741
• 45 cm Stainless Steel Rod	ME-8736
• Multi-Clamps (2)	ME-9507
• Chaos/Driven Harmonic Accessory	CI-6689A
• Mechanical Oscillator/Driver	ME-8750
• PASPORT Rotary Motion Sensor	PS-2120A
• Photogate Head	ME-9498A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Chaos Experiment..... EX-5523A
Required:
550 or 850 Universal Interface..... pp. 26-29
PASCO Capstone Software..... pp. 84-87

Driven Damped Harmonic Oscillations Experiment

EX-5522A

Concepts:

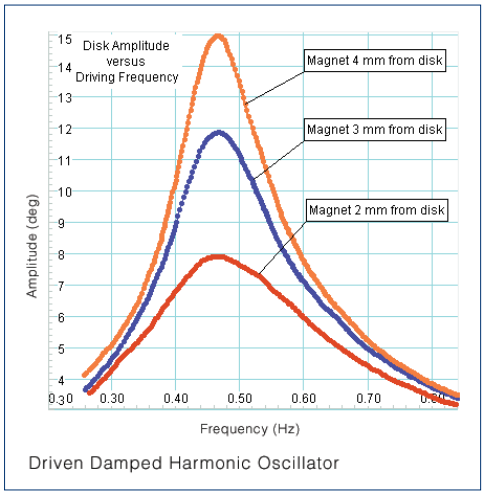
- Resonance curves for an oscillator: Amplitude vs. Frequency
- Resonant frequency
- Period of a pendulum
- Effect of magnetic damping on shape of resonance curve
- Phase difference between oscillator and driver at low, resonant, and high frequencies

In this experiment, the resonance of a driven damped harmonic oscillator is examined by plotting the Oscillation Amplitude vs. Frequency for various amounts of damping.

The oscillator consists of an aluminum disk with a pulley connected to two springs by a string. The angular positions and velocities of the disk and the driver are recorded as a function of time using two Rotary Motion Sensors. The amplitude of the oscillation is plotted vs. the driving frequency for different amounts of magnetic damping. Increased damping is provided by moving an adjustable magnet closer to the aluminum disk.

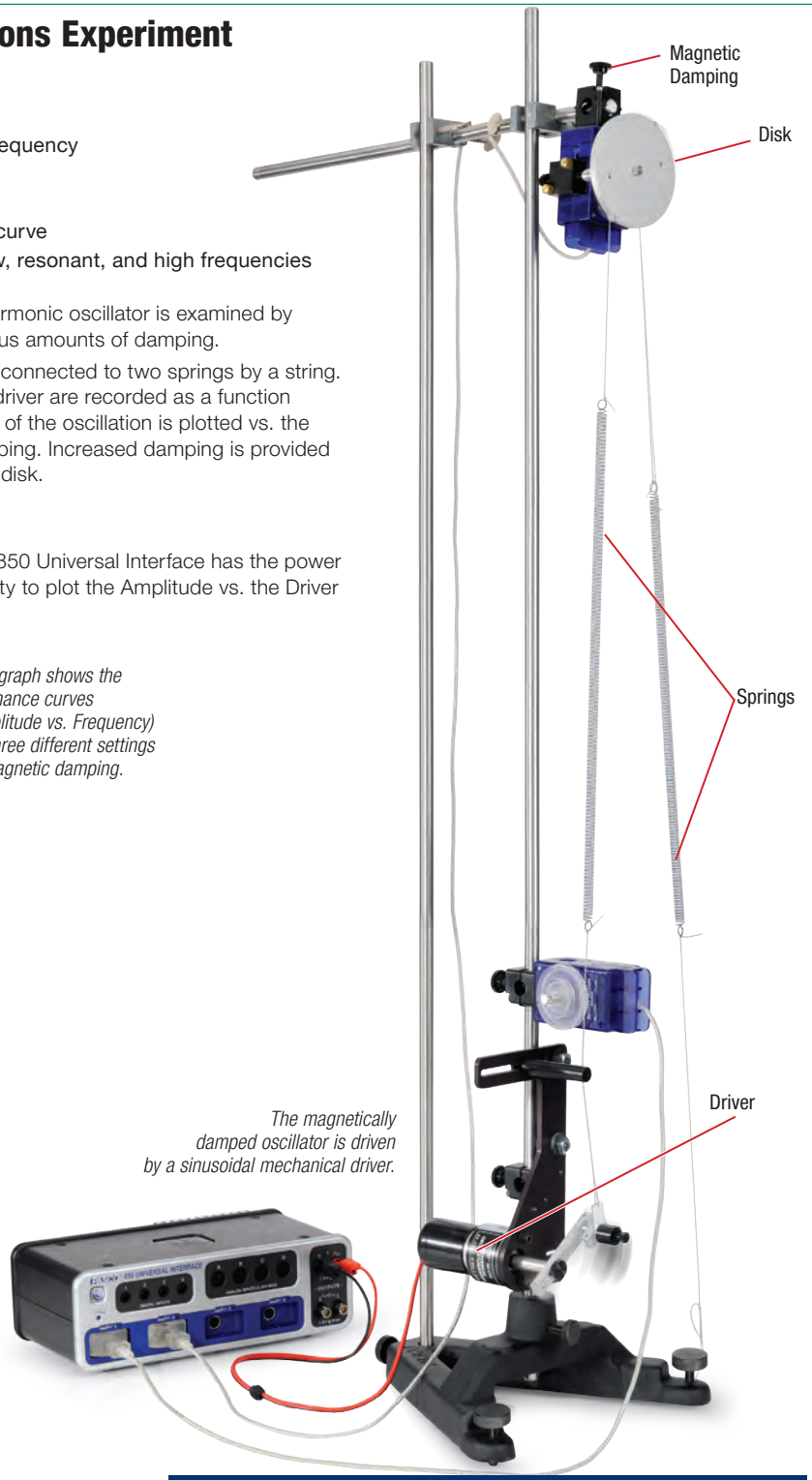
PASCO Advantage:

The combination of PASCO Capstone software and the 850 Universal Interface has the power to sweep through the driver frequencies and the capability to plot the Amplitude vs. the Driver Frequency in real time.



Driven Damped Harmonic Oscillator

This graph shows the resonance curves (Amplitude vs. Frequency) for three different settings of magnetic damping.



The magnetically damped oscillator is driven by a sinusoidal mechanical driver.

Includes:

• PASPORT Rotary Motion Sensor (2)	PS-2120A
• Mechanical Oscillator/Driver	ME-8750
• Chaos/Driven Harmonic Accessory	CI-6689A
• Large Rod Base	ME-8735
• 120 cm Stainless Steel Rod	ME-8741
• 45 cm Stainless Steel Rod	ME-8736
• Multi-Clamps (2)	ME-9507
• Braided Physics String	SE-8050

Order Information

Driven Damped Harmonic Oscillations Experiment	EX-5522A	
Required:		
850 Universal Interface	UI-5000	pp. 26-27
PASCO Capstone Software		pp. 84-87
Hooked Mass Set	SE-8759	p. 207
Digital Calipers	SE-8710	p. 202

Download This Experiment

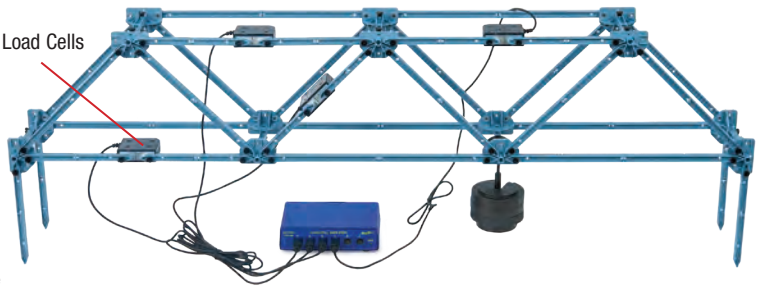
The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Basic Bridges

EX-5556

Concepts:

- Learn about different types of bridges through hands-on exploration.
- Measure the tension/compression in beams for different bridge designs.



Measuring Loads

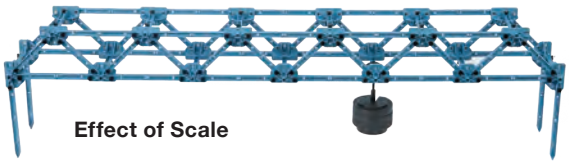
Each bridge is loaded by hanging a weight from the bridge. The tension and compression in the I-Beams are measured with Load Cells. The Load Cells can be moved around to explore the load in every beam in the bridge.

Rectangular Segments

First, students build a bridge with rectangular segments. Of course, bridges are never made this way, but students will never understand why until they try it.

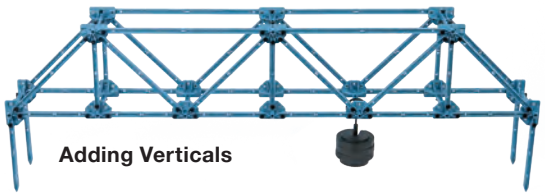
Triangular Segments

Next, students build a Warren bridge with triangular segments. This shows how much stronger triangular segments are than rectangular segments.



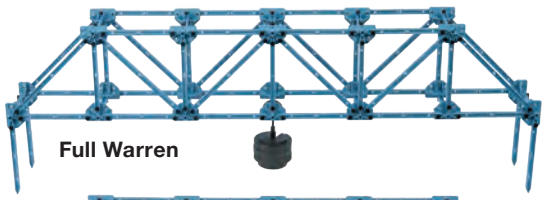
Effect of Scale

Students build a second Warren bridge on a different scale to discover how the forces change in this bridge, which has twice the number of segments but spans the same distance.



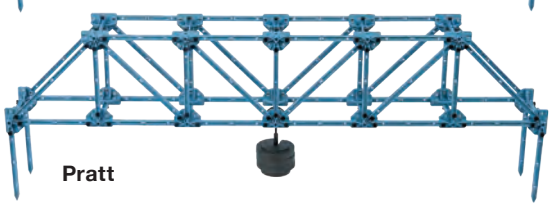
Effect of Adding Verticals

Verticals are added to the larger Warren bridge. Students will find that the loads do not change when the verticals are added; So why are verticals used?



Full Warren Bridge vs Pratt Bridge

Additional verticals are added to make a Full Warren bridge. Then the students change the Full Warren to a Pratt bridge. How are the forces different in a Pratt compared to a Full Warren?



Includes:

• Truss Set Members (3)	ME-6993
• Truss Set Screws (3)	ME-6994
• Structures #6 I-Beam Spares	ME-7008
• Large Slotted Mass Set (2 kg Set)	ME-7589
• PASPORT Load Cell Amplifier	PS-2198
• 100 N Load Cells (4)	PS-2200

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Basic Bridges..... EX-5556
Required:
550 or 850 Universal Interface..... pp. 26-29
OR
AirLink..... p. 60
PASCO Capstone Software..... pp. 84-87

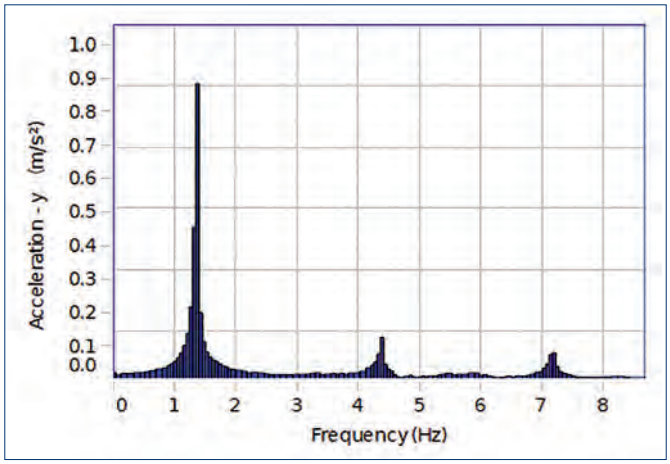
Shaking Tower Experiment

EX-5555

Concepts:

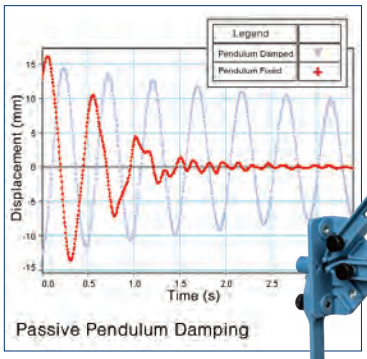
- Explore the resonance modes
- Measure accelerations with wireless sensors
- Demonstrate passive damping

Built from PASCO Structures beams, this tower is made to oscillate in its various resonance modes by a driver attached by a rubber band to the first floor of the tower. Wireless Load Cells with Accelerometers are attached to each floor to record how much shaking each floor experiences.

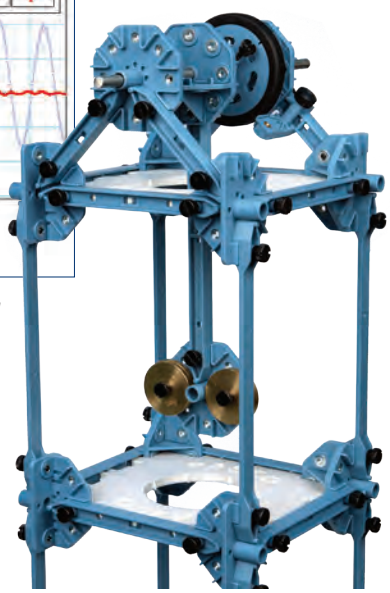


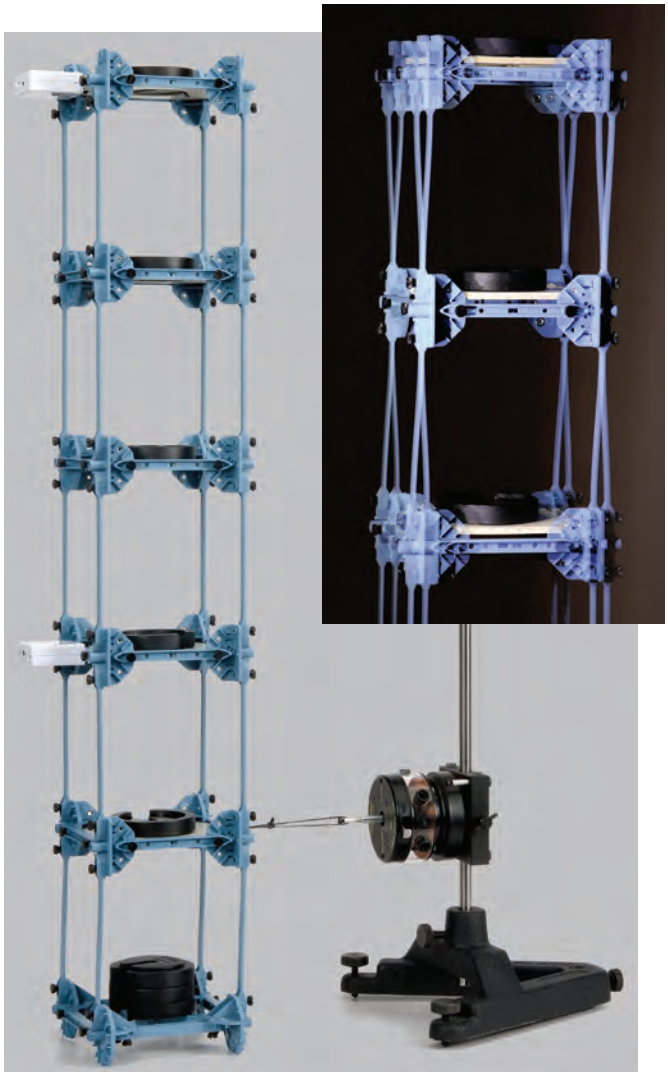
This FFT, generated in PASCO Capstone software, shows the frequency responses of the top Wireless Load Cell/Accelerometer.

In the second part of the experiment, a damping pendulum is installed on top of the tower. In modern buildings, passive damping mechanisms are installed to damp out oscillations during earthquakes. The damping pendulum in this tower quickly stops oscillations.



The gray graph shows the oscillation without the pendulum. The red graph shows the damping caused when the pendulum is allowed to oscillate. Data collected using PASCO Capstone.





The tower is shaken by the Mechanical Wave Driver, which is powered by an 850 Universal Interface or Function Generator.

Includes:

• Shaking Tower	ME-7018
• Mechanical Wave Driver	SF-9324
• 2 Meter Patch Cord Set	SE-9415A
• Large Rod Base	ME-8735
• Stainless Steel Rod, 25 cm Threaded	ME-8988
• Large Slotted Mass Set	ME-7566
• Wireless Load Cell and Accelerometers (4)	PS-3216

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

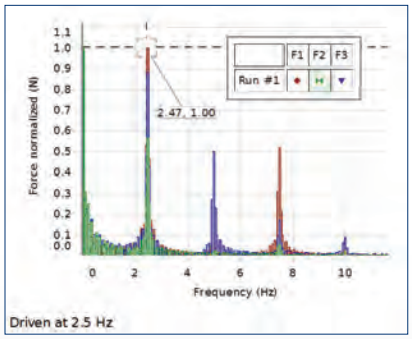
Shaking Tower Experiment..... EX-5555
Required:
850 Universal Interface..... pp. 26-27
OR
Function Generator..... PI-8127 p. 266
PASCO Capstone Software..... pp. 84-87

Bridge Vibrations Experiment

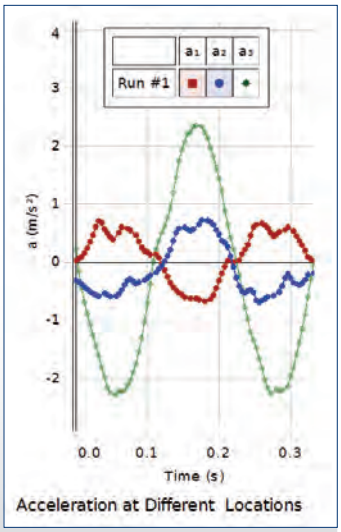
EX-5548

Concepts:

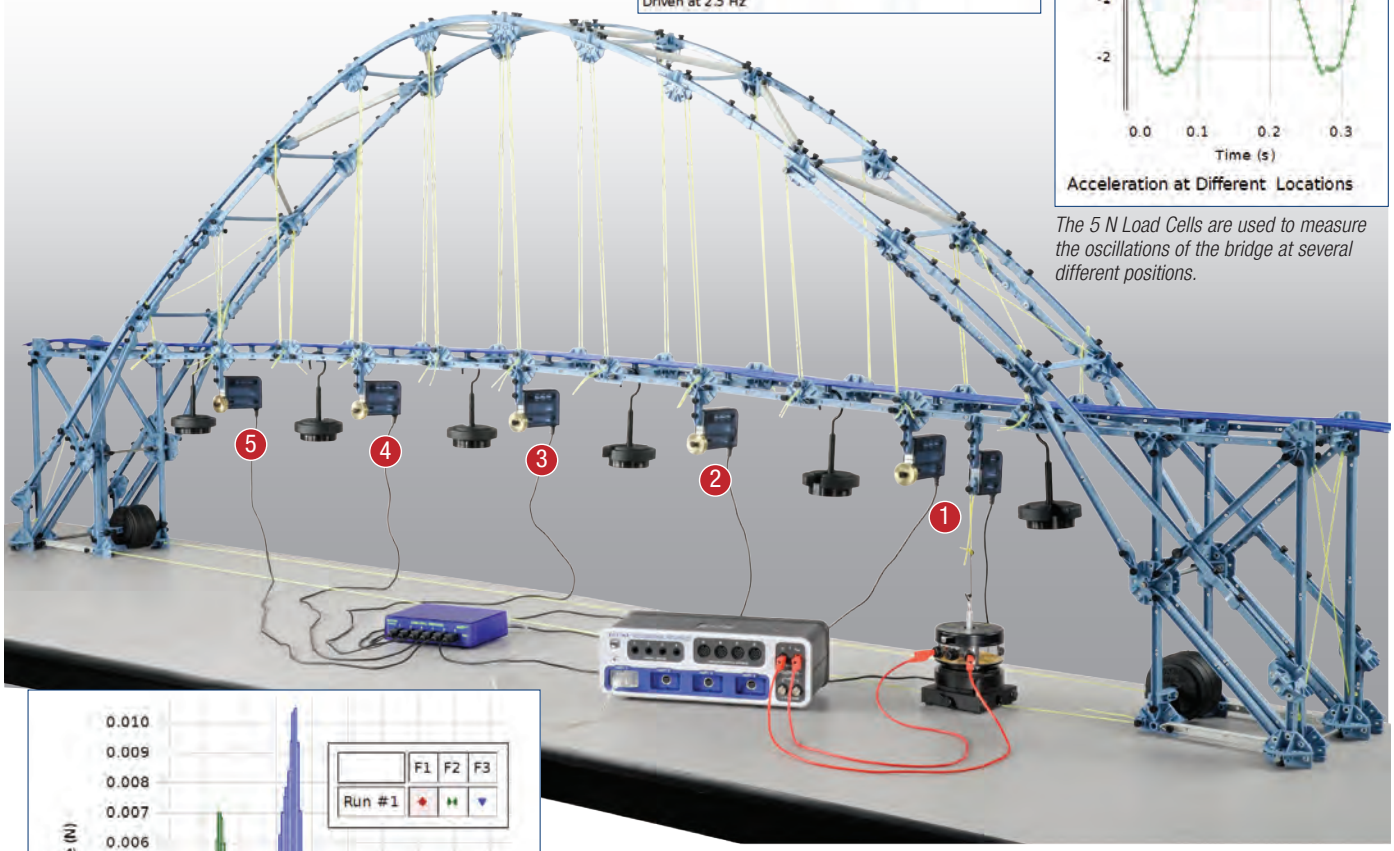
- Resonance in complex systems
- Driven vs. free vibrations

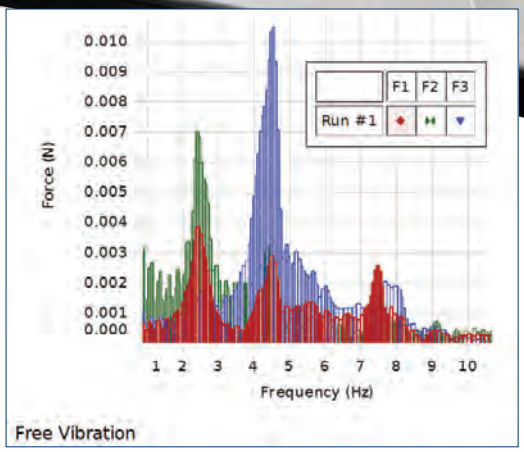


The resonance of the bridge is characterized by driving the bridge at different resonant frequencies. Note how different the amplitudes are at different locations on the bridge.



The 5 N Load Cells are used to measure the oscillations of the bridge at several different positions.





The bridge is struck by hand and allowed to freely oscillate. Using PASCO Capstone™, the FFT shows that there are several resonant frequencies. Note how different the amplitudes are at different locations on the bridge.

Includes:

• Large Structures Set	ME-7003
• PASPORT Load Cell Amplifier	PS-2198
• 100 N Load Cell	PS-2200
• 5 N Load Cell (5)	PS-2201
• Mechanical Wave Driver	SF-9324
• Banana Plug Cord-Red (5 Pack)	SE-9750
• Rubber Cord for IDS System (30m Spool)	ME-8986
• Large Slotted Mass Set (2 kg Set) (4)	ME-7589
• Short Mass Hanger (2)	ME-7590
• 20 g Replacement Mass Set (3 Sets of 6)	ME-8983

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Bridge Vibrations Experiment EX-5548
Required:
850 Universal Interface ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87

Specific Heat Experiment

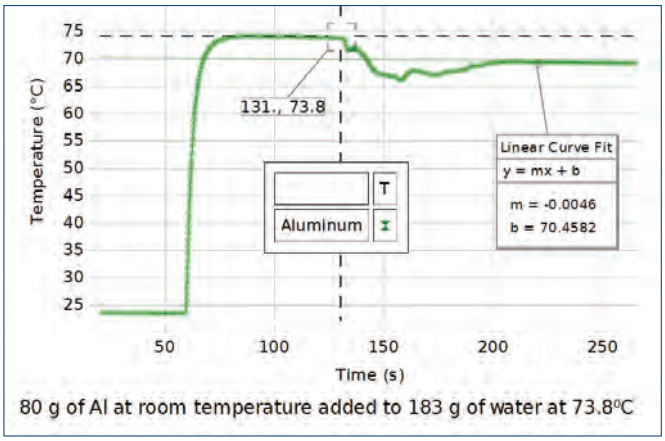
EX-5624

Topics Covered:

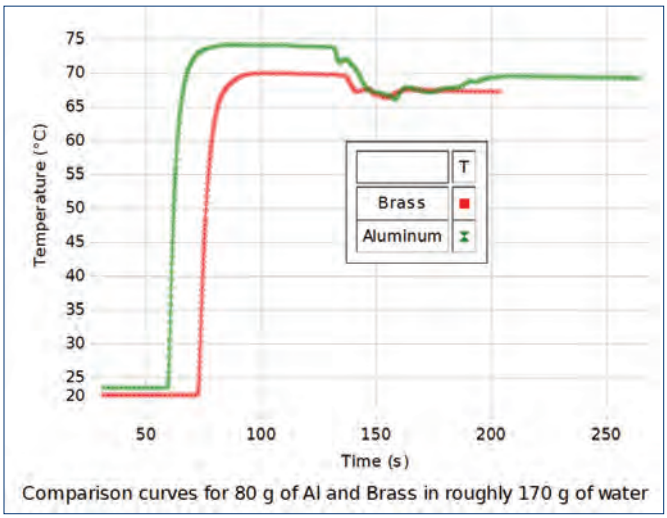
- Thermal energy
- Equilibrium temperature
- Specific heat

Designed for use with PASCO Capstone software, this experiment demonstrates that materials can be identified using specific heat as a measurable characteristic. A known mass of water is used and the unknown material is placed in the water. The initial temperature of the water and the unknown material are measured. The equilibrium temperature is found and from this the specific heat of the unknown material is derived.

By performing this experiment in two ways (water warming, water cooling) students explore how experiment design may alter results. Finally students explore sources of error and magnitude of error.



Room temperature Aluminum is added to hot water. After 210 s, the system comes to equilibrium and slowly cools. A linear fit to the cooling curve allows extrapolation back to find the equilibrium temperature that would have occurred at 131 s when the Aluminum was added, if the system had come to equilibrium instantaneously. This allows measurement of the specific heat within approximately 10%.



Comparison of a similar system shows that Aluminum causes about twice the drop in water temperature as does brass. The cooling slopes before and after support Newton's Law of Cooling.

Includes:

• Wireless Temperature Sensor	PS-3201
• Calorimetry Cup with Lid	
• Heater Stirrer	PS-3401
• Ohaus Triple-Beam Balance (without Tare)	SE-8723
• Graduated Cylinder, 50 mL	
• 1000-mL Beaker	
• Braided Physics String	SE-8050
• Specific Heat Set	SE-6849

Order Information

Specific Heat Experiment EX-5624
Required:
PASCO Capstone Software ..... pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5524A) online at pasco.com/capstoneexperiments

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Electrical Equivalent of Heat Experiment

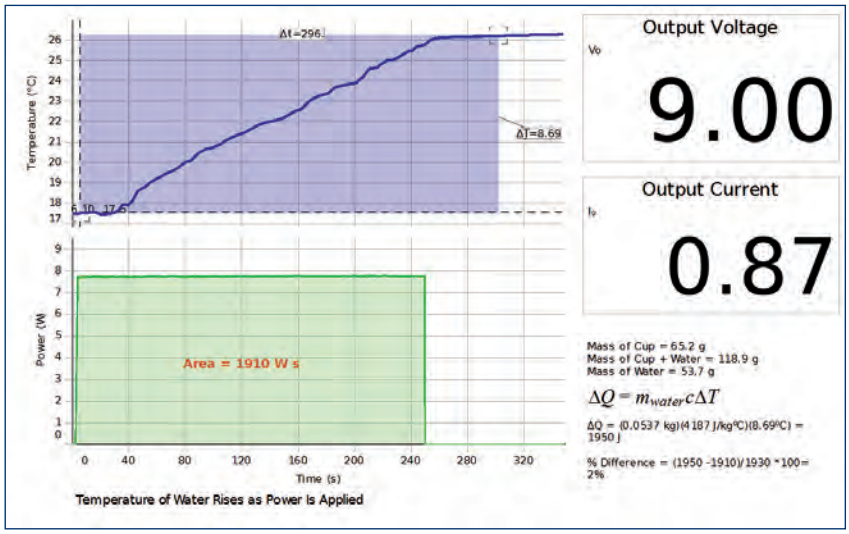
EX-5625

Concepts:

- Compare electrical energy input to changes in internal energy

A Wireless Current Sensor and a Wireless Voltage Sensor are used to measure the electrical power delivered to the resistor that is heating the water and a Wireless Temperature Sensor is used to measure the increase in temperature of the water.

The amount of electrical energy used to heat the water is equal to the area under the power versus time curve. The amount of heat delivered to the water can be calculated using the increase in temperature and the mass of the water. The comparison of the electrical energy to the heat results in a value for the number of Joules in a calorie.



The bottom graph displays the power output from the generator and the top graph shows the increase in temperature. The amount of electrical energy used to heat the water is determined by finding the area under the Power vs. Time curve.

Includes:

• Energy Transfer – Calorimeter	ET-8499
• Wireless Temperature Sensor	PS-3201
• Wireless Voltage Sensor	PS-3211
• Wireless Current Sensor	PS-3212
• Ohaus Triple-Beam Balance (with Tare)	SE-8707
• Student Power Supply	SE-8828

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Electrical Equivalent of Heat Experiment EX-5625
Required:
PASCO Capstone Software ..... pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5525) online at pasco.com/capstoneexperiments

Ideal Gas Law Experiment

EX-5627

Concepts:

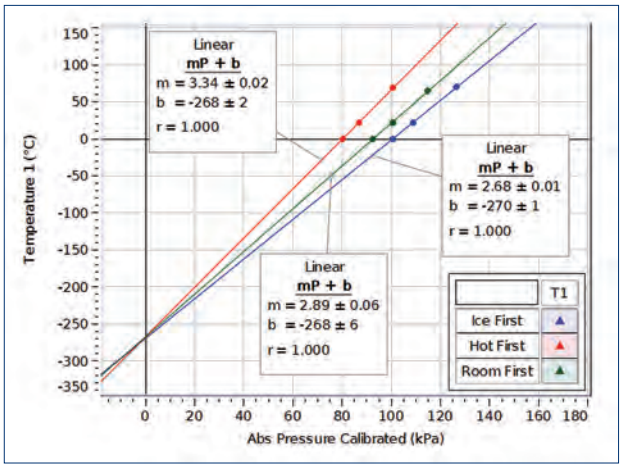
- Ideal Gas Law
- Boyle's Law
- Gay-Lussac's Law

In this experiment designed for use with PASCO Capstone software, the temperature, volume, and pressure of a gas are measured simultaneously to show that they change according to the Ideal Gas Law. Two special cases of the Ideal Gas Law are also examined: constant volume (Gay-Lussac's Law) and constant temperature (Boyle's Law). A syringe is used to vary the volume at constant temperature. A sphere of constant volume is immersed in different temperature water baths to show the change in pressure.

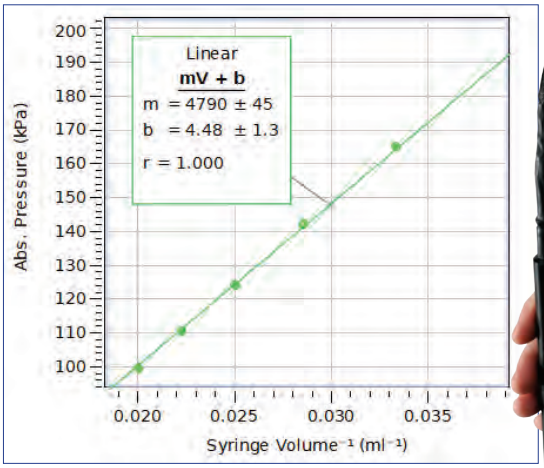
For the Ideal Gas Syringe (shown above) the slope of the Pressure vs. Inverse Volume is nRT.

PASCO Advantage:

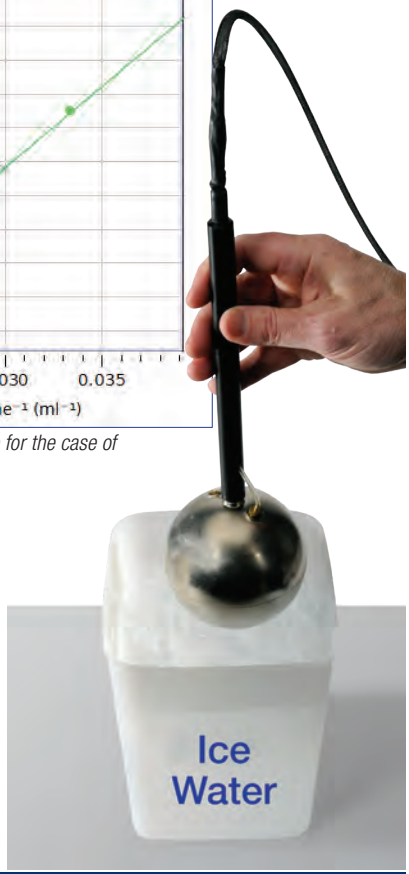
The Ideal Gas Syringe and Absolute Zero Sphere have a thermistor with small mass that responds quickly to temperature changes.



For the Absolute Zero Apparatus (shown at right), which has constant volume, the Pressure vs. Temperature graphs have different slopes corresponding to the different number of moles in the container.



Pressure is plotted versus Inverse Volume for the case of constant temperature.



Includes:

• Ideal Gas Law Apparatus	TD-8596A
• Wireless Pressure Sensor	PS-3203
• Wireless Temp Link	PS-3222
• Absolute Zero Sphere	TD-8595
• 3-Liter Plastic Tub (2-Pack)	ME-7559

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

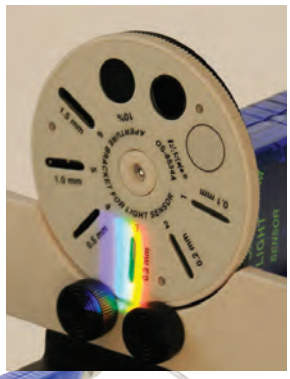
Order Information

Ideal Gas Law Experiment	EX-5627	
Required:		
PASCO Capstone Software		pp. 84-87
Digital Calipers	SE-8710	p. 202

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5527) online at pasco.com/capstoneexperiments

Blackbody Radiation Experiment

EX-5529A



The continuous blackbody spectrum is scanned using a prism spectrophotometer.

Concepts:

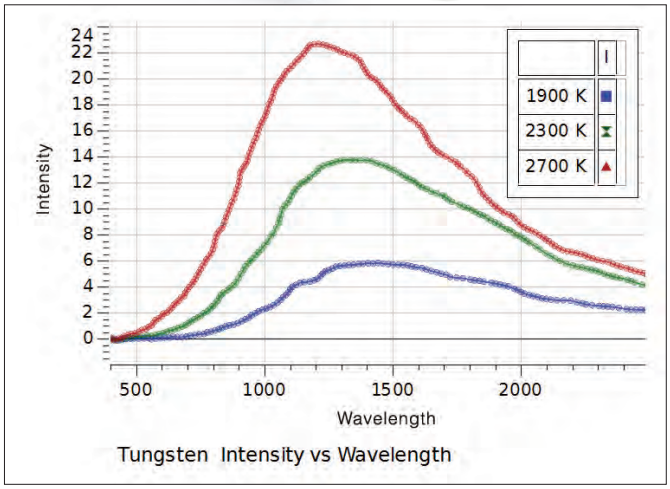
- Blackbody spectrum
- Peak wavelength vs. temperature

In this experiment designed for use with PASCO Capstone software, the classic blackbody spectrum of light intensity versus wavelength is obtained for a light bulb and the shift in the peak wavelength is demonstrated for different bulb temperatures.

The spectrum of an incandescent light bulb is scanned by hand using a prism spectrophotometer, which measures relative light intensity as a function of angle. A Broad Spectrum Light Sensor is used with a prism so that the entire spectrum (approximately 400 nm to 2500 nm) can be scanned without the overlapping orders caused by a grating. The wavelengths corresponding to the angles are calculated using the equations for a prism spectrophotometer. The relative light intensity can then be plotted as a function of wavelength as the spectrum is scanned, resulting in the characteristic blackbody curve. The intensity of the light bulb is reduced, reducing the temperature, and the scan is repeated to show how the curves nest with a shift in the peak wavelength.

The temperature of the bulb's filament can then be measured indirectly by determining the resistance of the bulb from the measured voltage and current. From the temperature, the theoretical peak wavelength can be calculated and compared to the measured peak wavelength.

Note: The results are qualitative, and suitable for introductory classes only.



Classic textbook diagram of the Intensity vs. Wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is decreased.

PASCO Advantage:

The light bulb is powered by the interface, making it easy to change its temperature by changing the voltage across the bulb. All the complex calculations for the angle-to-wavelength conversion are stored in the setup file for PASCO Capstone.

Includes:

• Prism Spectrophotometer Kit	OS-8544
• Optics Benches (60 cm)	OS-8541
• Educational Spectrophotometer Accessory Kit	OS-8537
• Aperture Bracket	OS-8534A
• PASPORT Broad Spectrum Light Sensor	PS-2150
• PASPORT Rotary Motion Sensor	PS-2120A
• Voltage Sensor (unshrouded)	UI-5100
• Replacement Light Bulbs (10)	SE-8509
• Banana Plug Cord-Black (5 Pack)	SE-9751

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Blackbody Radiation Experiment EX-5529A
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87

Heat Engine Cycles Experiment

EX-5630

Concepts:

- Heat engine efficiency
- Isothermal processes
- Isobaric processes
- Ideal Gas Law

A P-V diagram is generated as a heat engine is taken through a cycle. From this diagram, the heat added to the gas and the work done by the engine are measured to determine the efficiency of the engine. This actual efficiency is compared to the theoretical maximum efficiency.

The heat engine consists of air inside a cylinder that expands when an attached can is immersed in hot water. The expanding air pushes on a piston and does work by lifting a weight. The heat engine cycle is completed by immersing the can in cold water, which returns the air pressure and volume to the starting values.

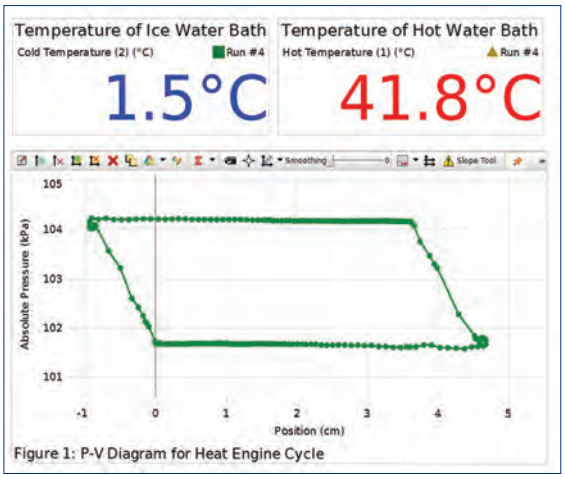


Figure 1: P-V Diagram for Heat Engine Cycle

The PASCO Capstone™ graph shows an isobaric/isothermal heat engine cycle operating between a cold water bath at 1.5°C and a hot water bath at 41.8°C.

The cycle is performed as follows:

- With the can in the cold bath, the 200 g mass is placed on the platform.
- The can is moved from the cold bath to the hot bath.
- The 200 g mass is removed from the platform.
- The can is moved from the hot bath to the cold bath.

The change in pressure is measured with a Wireless Pressure Sensor. The change in piston height is measured by the attached string over the Wireless Rotary Motion Sensor pulley. The change in volume is calculated by multiplying the change in piston height by the piston cross-sectional area.

The actual efficiency is determined for a heat engine that lifts a weight as heat is added to the gas.

PASCO Advantage:

This operating heat engine shows how a difference in temperature can be used to do work. Each part of the cycle is easily identifiable, and the actual efficiency as well as the maximum possible efficiency can be easily determined.

Includes:

• Heat Engine and Gas Law Apparatus	TD-8572A
• Large Rod Base	ME-8735
• Mass and Hanger Set	ME-8979
• 3-Liter Plastic Tub (2-Pack)	ME-7559
• Thread	
• Stainless Steel Temp Probe (2)	PS-2153
• 90 cm Stainless Steel Rod	ME-8738
• Wireless Rotary Motion Sensor	PS-3220
• Wireless Temperature Link (2)	PS-3222
• Wireless Pressure Sensor	PS-3203

Order Information

Heat Engine Cycles Experiment..... EX-5630
Required:
PASCO Capstone Software..... pp. 84-87

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5530B) online at pasco.com/capstoneexperiments

Ratio of Specific Heat Experiment

EX-5631

Concepts:

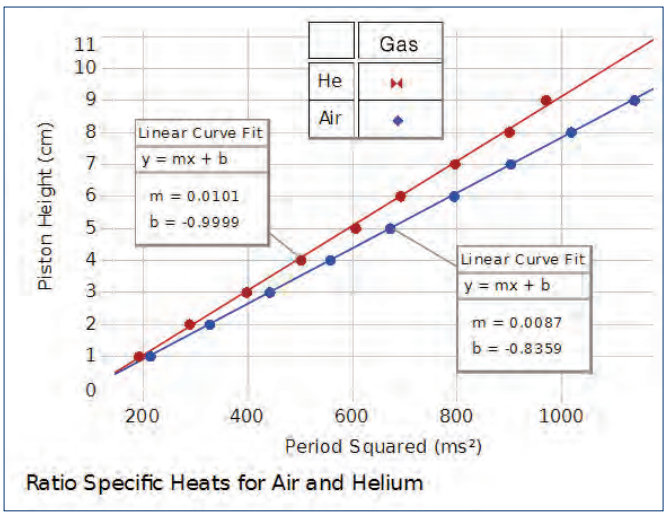
- C_p/C_v for a gas
- Ruchardt's method of measuring the ratio of specific heats
- Adiabatic process

In this experiment, the ratio of specific heat capacities for air is determined using Ruchardt's method of measuring the period of oscillation of the piston in a cylinder filled with air.

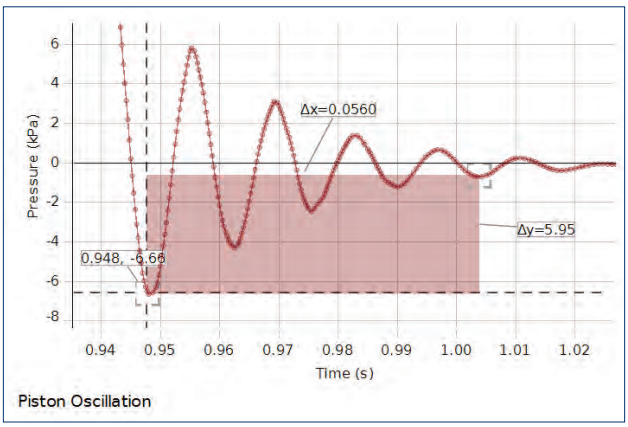
A cylinder is filled with air and a Wireless Pressure Sensor is attached. The piston is plucked by hand and allowed to oscillate. The oscillating pressure is recorded as a function of time and the period is determined. The ratio of specific heat capacities is calculated using the period of oscillation, according to Ruchardt's method.

PASCO Advantage:

Since the oscillations are plotted, it is easy to accurately measure the period of oscillation.



A plot of the Piston Height vs. the Period Squared shows that the period increases as the gas volume increases. The slope of the line is related to the ratio of specific heats (C_p/C_v) and is different for the two gases.



The pressure oscillates after the piston is plucked by hand.

Includes:

• Heat Engine and Gas Law Apparatus	TD-8572A
• Large Rod Base	ME-8735
• 45 cm Stainless Steel Rod	ME-8736
• Wireless Pressure Sensor	PS-3202

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Ratio of Specific Heat Experiment EX-5631
Required:
PASCO Capstone Software ..... pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5531A) online at pasco.com/capstoneexperiments

Electrostatic Charge Experiment

EX-5532

Topics Covered:

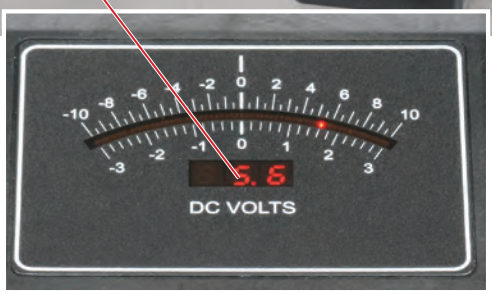
- Methods of Charging
- Charge Distribution
- Conservation of Charge

Using classic equipment (a Faraday Ice Pail and Conductive Spheres), students learn to charge objects by direct contact and by induction. The charge is measured using a high impedance electrometer.

Students explore the distribution of charge on different shaped conductive shapes. A sphere with a hole in it is provided to show that no charge resides on the inner surface of the conductor when it is charged.

Use the ball end to sample inside the hollow sphere.

New Digital Readout



Includes:

• Basic Electrometer	ES-9078A
• Charge Producers and Proof Plane	ES-9057C
• Faraday Ice Pail	ES-9042A
• Conductive Spheres	ES-9059C
• Conductive Shapes	ES-9061
• Electrostatics Voltage Source	ES-9077

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Electrostatic Charge Experiment EX-5532
Required:
PASCO Capstone Software ..... pp. 84-87
(No interface required.)

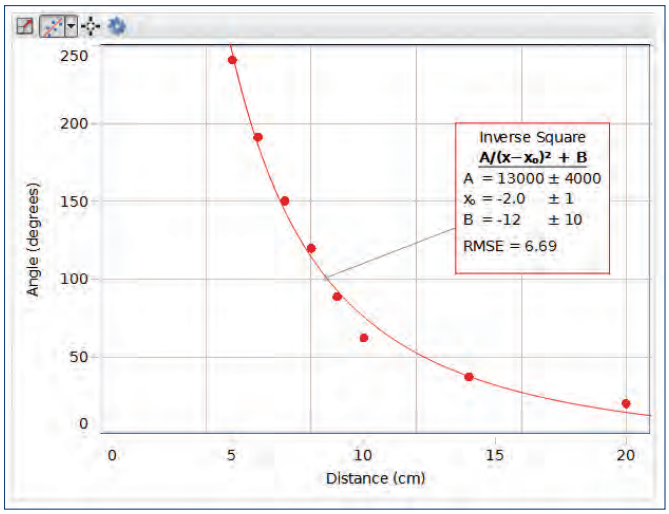
Coulomb's Law Experiment

EX-9930B

Concepts:

- Verify the Inverse Square Law: $F \sim 1/R^2$
- Verify the Force/Charge Relationship: $F \sim q_1 q_2$
- Determine Coulomb's Constant: $k = 9.0 \times 10^9\ Nm^2/C^2$

A conductive sphere is mounted on the end of an insulating counterbalanced rod and suspended from a very thin torsion wire. An identical sphere is mounted on a calibrated linear track and can be positioned at various distances from the first sphere. When the conductive spheres are charged, the force between them is proportional to the twist of the torsion wire that is required to bring the balance back to its equilibrium position. Introductory physics students can determine the Inverse Square Law in a simple experiment, while advanced students can perform investigations into all the variables involved in electrostatic repulsion.



Electrostatic force is directly proportional to the angle of twist, and the angle of twist is proportional to the inverse square of the separation of the balls.

When an electrostatic force is applied, the torsion wire is twisted to return the balance to equilibrium. The twist of the wire is proportional to the electrostatic repulsion force.

Includes:

• Coulomb's Law Apparatus	ES-9070
• Kilovolt Power Supply	SF-9586B
• Basic Electrometer	ES-9078A
• Faraday Ice Pail	ES-9042A
• Charge Producers and Proof Plane	ES-9057C
• Coulomb's Law Experiment Manual	

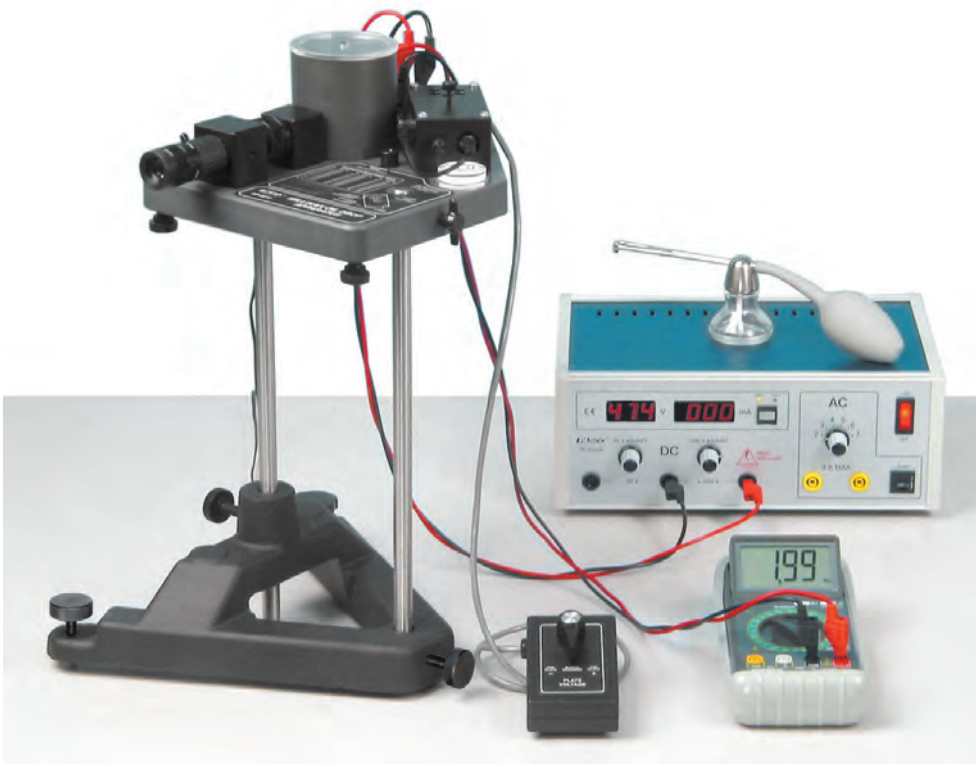
Download This Experiment

Search for EX-9930B at **www.pasco.com**

Order Information

Coulomb's Law Experiment EX-9930B
(No interface required.)

Charge of an Electron Experiment



Concepts:

- Accurately measure the charge of a single electron
- Recreate Robert Millikan's historical experiment

Small droplets of oil are introduced into a chamber where an electric field of known strength is present. Using the viewing scope and a stopwatch, the velocity of a falling oil droplet is measured and recorded. Next, the electric field in the chamber is increased, causing the oil droplet to move upward. This allows the measurement of the force on the droplet and, ultimately, the charge of the droplet. By measuring the charge of several different oil droplets, the smallest difference in charge between them can be equated to the charge of an electron.

PASCO Advantage:

PASCO's Charge of an Electron Experiment features a 30x, bright-field, erect-image microscope for clear viewing of the oil droplets. The droplet viewing chamber utilizes a special condenser to minimize droplet drift typically caused by droplet illumination and outside air currents. An ionization source allows the droplet charge to be changed.

Experiment components sold separately.

The complete experiment requires:

• Millikan Oil Drop Apparatus	AP-8210A
• Basic Digital Multimeter	SE-9786A
• High Voltage Power Supply	SF-9585A
• Large Rod Base	ME-8735
• 45 cm Stainless Steel Rod (2)	ME-8736
• Banana Plug Cord-Red (5 Pack)	SE-9750
• Banana Plug Cord-Black (5 Pack)	SE-9751
• Charge of an Electron Experiment Manual	

Easy Cleaning
The condenser system easily disassembles for cleaning and inspection.

Condenser Housing

Droplet Hole Cover
Prevents additional droplets from entering the chamber once the experiment has started.

Minimum Electric Field Distortion
A 0.5 mm diameter droplet entry hole in the top capacitor plate has a negligible effect on the electric field.

Polished Surfaces
Polished surfaces on the plate spacer minimize absorption of light (and heat) through the chamber walls.

Ionization Source
The thorium-232 alpha source can be activated by the switch on the side of the chamber. The source allows the charge on the oil droplets to be changed.

Electrical Connection
Electrical connection to the top plate.

Condenser Assembly

Order Information

Millikan Oil Drop Apparatus	AP-8210A	p. 250, 316
Basic Digital Multimeter	SE-9786A	p. 240, 267
High Voltage Power Supply	SF-9585A	p. 263
Large Rod Base	ME-8735	p. 196
45 cm Stainless Steel Rod	ME-8736	p. 196
Banana Plug Cord-Red (5 Pack)	SE-9750	p. 238
Banana Plug Cord-Black (5 Pack)	SE-9751	p. 238

(No interface required.)

Capacitance Experiment

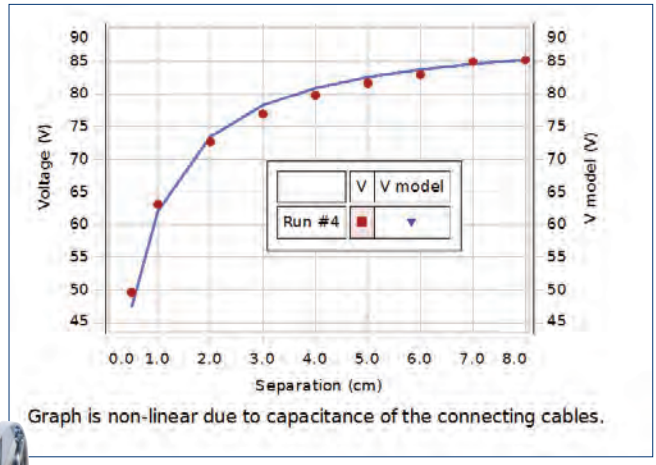
EX-5533

Topics Covered:

- Capacitance
- Parallel Plate Capacitor
- Factors Affecting Capacitance

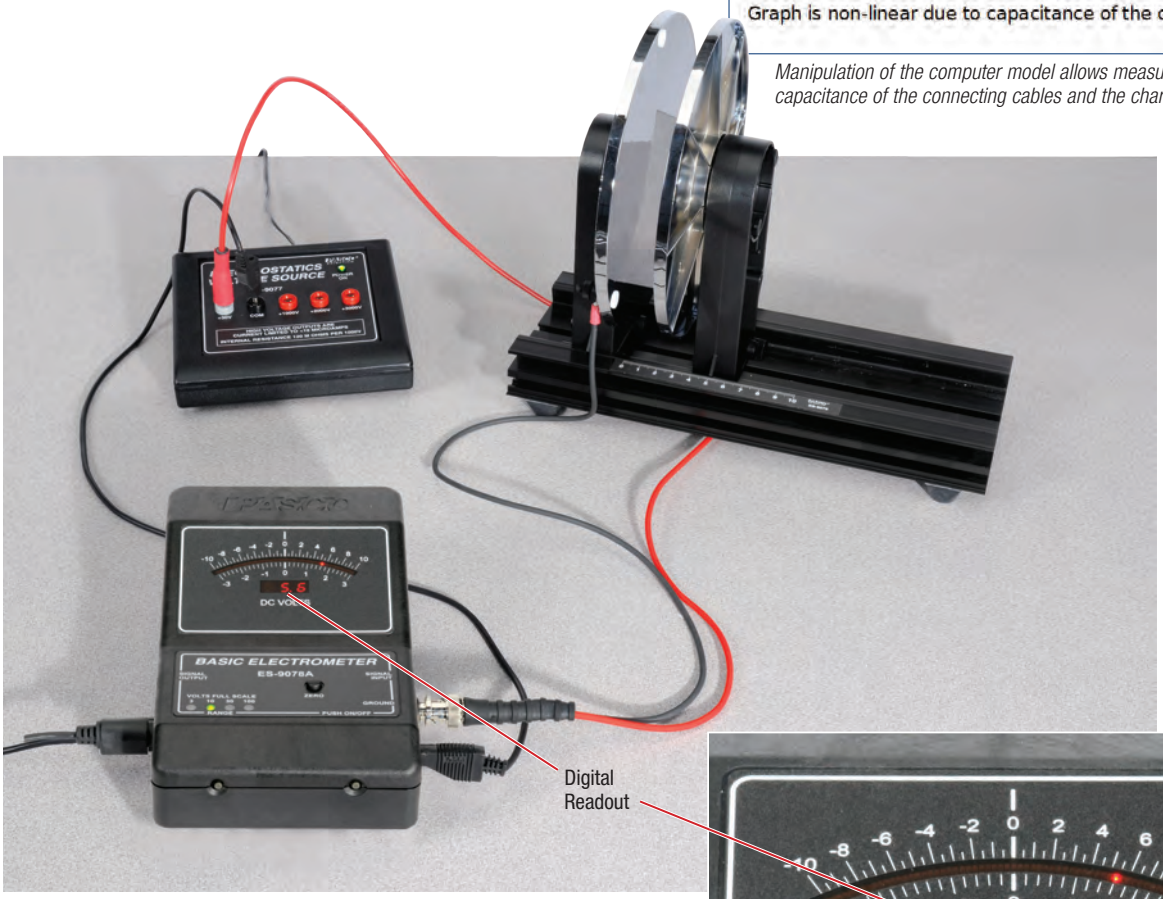
This lab explores the effect of varying plate distances and insulating dielectric materials in a variable flat plate capacitor.

The electrometer used in this experiment allows you to measure the voltage across the capacitor plates, without discharging the capacitor, since it has an internal resistance of 1014 ohms.



Graph is non-linear due to capacitance of the connecting cables.

Manipulation of the computer model allows measurement of the capacitance of the connecting cables and the charge on the system.



Includes:

• Basic Electrometer	ES-9078A
• Basic Variable Capacitor	ES-9079
• Electrostatics Voltage Source	ES-9077

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Capacitance Experiment EX-5533
Required:
550 or 850 Universal Interface ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87

Resistivity Experiment

EX-5534

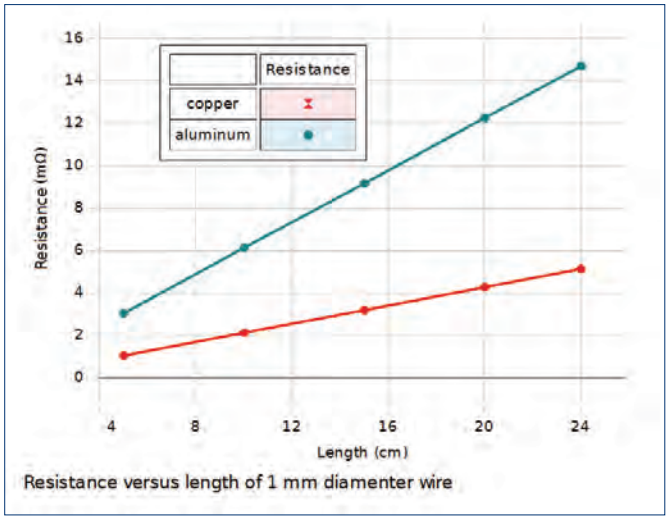
Concepts:

- Relate resistance to wire length
- Determine resistivity of different materials

Discover the relationship between the resistance of a wire and its length, diameter, and the resistivity of the metal.

The current is measured directly by the 850 Universal Interface, and the voltage drop over the selected section of wire is measured by the Voltage Sensor. This allows easy calculation of the resistance of the length of wire. The resistance is plotted vs. the length of the wire, and the slope of the resulting straight line is used to determine the resistivity.

Using wires of the same diameter made of different materials allows examination of the effect of resistivity. Using brass wires with various diameters allows examination of the effect diameter has on resistance.



Resistance versus length of 1 mm diamenter wire

Since both wires have the same diameter, the resistivity is directly proportional to the slope. The graph shows that the resistivity of copper is about one-third that of aluminum.

The Resistance Apparatus has a slide wire probe to easily change the measured length of the wire, and it utilizes a four wire hook-up to accurately measure the voltage drop. It comes with four different brass wire diameters and four other wire materials.

PASCO Advantage:

The Resistance Apparatus has a slide-wire probe to easily change the measured length of the wire. It utilizes a four-wire hook-up to accurately measure the voltage drop.

The 850 Universal Interface Power Amplifier makes it possible to scan the voltages, allowing more time to examine wires made of different metals and with different diameters.

Includes:

- Resistivity Apparatus EM-8812
- Voltage Sensor (unshrouded) UI-5100
- Banana Plug Cord-Red (5 Pack) SE-9750

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Resistivity Experiment..... EX-5534
Required:
550 or 850 Universal Interface..... pp. 26-29
PASCO Capstone Software..... pp. 84-87
Micrometer..... p. 202

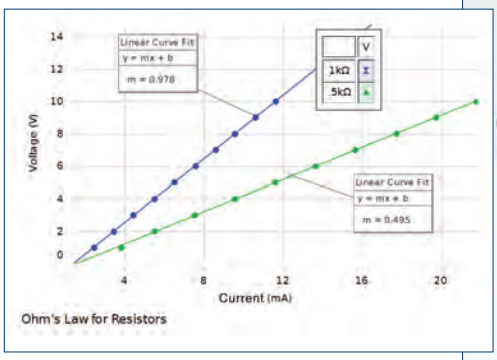
Ohm's Law Experiment

EX-5535

Concepts:

- Relationship between voltage and current

In this experiment, students simultaneously measure both current and voltage for a simple DC circuit. The relationship between current and voltage is explored for different resistors in parallel. A graph of Voltage vs. Current is used to verify Ohm's Law and recognize the physical meaning of slope.



The relationship between voltage and current varies for different resistance values.

Includes:

- Resistor Capacitor Inductor Network UI-5210
- Banana Plug Cord Sets, 30 cm Length (set of 8) SE-7123

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Ohm's Law Experiment..... EX-5535
Required:
550 or 850 Universal Interface..... pp. 26-29
PASCO Capstone Software..... pp. 84-87

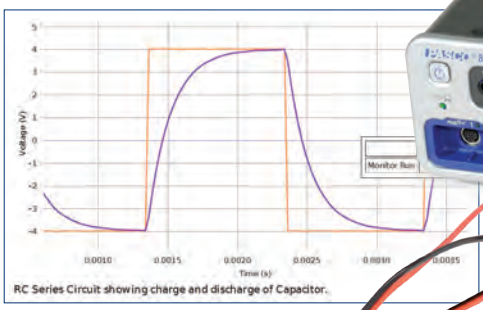
RC Circuit Experiment

EX-5536

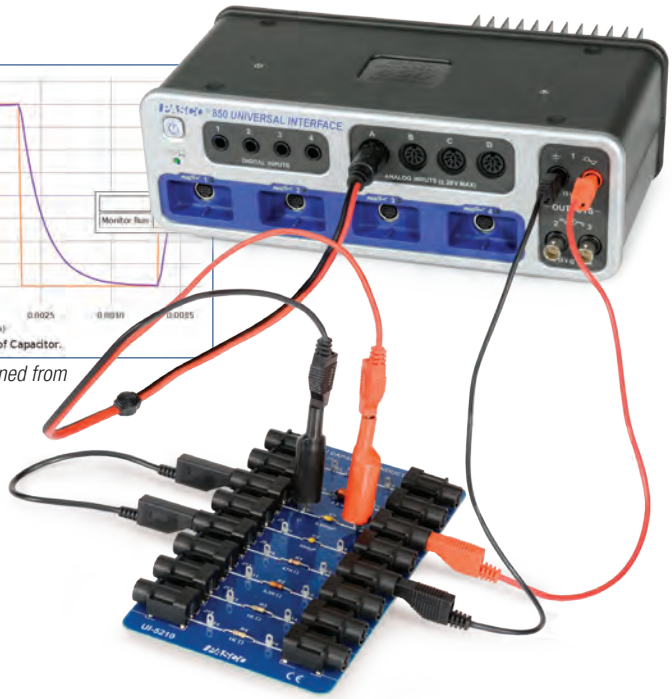
Concepts:

- Charging and discharging a capacitor
- Exponential growth and decay
- Time constants

Students collect data to understand the relationship between charging and discharging rates and the capacitance and resistance in a simple circuit. The time constant is derived and exponential growth and decay are explored.



The actual capacitance is determined from the charge/discharge curve.



PASCO Advantage:

The RC Circuit experiment is extremely simple and transparent to set up. It is very easy to measure the time to half charge. It is also easy to verify that the curve is exponential using the curve-fitting capability of PASCO Capstone software.

Includes:

- Resistor Capacitor Inductor Network UI-5210
- Voltage Sensor (unshrouded) UI-5100
- Banana Plug Cord Sets, 30 cm Length (8) SE-7123

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

RC Circuit Experiment..... EX-5536
Required:
550 or 850 Universal Interface..... pp. 26-29
PASCO Capstone Software..... pp. 84-87

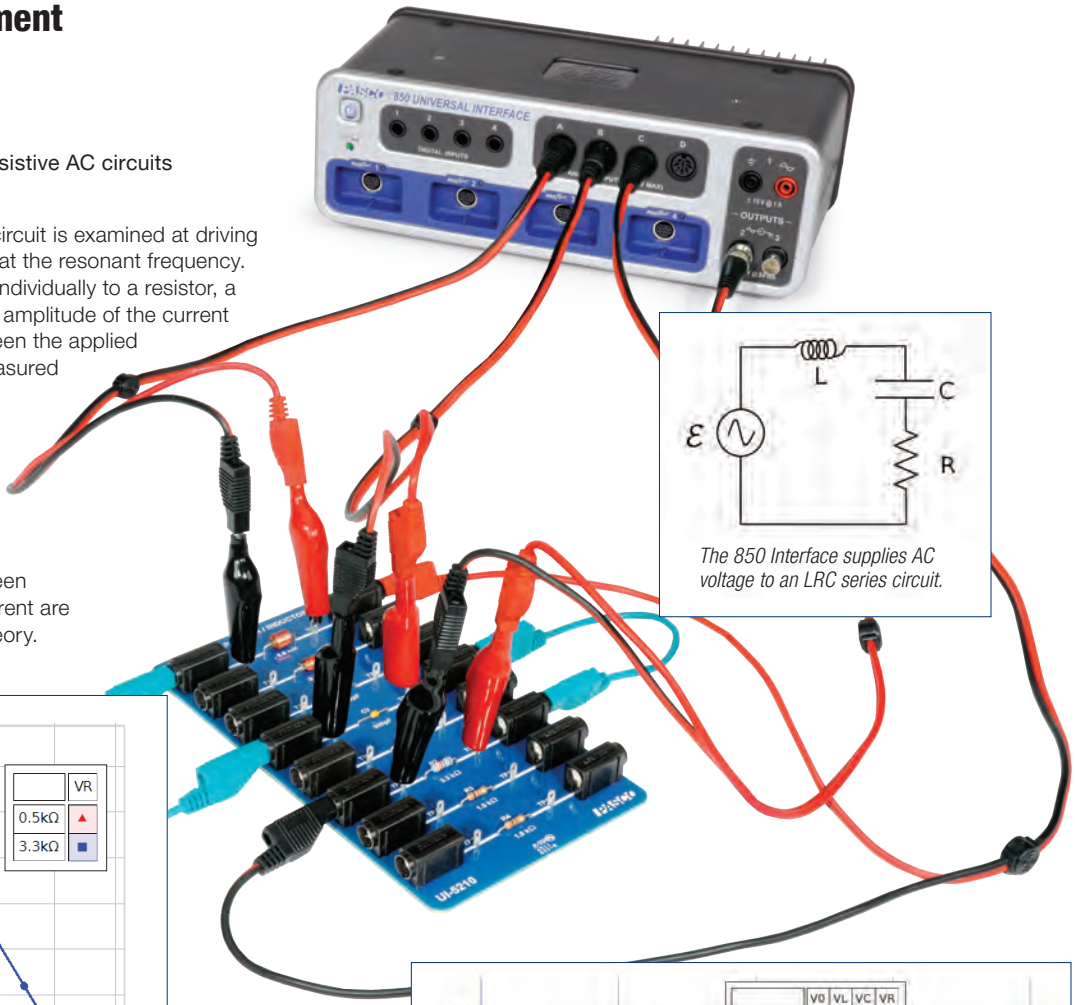
LRC Circuit Experiment

EX-5537

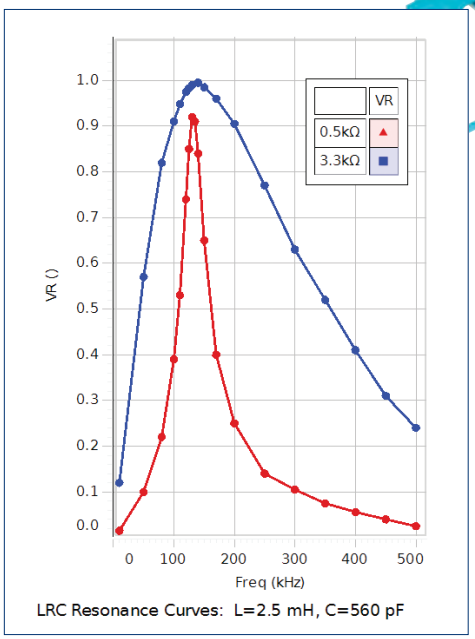
Concepts:

- LC oscillations
- Inductive, capacitive, and resistive AC circuits
- LRC resonant frequency

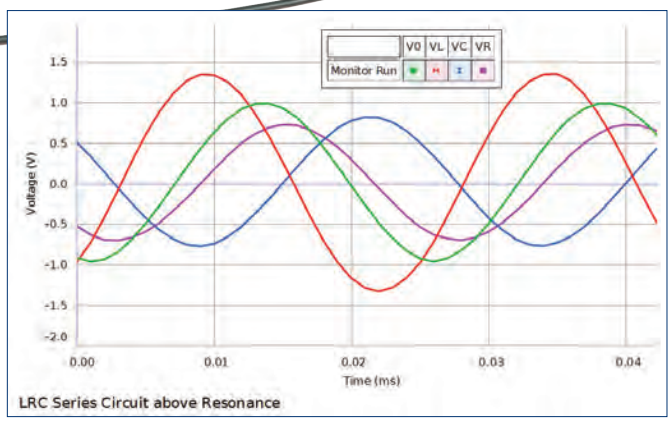
The response of a series LRC circuit is examined at driving frequencies above, below, and at the resonant frequency. A sinusoidal voltage is applied individually to a resistor, a capacitor, and an inductor. The amplitude of the current and the phase difference between the applied voltage and the current are measured in each of the three circuits to see the effect each component has on the current. Finally, a sinusoidal voltage is applied to an inductor, resistor, and capacitor in series. The amplitude of the current and the phase difference between the applied voltage and the current are measured and compared to theory.



The 850 Interface supplies AC voltage to an LRC series circuit.



The effect of circuit resistance on peak width is clear and leads to an understanding of how to design a filter for a circuit.



The oscilloscope display in PASCO Capstone is used to simultaneously display the voltages across the inductor, capacitor, and resistor, as well as the source voltage.

Includes:

• Resistor Capacitor Inductor Network	UI-5210
• Voltage Sensors (unshrouded) (3)	UI-5100
• Banana Plug Cord Sets, 30 cm Length (8)	SE-7123
• BNC Function Generator Output Cable (unshrouded)	UI-5119

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

LRC Circuit Experiment EX-5537
Required:
550 or 850 Universal Interface ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87

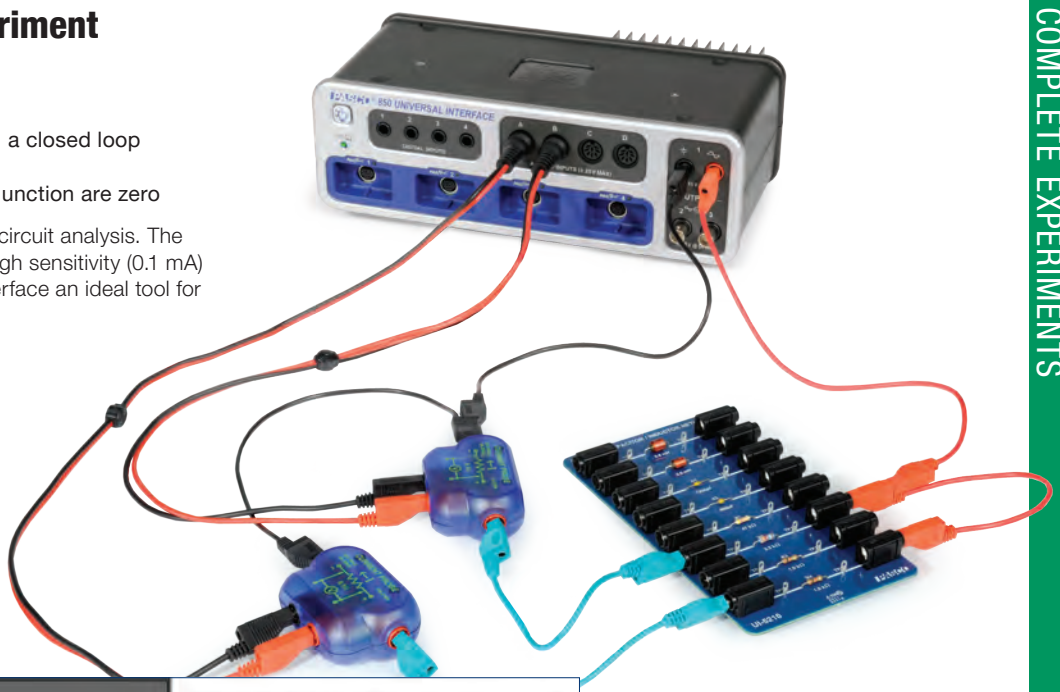
Kirchhoff's Rules Experiment

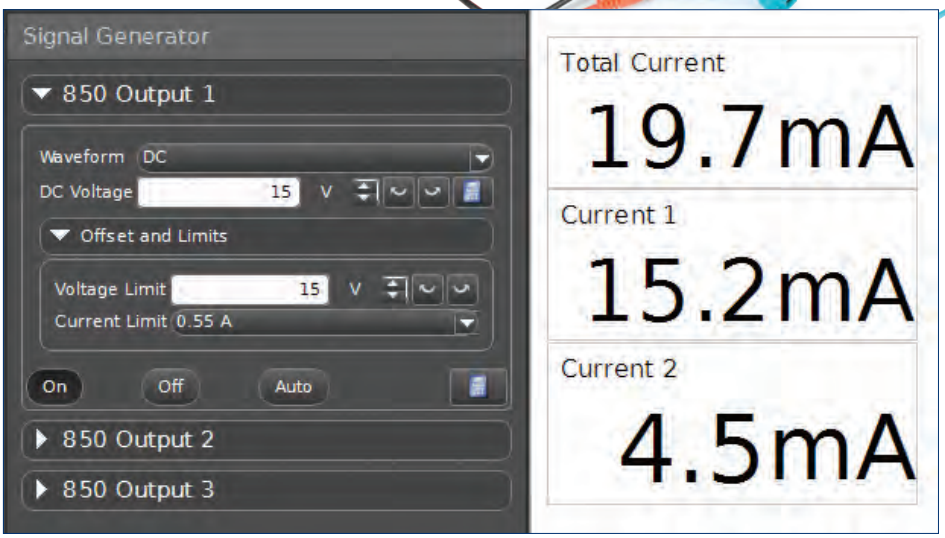
EX-5538

Concepts:

- Summation of the voltages around a closed loop are zero at any instant
- Summation of the currents at any junction are zero

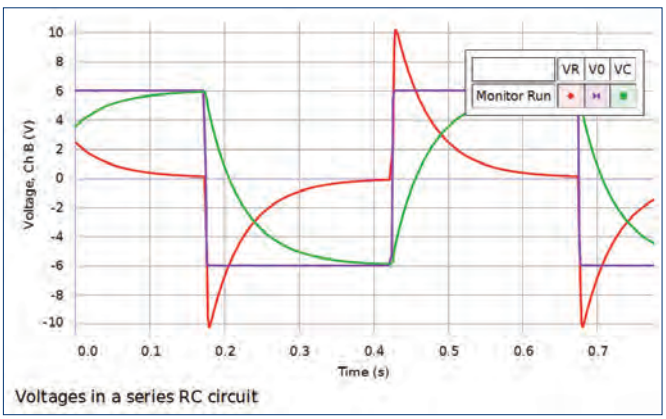
Kirchhoff's Laws form the basis of all circuit analysis. The high speed for AC applications and high sensitivity (0.1 mA) for DC applications make the 850 Interface an ideal tool for investigating AC and DC circuits.





Measurement of voltages and currents in series-parallel DC circuits demonstrates the validity of Kirchhoff's Laws. The use of multiple current probes avoids student confusion that can arise when rearranging the circuit to measure currents at different points.

Students control output from the 850 signal generators directly from the user interface in PASCO Capstone. Students compare the current flow through each resistor to the total current output from the 850.



Voltages in a series RC circuit

The high speed of the 850 Universal Interface, in scope mode, allows the examination of time varying voltages in an RC circuit to verify that Kirchhoff's loop theorem holds even when voltage is not constant.

Includes:

• Resistor Capacitor Inductor Network	UI-5210
• Voltage Sensors (unshrouded) (3)	UI-5100
• PASPORT Current Probes (2)	PS-2184
• Banana Plug Cord Sets, 30 cm Length (8)	SE-7123

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Kirchhoff's Rules Experiment EX-5538

Required:

550 or 850 Universal Interface ..... pp. 26-29

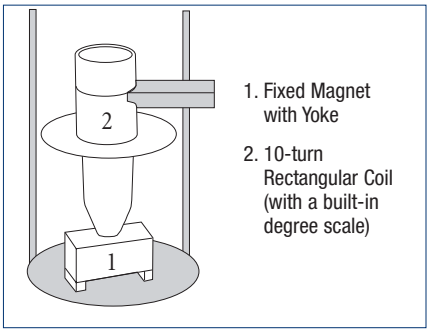
PASCO Capstone Software ..... pp. 84-87

Magnetic Forces on Wires Experiment

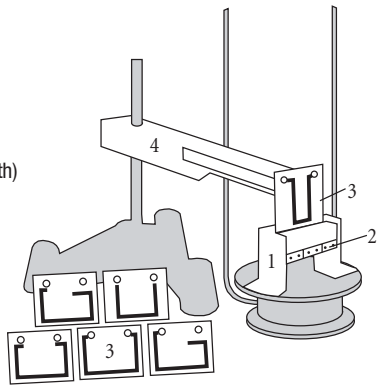
EX-9933

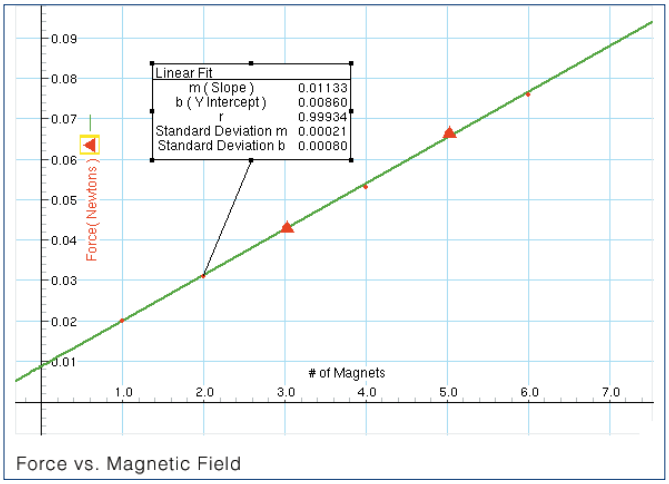
Concepts:

- Examine the relationships between: force and current, force and length of wire, force and magnetic field strength, and force and angle



1. Iron Yoke (holds magnets)
2. Removable Magnets (six)
3. Six Conductors (1, 2, 3, 4, 6 and 8 cm in length)
4. Mount (for holding/positioning conductors)





Force vs. Magnetic Field

Graph illustrates the direct relationship between magnetic field and magnetic force.

Magnets are mounted on an iron yoke and placed on a balance (resolution of at least 0.01 g). One of the conducting paths is suspended between the magnets. The balance is used to measure the mass of the magnets and yoke prior to any current passing through the conducting path. Current is then passed through the conducting path, producing a force. The change in reading on the balance can be converted to find the magnetic force between the conductor and magnetic field.

Conductors of different lengths are included to measure the effect of length on magnetic force. Magnetic field can be varied by changing the number of magnets in the yoke. The power source is used to change the current supplied to the conductor. The Current Balance Accessory includes all the components needed to test the effect of angle on magnetic force.

PASCO Advantage:

PASCO's Magnetic Forces on Wires Experiment allows students to study the key variables (conductor length, current, magnetic field strength, and angle) that affect magnetic force.

Includes:

• Basic Current Balance	SF-8607
• The Current Balance Accessory Kit	SF-8608
• Ohaus Cent-O-Gram Balance	SE-8725
• Low Voltage AC/DC Power Supply	SF-9584B
• Base and Support Rod	ME-9355
• Banana Plug Cord-Red (5 Pack)	SE-9750
• Banana Plug Cord-Black (5 Pack)	SE-9751
• Magnetic Forces on Wires Experiment Manual	

Download This Experiment

Search for EX-9933 at **www.pasco.com**

Order Information

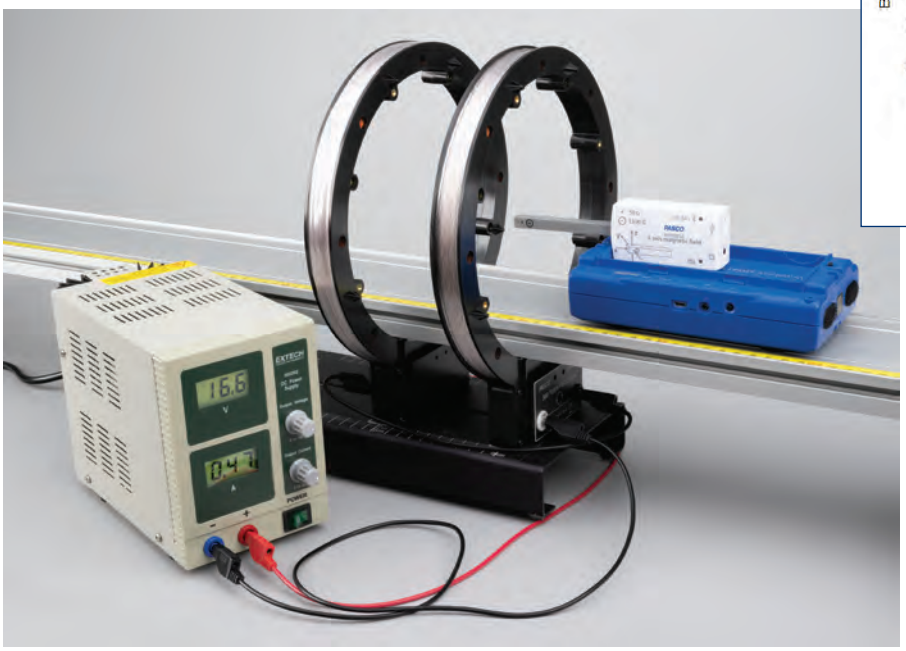
Magnetic Forces on Wires Experiment..... EX-9933
(No interface required.)

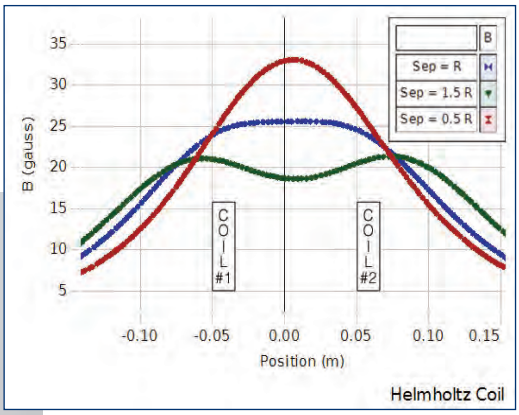
Magnetic Fields of Coils Experiment

EX-5640

Concepts:

- Magnetic fields of single coil, Helmholtz coils, and inside a solenoid





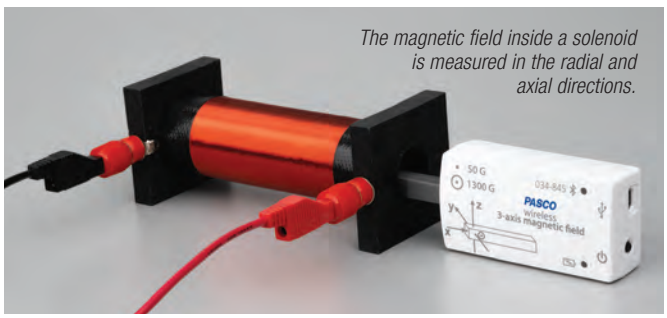
This plot shows the magnetic field strength along the axis of Helmholtz coils for three different coil separations. The blue data was collected using coils with the proper separation (the coil radius); the red data was collected using coils that were too close together; and the green data was collected from coils that were too far apart.

The magnetic field of Helmholtz coils is measured as a function of distance along the perpendicular axis.

The dependence of the magnetic field strength of current-carrying coils on the distance from the coil along the perpendicular axis is determined and compared to the theoretical curve. In addition, the effect of varying the coil separation on the shape of the magnetic field between the Helmholtz coils is examined.

To perform the experiment, a Wireless Magnetic Field Sensor is mounted to a Smart Cart and placed on a track with coils. As the cart passes through the coils, a real-time plot of the magnetic field strength vs. position is created.

It is particularly interesting to compare the field from Helmholtz coils properly separated by the coil radius to the field from coils separated at less than or more than the coil radius. The magnetic field inside a solenoid can be examined in both the radial and axial directions.



The magnetic field inside a solenoid is measured in the radial and axial directions.

Includes:

• Helmholtz Coil Base	EM-6715
• 500-Turn Field Coils (2)	EM-6723A
• Primary and Secondary Coils	SE-8653A
• Banana Plug Cord-Red (5 Pack)	SE-9750
• Banana Plug Cord-Black (5 Pack)	SE-9751
• Dynamics Track	ME-9493
• Student Power Supply	SE-8828
• Round Base with Rod (2 of each)	ME-8270
• Track Rod Clamp (2)	ME-9836
• Wireless Magnetic Field Sensor	PS-3221
• Wireless Smart Cart (blue)	ME-1241

PASCO Advantage:

When used with the Wireless Magnetic Field Sensor, the Smart Cart's built-in position sensor makes it easy to pair magnetic field measurements with precise position data.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Magnetic Fields of Coils Experiment..... EX-5640
Required:
PASCO Capstone Software.....pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5540A) online at pasco.com/capstoneexperiments

Ampere's Law

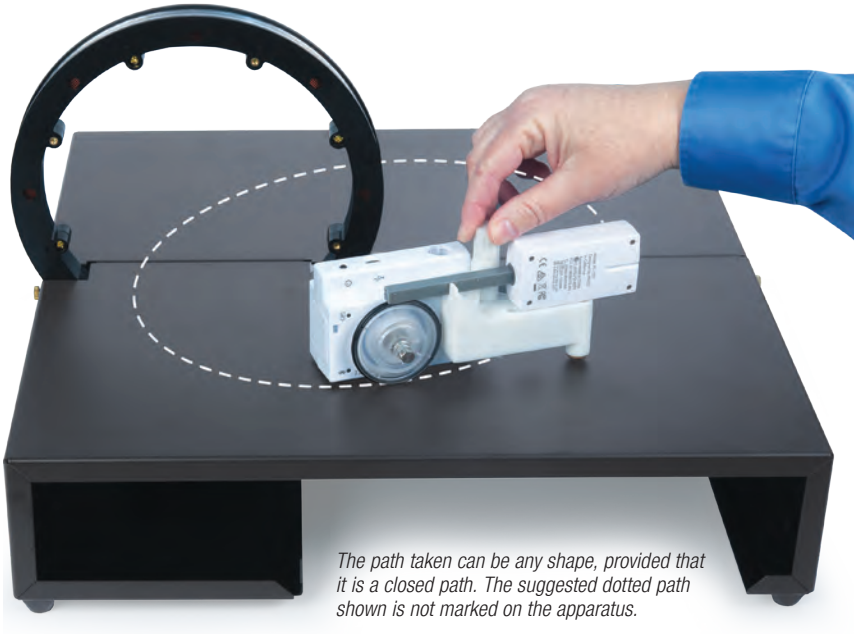
EX-5552

Concepts:

- Verify Ampere's Law
- Plot magnetic field tangent to path
- Closed integral is area under B vs. Distance plot
- Choose to enclose current in path or not

Students can verify Ampere's Law experimentally by graphing the magnetic field strength that is tangent to the path taken along a closed path that encloses a current source.

The magnetic field strength is measured with a Wireless Magnetic Field Sensor which rides on a Rotary Motion Sensor. The student pushes the Rotary Motion Sensor, which rolls on its wheel along a closed path.



The path taken can be any shape, provided that it is a closed path. The suggested dotted path shown is not marked on the apparatus.

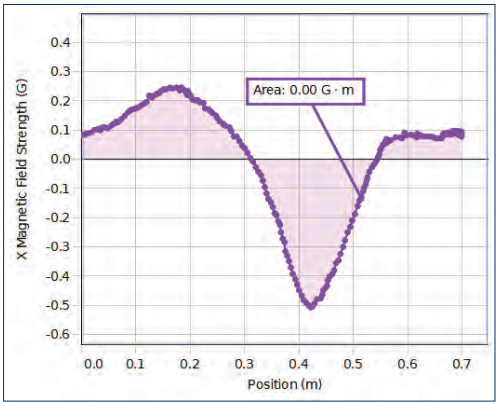
PASCO Advantage:

The Wireless 3-Axis Magnetic Field and Rotary Motion sensors allow students to move in any shaped path without wires getting wrapped around the coil. Students can choose any path they want; a circular path is unnecessary because the sensors are recording the field tangent to any path.

Ampere's Law

$$\oint \vec{B} \cdot \vec{dl} = \mu_o N I$$

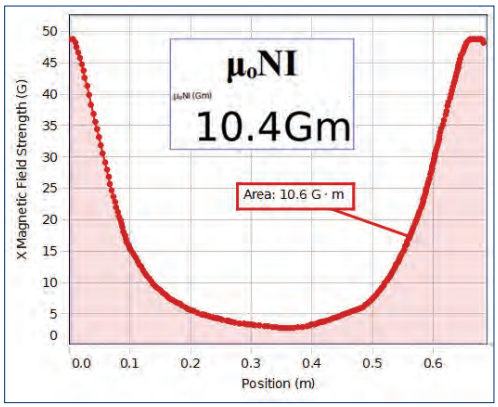
Area under B vs. Distance curve = μ_o (# of coil turns enclosed in path) (Current)



No current enclosed: Area is zero.

The key to making this work is that the Magnetic Field Sensor element is positioned tangent to the Rotary Motion Sensor's wheel. This accomplishes the dot product in Ampere's Law because only the component of the magnetic field that is tangent to the path is recorded.

If you traverse a path that does not enclose any current source, the area under the curve is zero. The magnetic field of the Earth or any nearby source is measured, but they cancel out in a closed loop that encloses no current.



Current enclosed: Area is $\mu_o NI$.

Includes:

• Ampere's Law Accessory	EM-6720
• Wireless Magnetic Field Sensor	PS-3221
• Wireless Rotary Motion Sensor	PS-3220
• 500-Turn Field Coil	EM-6723A
• Zero Gauss Chamber	EM-8652

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Ampere's Law EX-5552
Required:
PASCO Capstone Software ..... pp. 84-87
(No interface required.)

Faraday's Law of Induction Experiment

EX-5641

Concepts:

- Magnetic flux
- Faraday's Law of Induction
- Lenz's Law
- Conservation of energy
- Electrical power

A voltage is induced in a coil swinging through a magnetic field. Faraday's Law and Lenz's Law are examined, and the energy dissipated in a load resistor is compared to the loss of energy of the coil pendulum.

A rigid pendulum with a coil at its end swings through a horseshoe magnet. A resistive load is connected across the coil, and the induced voltage is recorded using a Wireless Voltage Sensor. The angle is measured with a Wireless Rotary Motion Sensor, which also acts as a pivot for the pendulum. The induced voltage is plotted vs. time and angle. The power dissipated in the resistor is calculated from the voltage, and the energy converted to thermal energy is determined by finding the area under the Power vs. Time curve. This energy is compared to the loss of energy determined from the amplitude and the speed of the pendulum.

Faraday's Law is used to estimate the magnetic field of the magnet from the maximum induced voltage. Additionally, the direction of the induced voltage as the coil enters and leaves the magnetic field is examined and analyzed using Lenz's Law.

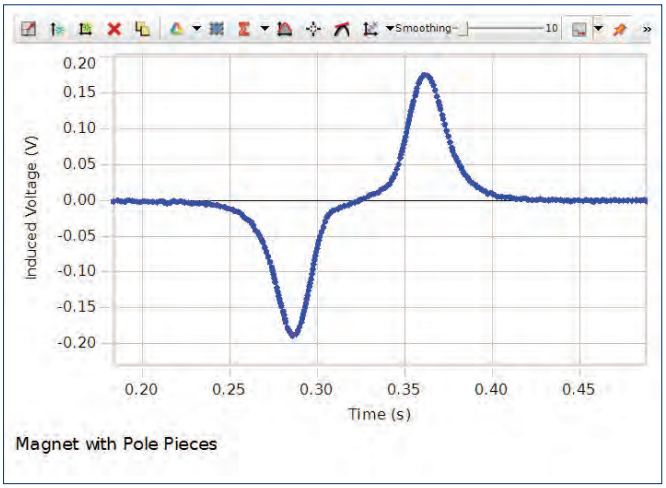
A voltage is induced in a coil swinging through a magnetic field.

PASCO Advantage:

Students can use PASCO Capstone™ to calculate energy and power from the voltage and angle data. The induced voltage and calculations are plotted in real time as the coil swings through the magnet.

Includes:

• Induction Wand	EM-8099
• Large Rod Base	ME-8735
• 45 cm Stainless Steel Rods (2)	ME-8736
• Multi-Clamp	ME-9507
• Wireless Voltage Sensor	PS-3211
• Wireless Magnetic Field Sensor	PS-3221
• Wireless Rotary Motion Sensor	PS-3220
• Variable Gap Magnet	EM-8618
• 2-Meter Patch Cord Set	SE-9415A



Plot of induced voltage as coil swings through the magnet.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Faraday's Law of Induction Experiment..... EX-5641
Required:
PASCO Capstone Software..... pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5541A) online at pasco.com/capstoneexperiments

Mechanical Waves Experiment

EX-9952

Concepts:

- Speed of waves in a string
- Speed of sound in air
- Resonance in strings and air columns
- Harmonics

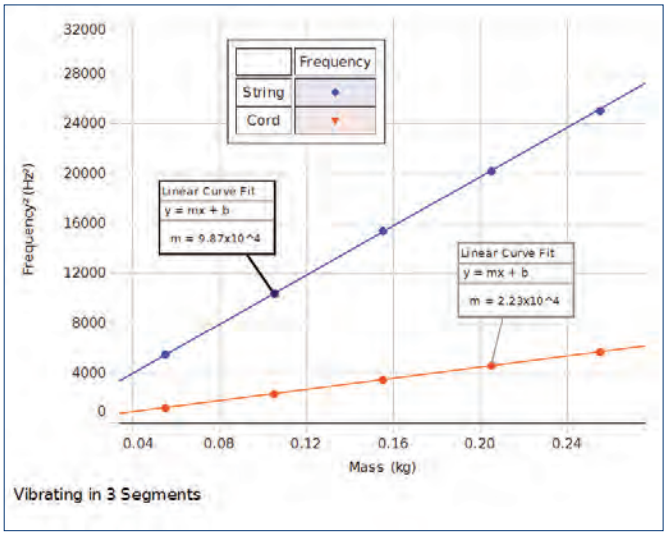
Use this experiment to study standing waves in strings and air columns. Using a Sine Wave Generator to drive a String Vibrator, the driving frequency, length, density, and tension of the string are varied to explore standing waves in strings and to determine the speed of the wave. To produce sound waves in the air column, a speaker is used to drive a resonance tube. The driving frequency and the length of the tube are varied for both open and closed tubes. The relationship between resonant frequency modes and tube length is determined for both closed and open tubes.

PASCO Advantage:

The frequency of the vibration of the string is not limited to the line frequency, so the frequency can be varied as well as the length and the tension.

Includes:

• String Vibrator	WA-9857A
• Sine Wave Generator	WA-9867
• Open Speaker	WA-9900
• Economy Resonance Tube	WA-9495
• Elastic Wave Cord	SE-9409
• Braided Physics String	SE-8050
• Mass and Hanger Set	ME-8979
• Universal Table Clamp (2)	ME-9376B
• Adjustable Angle Clamp	ME-8744
• Super Pulley	ME-9450A
• Pulley Mounting Rods	SA-9242
• 45 cm Stainless Steel Rod (2)	ME-8736
• Banana Plug Cord-Red (5 Pack)	SE-9750
• Waves Experiment Manual	



Graphs of the square of the frequency vs. the hanging mass for two different types of strings have different slopes corresponding to different string densities.

Download This Experiment

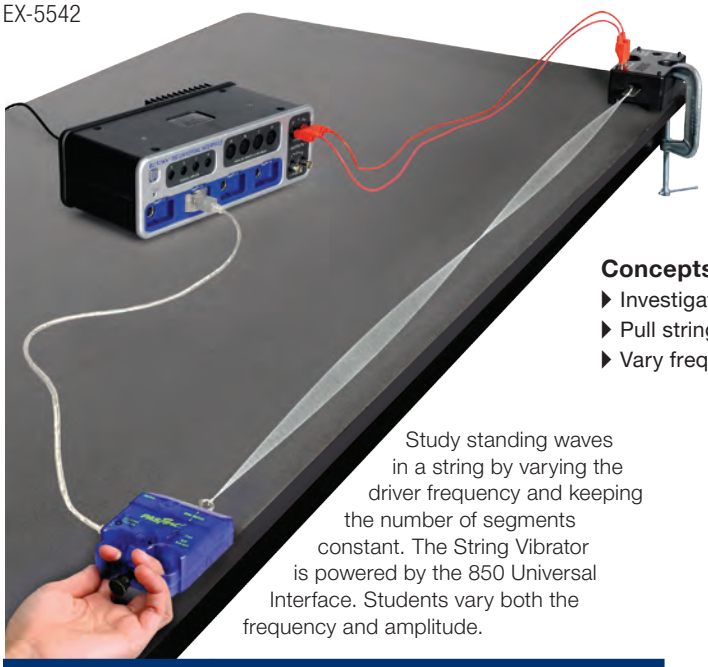
Search for EX-9952 at **www.pasco.com**

Order Information

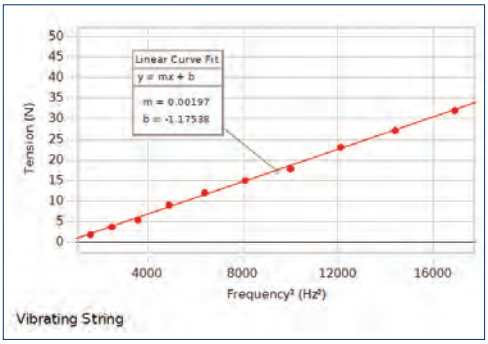
Mechanical Waves Experiment..... EX-9952
(No interface required.)

Vibrating Strings Experiment

EX-5542



The string tension is measured directly with a Force Sensor, enabling students to feel the force required to obtain a certain number of segments.



Concepts:

- Investigate standing waves
- Pull string to adjust number of segments
- Vary frequency of vibration

Study standing waves in a string by varying the driver frequency and keeping the number of segments constant. The String Vibrator is powered by the 850 Universal Interface. Students vary both the frequency and amplitude.

Includes:

• String Vibrator	WA-9857A
• Braided Physics String	SE-8050
• PASPORT High Resolution Force Sensor	PS-2189
• Large "C" Clamp	
• Banana Plug Cord-Red (5 Pack)	SE-9750
• 30 Meter Measuring Tape	SE-8712A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Vibrating Strings Experiment EX-5542
Required:
550 or 850 Universal Interface ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87

Sound of Vibrating Strings Experiment

EX-5565

Concepts:

- How Frequency Depends on String Tension
- How Frequency Depends on String Length
- How Frequency Depends on String Linear Density

Examine how tension and string length affect the sound of a vibrating string.

First, the length of the vibrating string is varied, and the tone is observed. Then the frequency of the sound is measured with the Wireless Sound Sensor, and the relationship between string length and frequency is determined.

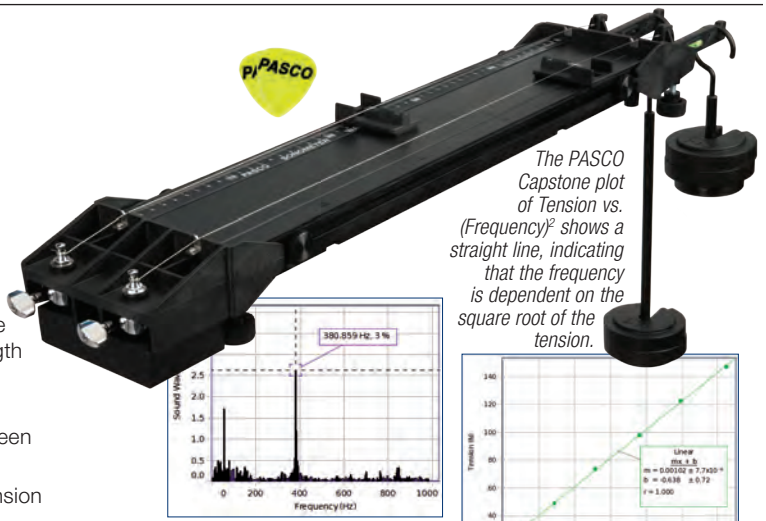
Next, the tension in the vibrating string is varied, and the tone is observed. The frequency is measured and the relationship between the string tension and the frequency is determined.

Finally, the frequencies of two strings of the same length and tension but different linear densities are compared.

For a given string tension, the length of a string is adjusted until each tuning fork in the set causes the string to resonate. The vibrating tuning fork is held against the Sonometer sounding board, and when the resonant frequency of the string matches the frequency of the tuning fork, the paper riders on the string will vibrate. The relationship between the frequencies and the length is determined.

Includes:

• Sonometer	WA-7428
• Wireless Sound Sensor	PS-3227
• Tuning Fork Set	SE-7342
• Large Slotted Mass Set	ME-7566
• Short Mass Hanger	ME-7590



The frequency of the sound can be determined using a Sound Sensor and the FFT in PASCO Capstone.

The PASCO Capstone plot of Tension vs. (Frequency)² shows a straight line, indicating that the frequency is dependent on the square root of the tension.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Sound of Vibrating Strings Experiment EX-5565
Required:
PASCO Capstone Software ..... pp. 84-87
(No interface required.)

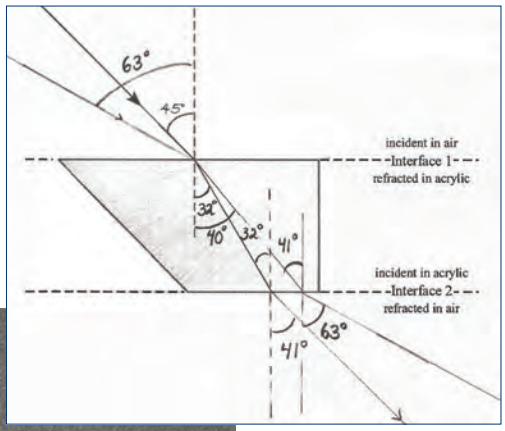
Reflection and Refraction

EX-9987

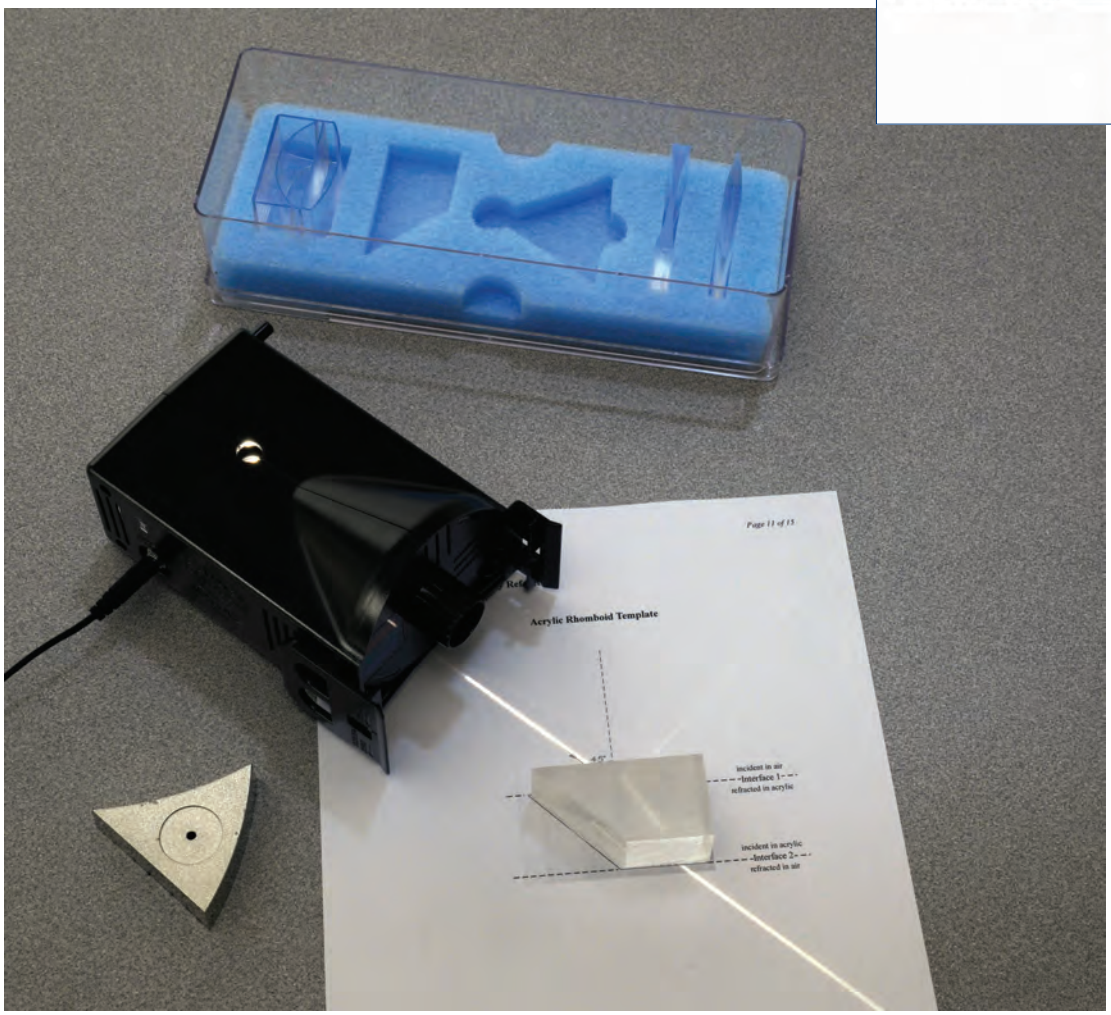
Concepts:

- Reflection and Refraction
- Index of Refraction

Students experimentally derive the Law of Reflection for curved and flat mirrors. Snell's Law is explored and the index of refraction for a piece of acrylic material is found.



Sample of student work, showing the path of two different rays passing through the acrylic rhomboid.



PASCO Advantage:

Students trace the rays on the provided templates and make angle measurements directly from their drawings. This reinforces the connection between the real rays they can see in the lab and the type of ray diagrams seen in the classroom.

Includes:

• Ray Optics Kit	OS-8516A
• Basic Optics Light Source	OS-8470
• Reflection and Refraction Experiment Manual	

Download This Experiment

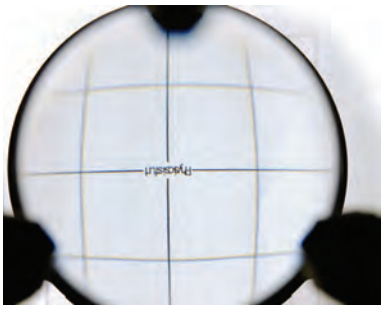
Search for EX-9987 at **www.pasco.com**

Order Information

Reflection and Refraction EX-9987
Required:
Protractor and Ruler

Telescope/Microscope

EX-9988



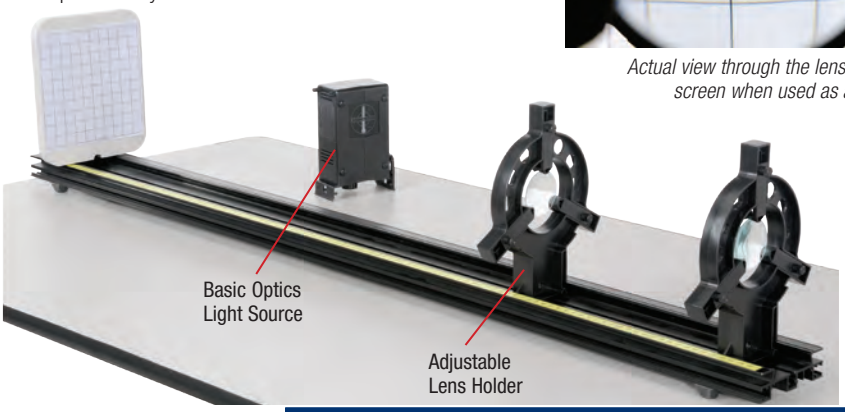
Actual view through the lens of magnified screen when used as a microscope

Topics Covered:

- Multiple Lens Systems
- Magnification
- Parallax
- Description of Images

Students construct an astronomical telescope, a Galilean telescope, and a compound microscope on the optical bench. Using a viewing screen with grid, they find and describe the ways in which images are changed by the multiple lens systems.

The parallax method is used to locate virtual images. Students draw ray diagrams and measure the magnification of the instruments.



PASCO Advantage:

Using the Basic Optics Track and Adjustable Lens Holders makes it easy for students to quickly build each of the instruments. The open construction allows all students to see the location and types of lenses used.

Includes:

• Basic Optics Light Source	OS-8470
• Adjustable Lens Holder (2)	OS-8474
• Geometric Lens Set	OS-8466A
• Basic Optics Viewing Screen	OS-8460
• 1.2 m Optics Track	OS-8508

Download This Experiment

Search for EX-9988 at **www.pasco.com**

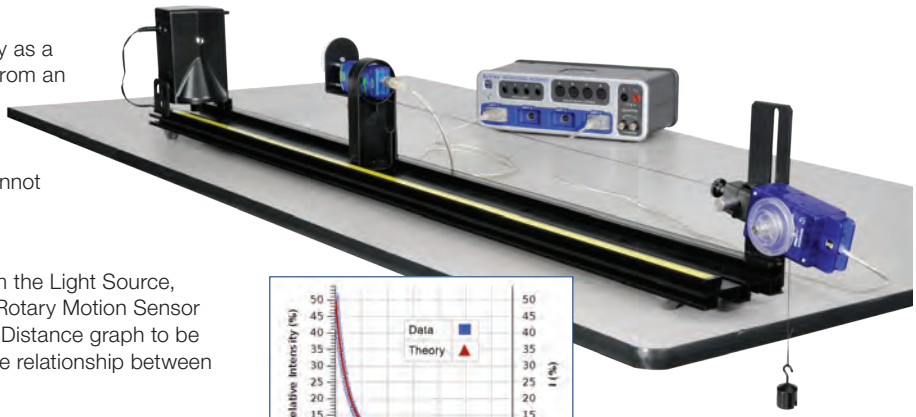
Order Information

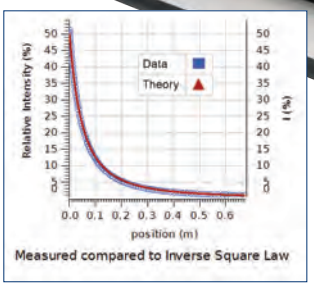
Telescope/Microscope EX-9988
Required:
Rubber Bands and Ruler

Light Intensity vs. Distance Experiment

EX-5547A

In this experiment the student measures intensity as a function of distance from a point of source and from an extended (5 cm x 5 cm) source. Manipulation of a computer model verifies that for the point source, the intensity drops off like an inverse square. But for the extended source the data cannot be fit by an inverse square relationship.





Measured compared to Inverse Square Law

PASCO Advantage:

As the student slides the Light Sensor away from the Light Source, the Optics Track keeps everything aligned. The Rotary Motion Sensor measures the position, allowing the Intensity vs. Distance graph to be plotted in real time. Students immediately see the relationship between distance and intensity of light.

Includes:

• 1.2 m Optics Track	OS-8508
• Basic Optics Light Source	OS-8470
• Aperture Bracket	OS-8534A
• Hooked Mass Set	SE-8759
• PASPORT High Sensitivity Light Sensor	PS-2176
• PASPORT Rotary Motion Sensor	PS-2120A
• Dynamics Track Mount	CI-6692

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Light Intensity vs. Distance Experiment EX-5547A
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Interference and Diffraction of Light Experiment

EX-5645

NEW EXPERIMENT!

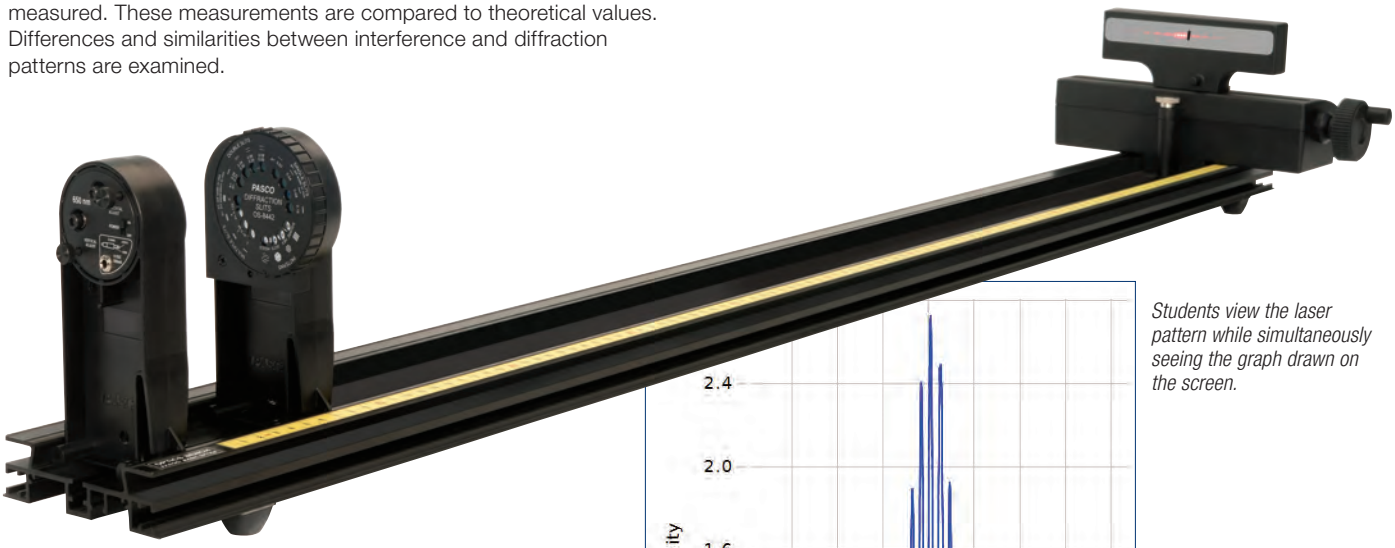
Concepts:

- Two-slit interference
- Single-slit diffraction
- Multiple-slit minor maxima

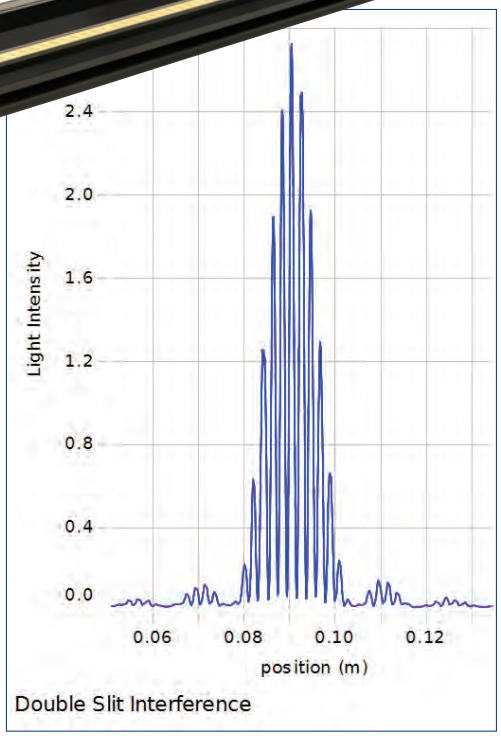
Interference and diffraction patterns from laser light passing through various single-slits and multiple-slits are scanned and plotted in real time. These patterns are then examined for similarities and differences. The effect of wavelength is studied using red and green lasers.

The distances between the central maximum and the diffraction minima for a single slit are measured by scanning the laser pattern with a Light Sensor and plotting Light Intensity vs. Distance. Then, the distances between interference maxima for two or more slits are measured. These measurements are compared to theoretical values. Differences and similarities between interference and diffraction patterns are examined.

The laser interference pattern is scanned by turning the crank.



Students view the laser pattern while simultaneously seeing the graph drawn on the screen.



A computer scan of a double-slit interference pattern (slit width 0.08 mm and slit separation 0.50 mm) is shown at left.

PASCO Advantage:

Easily select a different slit pattern by rotating the slit disk. Several single-slit and multiple-slit options are provided for comprehensive analysis.

Includes:

• 1.2 m Optics Track	OS-8508
• Diffraction Slits	OS-8442
• Red Diode Laser	OS-8525A
• Green Diode Laser	OS-8458B
• Wireless Diffraction Scanner	OS-8441

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Interference and Diffraction of Light Experiment..... EX-5645
Required:
PASCO Capstone Software..... pp. 84-87

View the 550 or 850 Universal Interface-compatible version of this experiment (EX-5545A) online at pasco.com/capstoneexperiments

Polarization Experiment

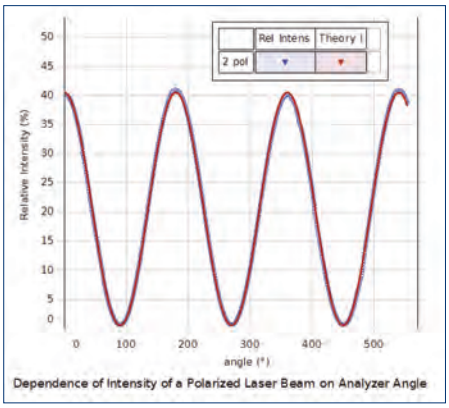
EX-5543A

Concepts:

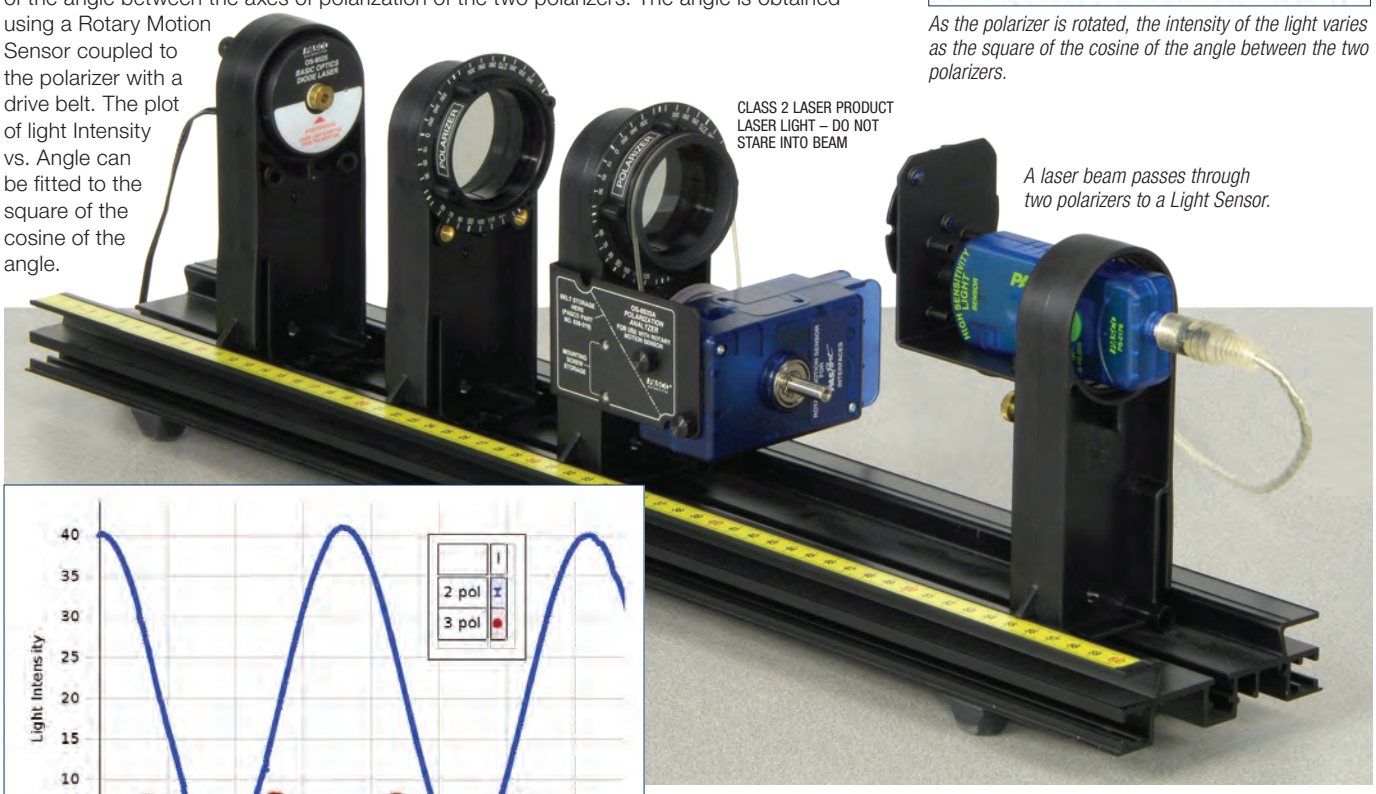
- Measure the Zeeman Effect with polarization perpendicular and parallel to the field
- Observe the light along the magnet axis
- Calculate the value of the Bohr magneton
- Malus' Law of Polarization

In this experiment, Malus' Law of Polarization is verified by showing that the intensity of light passed through two polarizers depends on the square of the cosine of the angle between the two polarization axes.

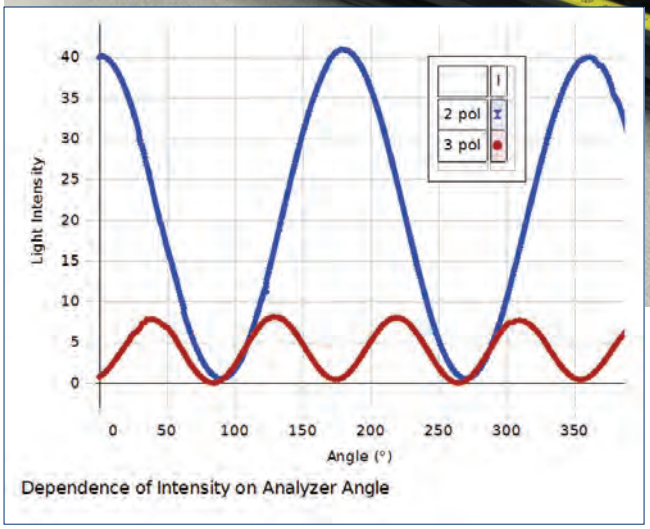
Laser light (peak wavelength = 650 nm) is passed through two polarizers. As the second polarizer (the analyzer) is rotated by hand, the relative light intensity is recorded as a function of the angle between the axes of polarization of the two polarizers. The angle is obtained using a Rotary Motion Sensor coupled to the polarizer with a drive belt. The plot of light Intensity vs. Angle can be fitted to the square of the cosine of the angle.



As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.



A laser beam passes through two polarizers to a Light Sensor.



The laser's polarization can be used to produce a three-polarizer system. The data (red trace) at left shows that there are four oscillations per full rotation for a three-polarizer system.

PASCO Advantage:

Laser light is used in this experiment because its wavelength is more completely extinguished by the crossed polarizers.

Includes:

• Polarization Analyzer	OS-8533A
• Optics Benches (60 cm)	OS-8541
• Red Diode Laser	OS-8525A
• PASPORT High Sensitivity Light Sensor	PS-2176
• PASPORT Rotary Motion Sensor	PS-2120A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Polarization Experiment EX-5543A

Required:

550 or 850 Universal Interface* ..... pp. 26-29

PASCO Capstone Software ..... pp. 84-87

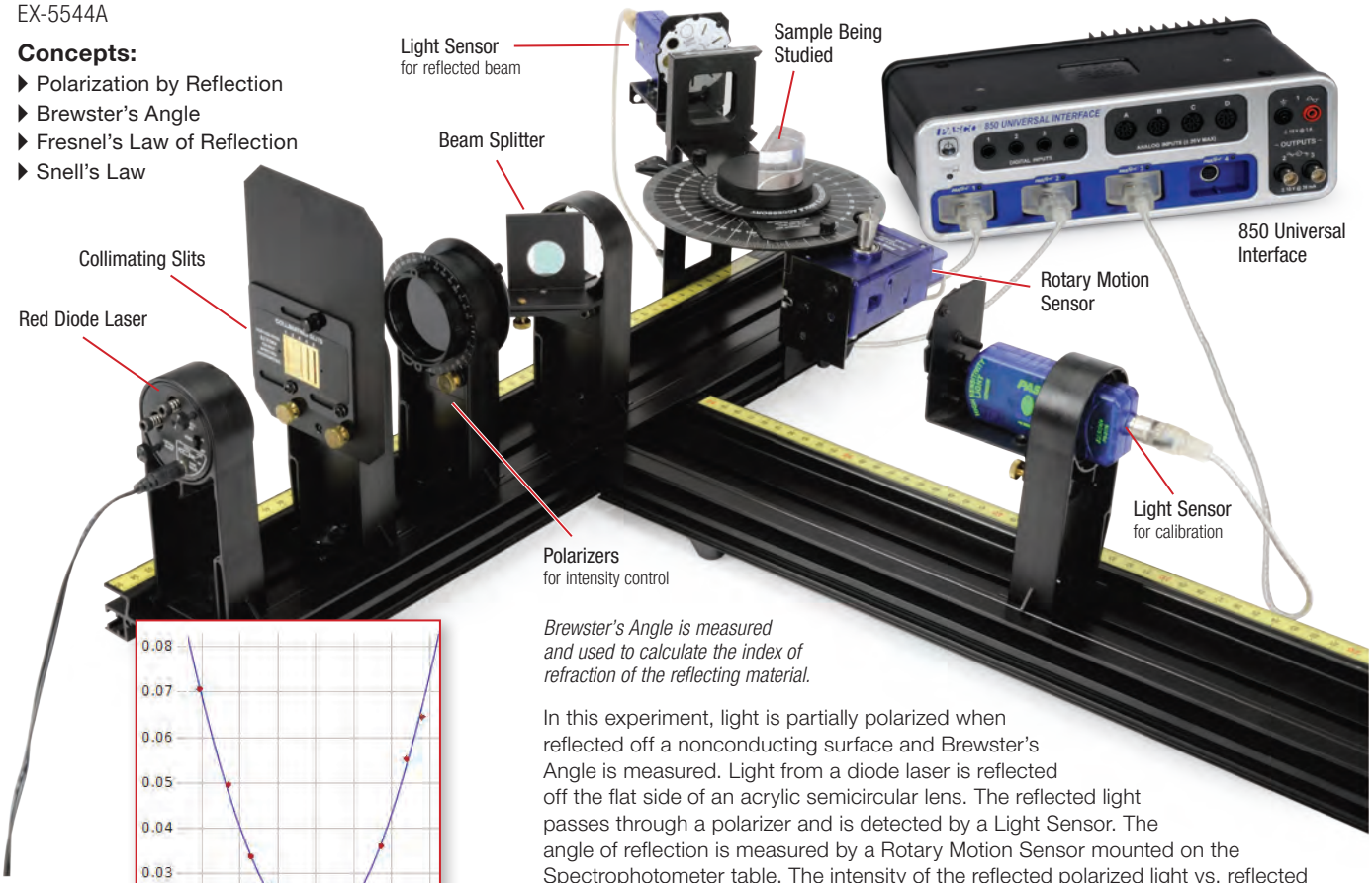
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Brewster's Angle Experiment

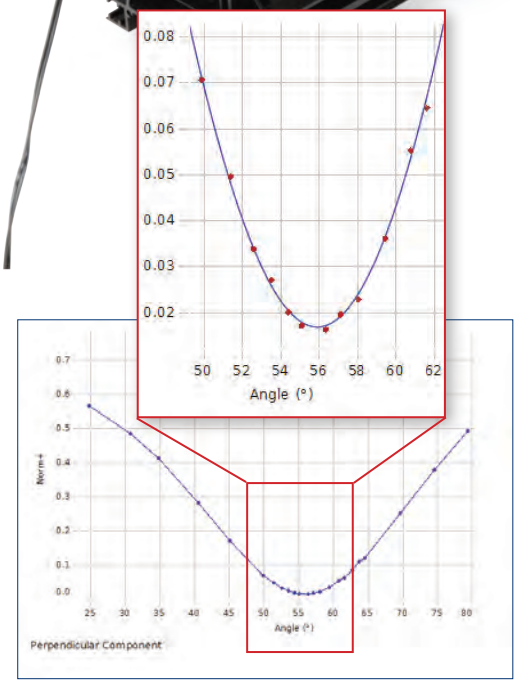
EX-5544A

Concepts:

- Polarization by Reflection
- Brewster's Angle
- Fresnel's Law of Reflection
- Snell's Law



Brewster's Angle is measured and used to calculate the index of refraction of the reflecting material.



Brewster's Angle is determined by finding the angle at which no light is transmitted through the analyzing polarizer.

In this experiment, light is partially polarized when reflected off a nonconducting surface and Brewster's Angle is measured. Light from a diode laser is reflected off the flat side of an acrylic semicircular lens. The reflected light passes through a polarizer and is detected by a Light Sensor. The angle of reflection is measured by a Rotary Motion Sensor mounted on the Spectrophotometer table. The intensity of the reflected polarized light vs. reflected angle is graphed to determine the angle at which the light intensity is a minimum. This is Brewster's Angle, which is used to calculate the index of refraction of acrylic.

PASCO Advantage:

It is possible to determine the difference in index of refraction for different wavelengths of light. This is accomplished by using a beam-splitter and a second light sensor to compensate for the variation of the laser intensity. The reflected beam intensity is normalized by the intensity of the laser. This modification to the experiment was suggested by Cristian Bahrim and Wei-Tai Hsu in the American Journal of Physics article: "Precise Measurement of the Refractive Indices for Dielectrics Using an Improved Brewster Angle Method", Vol. 77, page 337 (2009).

Developed using original ideas from P.J. Ouseph, Professor of Physics at University of Louisville, KY: "Polarization of Light by Reflection and the Brewster Angle" by P.J. Ouseph, Kevin Driver, and John Conklin, Am. J. Phys. 69, 1166 (2001).

Includes:

• Brewster's Angle Accessory	OS-8170A
• Educational Spectrophotometer Accessory Kit	OS-8537
• Optics Benches (60 cm) (2)	OS-8541
• PASPORT Rotary Motion Sensor	PS-2120A
• PASPORT High Sensitivity Light Sensor (2)	PS-2176
• Aperture Bracket (2)	OS-8534A
• Red Diode Laser	OS-8525A
• Polarizer Set	OS-8473

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Brewster's Angle Experiment EX-5544A
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Speed of Light Experiment

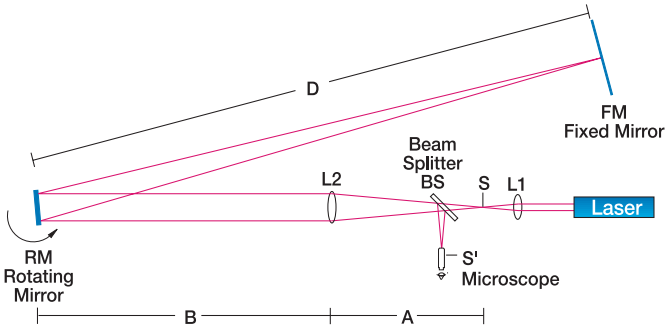
EX-9932A

Concepts:

- Determine the Speed of Light in Air
- Recreate Foucault's Historical Experiment

The Speed of Light Experiment uses laser light and a high speed rotating mirror to determine this fundamental constant using the Foucault method.

Laser light passes through a series of lenses to produce an image of the light source at a measured position. The light is then directed to a rotating mirror, which reflects the light to a fixed mirror at a known distance from the rotating mirror. The laser light is reflected back through its original path and a new image is formed at a slightly different position. The difference between the final and initial positions, the angular velocity of the rotating mirror, and the distance traveled by the light are then used to calculate the speed of light in air.



PASCO Advantage:

PASCO's Speed of Light Experiment allows students to experimentally measure the speed of light within 5% of the accepted value. In addition, the experiment can be performed on a desktop or in a hallway.

Includes:

- Complete Speed of Light Apparatus OS-9261C
- Speed of Light Experiment Manual

Download This Experiment

Search for EX-9932B at **www.pasco.com**

Order Information

Speed of Light Experiment EX-9932A
(No interface required.)

Atomic Spectra Experiment

EX-5546B

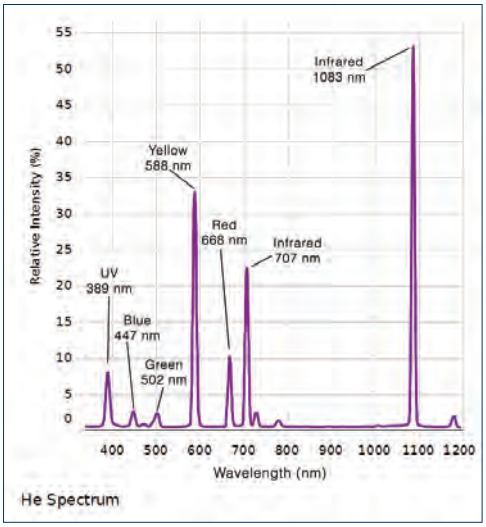
Concepts:

- Hydrogen balmer series
- Helium spectrum
- Mercury doublet

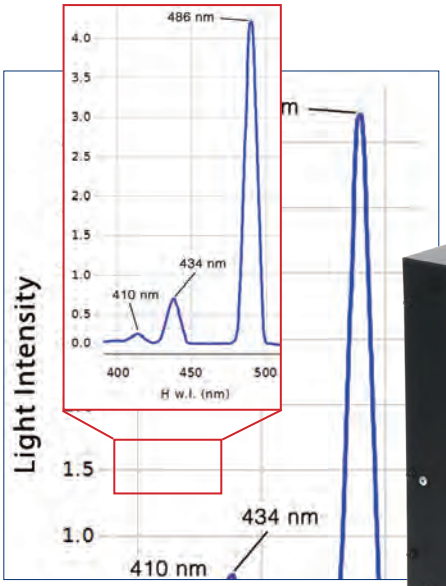
The wavelengths of the discrete lines of the atomic spectra of various gases are measured using a grating spectrophotometer.

The atomic spectra of hydrogen, helium, and mercury are scanned by hand using a grating spectrophotometer, which measures relative light intensity as a function of angle. From the resulting graph, the wavelengths of the spectral lines are determined by measuring the angle from the central maximum to each line. First and second order lines are examined.

The wavelengths of the spectral lines are compared to the accepted values and, in the case of hydrogen, the electron orbit transitions corresponding to the lines are identified.



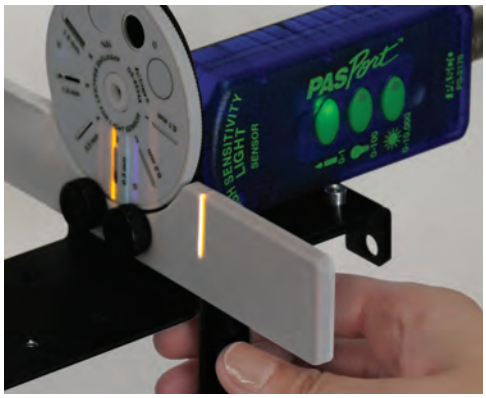
The spectral lines of helium are scanned.

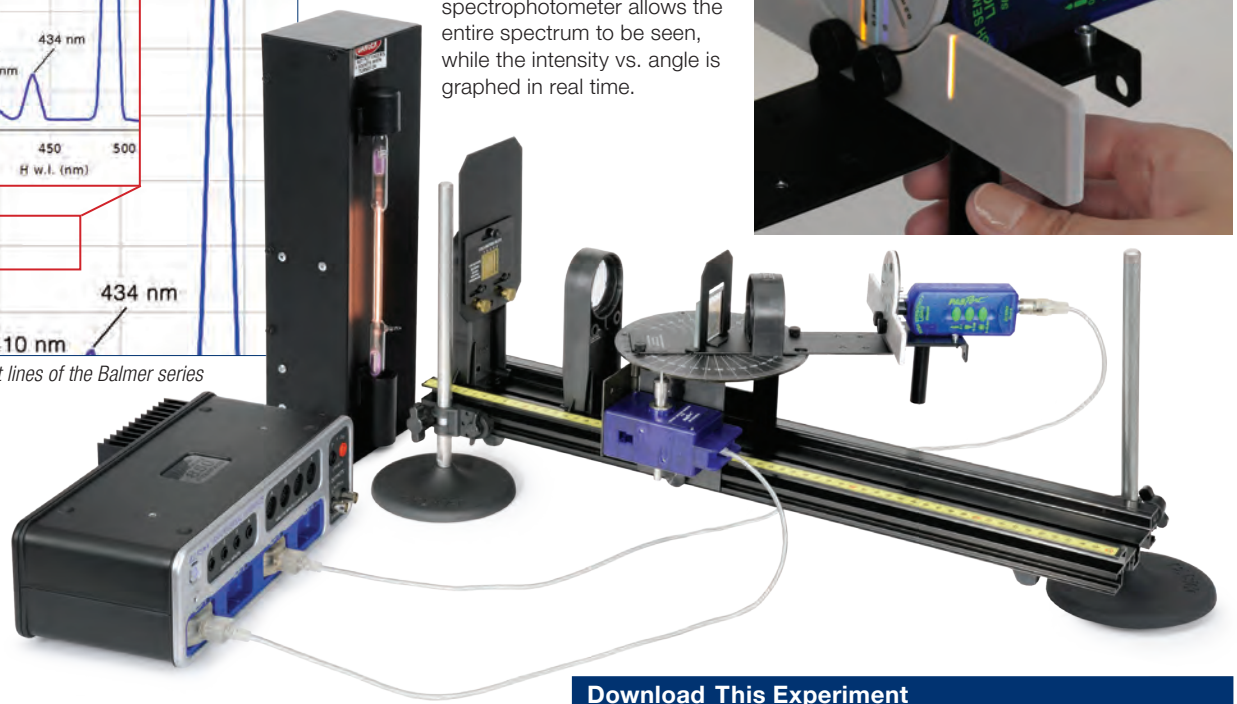


The four brightest lines of the Balmer series for hydrogen

PASCO Advantage:

The open construction of the spectrophotometer allows the entire spectrum to be seen, while the intensity vs. angle is graphed in real time.





Includes:

• Educational Spectrophotometer Accessory Kit	OS-8537
• Optics Benches (60 cm)	OS-8541
• Aperture Bracket	OS-8534A
• PASPORT High Sensitivity Light Sensor	PS-2176
• PASPORT Rotary Motion Sensor	PS-2120A
• Round Base with Rod (2)	ME-8270
• Spectral Tube Power Supply and Mount	SE-9460
• Spectral Tube (Hydrogen)	SE-9461
• Spectral Tube (Helium)	SE-9462
• Spectral Tube (Mercury)	SE-9466

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Atomic Spectra Experiment..... EX-5546B
Required:
550 or 850 Universal Interface* ..... pp. 26-29
PASCO Capstone Software..... pp. 84-87
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Photoelectric Effect Experiment

EX-5549A

Concepts:

- Connects to the 850 Universal Interface for data collection in PASCO Capstone
- Find Planck's Constant within 5%
- Verify that stopping voltage is independent of intensity
- Find characteristics of the photodiode

The Photoelectric Effect System is used to perform the photoelectric experiment, determining Planck's Constant within 5%. This apparatus uses the conventional method of determining Planck's Constant. The metal plate in the photodiode is illuminated with various frequencies of light, selected from a mercury lamp using filters. The voltage is then adjusted to stop the photoelectric current. The stopping voltage is plotted vs. the frequency, and Planck's Constant is determined from the slope of the graph.

The concept that the stopping voltage does not change with light intensity is tested using the various apertures that change the light intensity by partially blocking the light.

Use the 850 Universal Interface and PASCO Capstone to collect and analyze data.

Both the picoammeter and the power supply for the stopping voltage have sensor ports on the front that connect to the analog sensor ports of the 850 Universal Interface. PASCO Capstone automatically recognizes these instruments and can read the current and the voltage. During the experiment, each time a different filter is applied, the user clicks "Keep" in PASCO Capstone and the value of the stopping voltage for that frequency is recorded and automatically graphed vs. frequency.

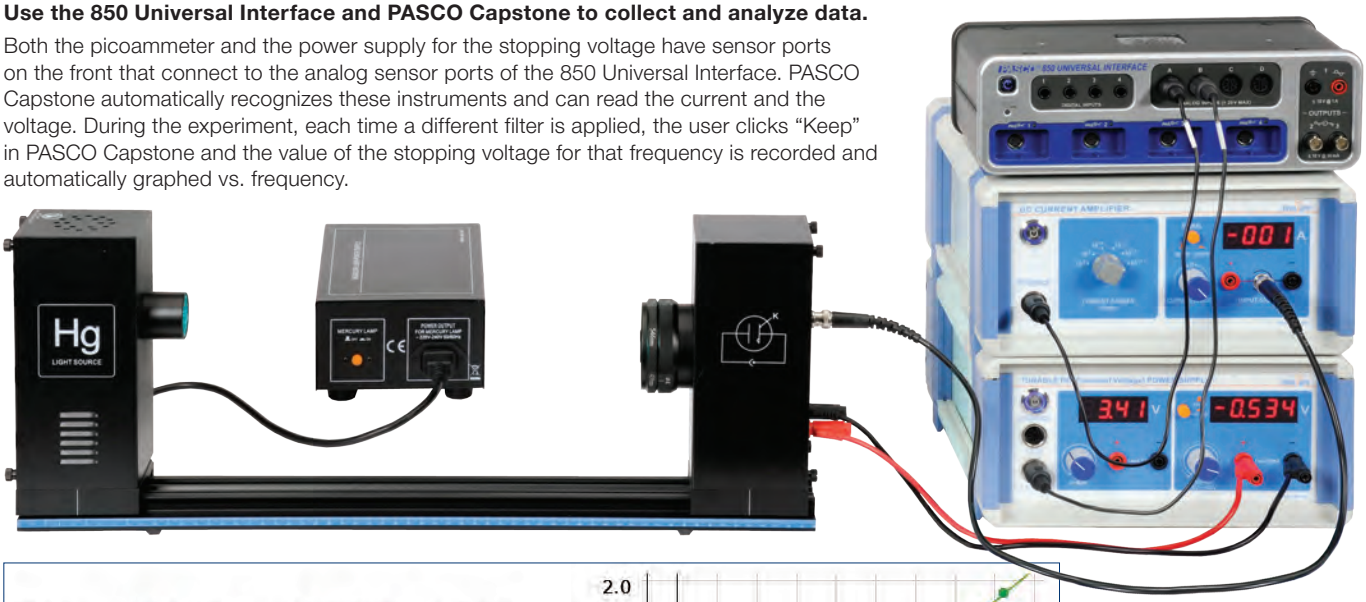
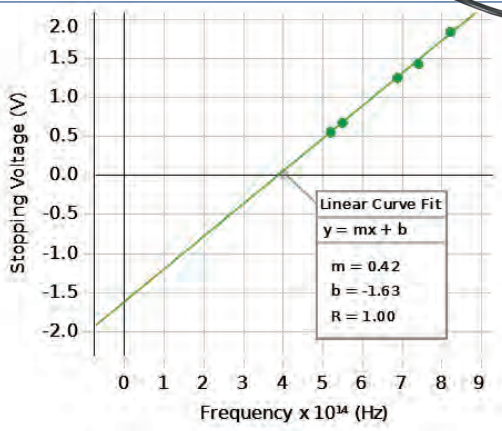


Table I: Photoelectric Effect with 4 mm Aperture

	Run #1	Run #1
	Frequency x 10^{14} (Hz)	Stopping Voltage (V)
1	8.214	1.835
2	7.408	1.428
3	6.879	1.248
4	5.490	0.671
5	5.196	0.551



For the typical sample data shown, the graph of Stopping Voltage vs. Frequency gives a slope of 4.2 x 10^{-15} V·s. This results in a value for Planck's Constant of 6.7 x 10^{-34} J·s, which is 1.3% above the accepted value. Graph generated using PASCO Capstone software.

Includes:

- Basic Photoelectric Effect Apparatus SE-6614
- DC Current Amplifier SE-6621
- DC Power Supply I (Constant Voltage) SE-6615
- Cables for 850 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

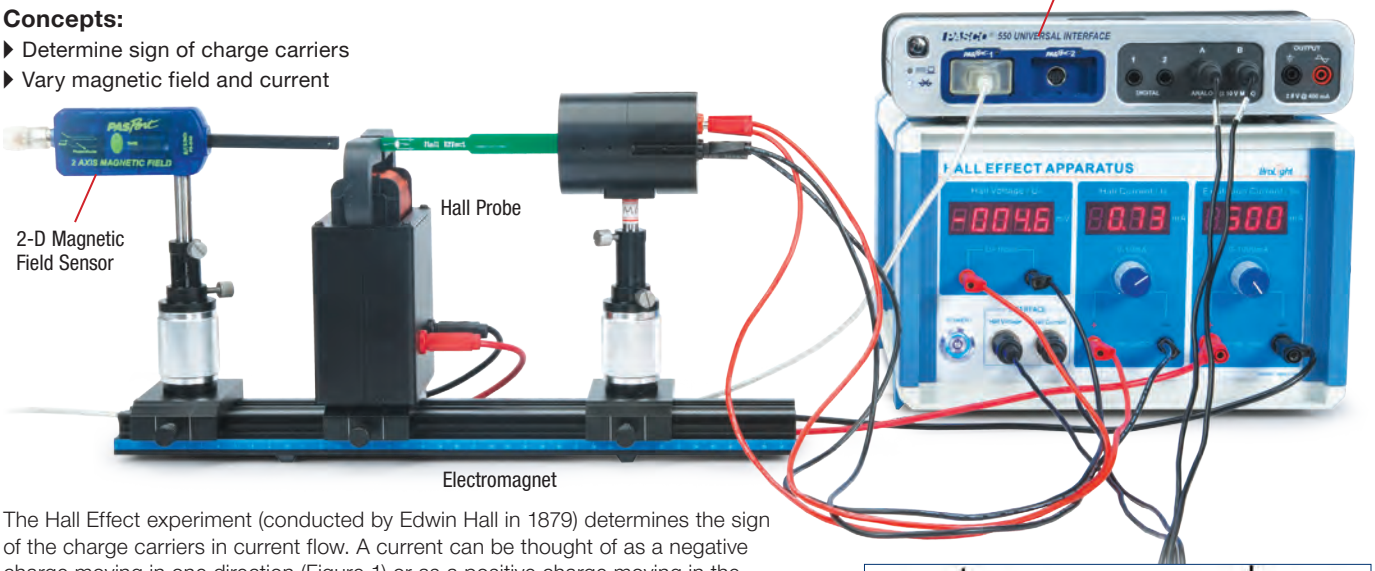
Photoelectric Effect Experiment EX-5549A
Required:
550 or 850 Universal Interface ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87

Hall Effect Experiment

EX-5560

Concepts:

- Determine sign of charge carriers
- Vary magnetic field and current



The Hall Effect experiment (conducted by Edwin Hall in 1879) determines the sign of the charge carriers in current flow. A current can be thought of as a negative charge moving in one direction (Figure 1) or as a positive charge moving in the opposite direction (Figure 2). To determine which it actually is, the semiconductor is immersed in the magnetic field transverse to the direction of the current flow. The moving charge experiences a force, causing a charge buildup on one side of the semiconductor (creating an electric field), which in turn leads to a force. The direction of the electric field will depend on the sign of the charge carriers, which is revealed by the polarity of the Hall voltage across the semiconductor.

The magnitude of the Hall voltage is dependent on the current, the charge carrier density, and the magnitude of the magnetic field. In modern day electronics, the Hall Effect is used to measure the magnitude and direction of magnetic fields.

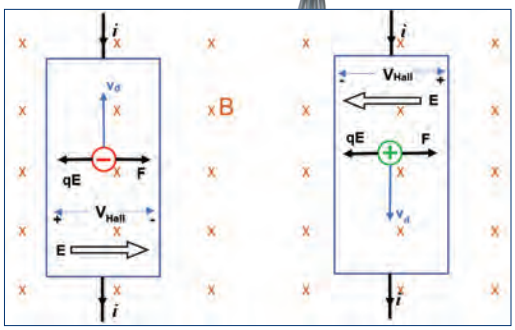
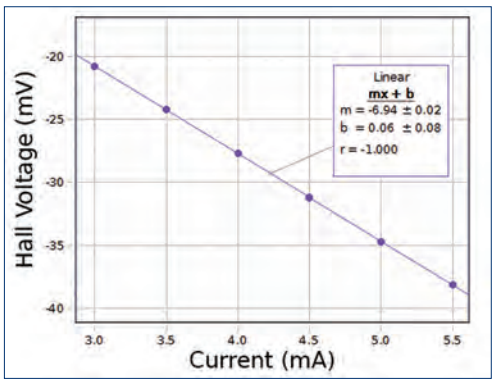


Figure 1 Figure 2



Using the 550 Universal Interface to record data, this plot of the Hall Voltage vs. the Current was made in PASCO Capstone software. In this case, the magnetic field was held constant and the current through the semiconductor was varied.

PASCO Advantage:

The open design of this Hall Effect apparatus makes it possible for students to see the direction of the current and the magnetic field, enabling them to use the sign of the Hall voltage to deduce the sign of the charge carriers.

The directions of the current and the voltage probe are clearly marked on the probe that holds the semiconductor.

Includes:

- Hall Probe Unit, n-Semiconductor (GaAs)
- Hall Effect Power Supply
- U-Core Electromagnetic Coil
- Track, Length 40 cm
- Optical Carrier (2)
- PASPORT 2-Axis Magnetic Field Sensor PS-2162
- Adjustable Post Holder with 9 cm Post (2)
- Adjustable Post Holder with 9 cm Post (2)
- Banana Cords (6)
- Connecting Cables for 550/850 Interface (2)

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Hall Effect Experiment..... EX-5560
Required:
550 or 850 Universal Interface..... pp. 26-29
PASCO Capstone Software..... pp. 84-87

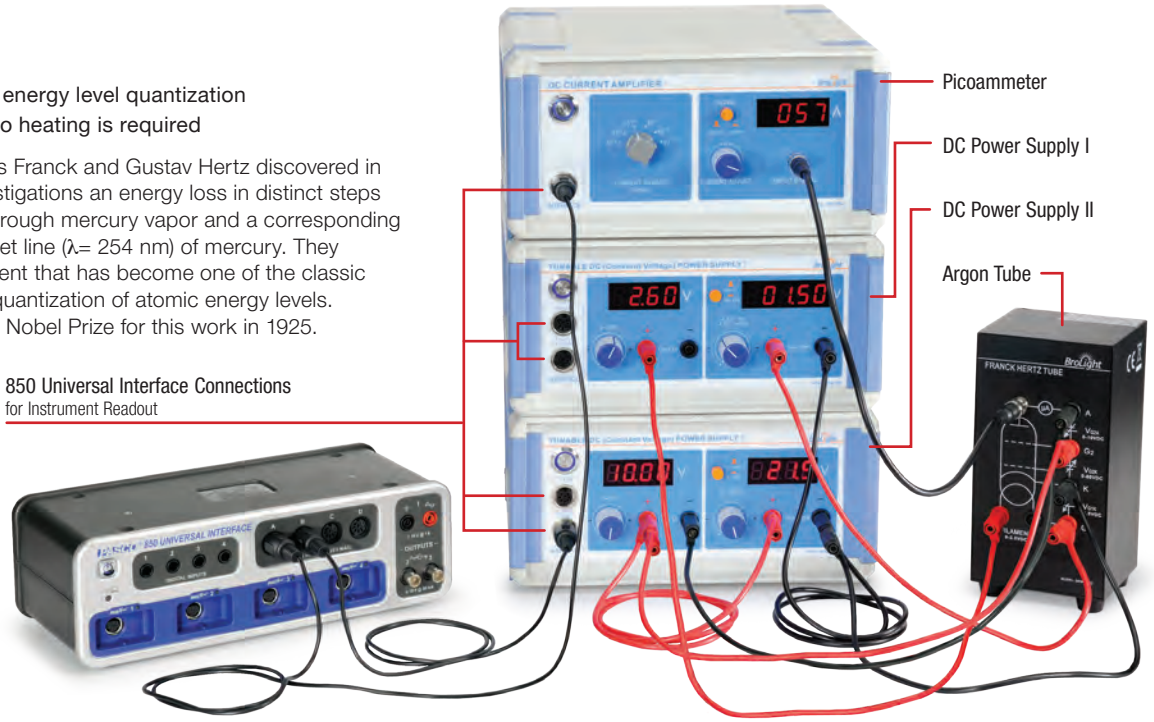
Franck-Hertz Experiment

EX-5561

Concepts:

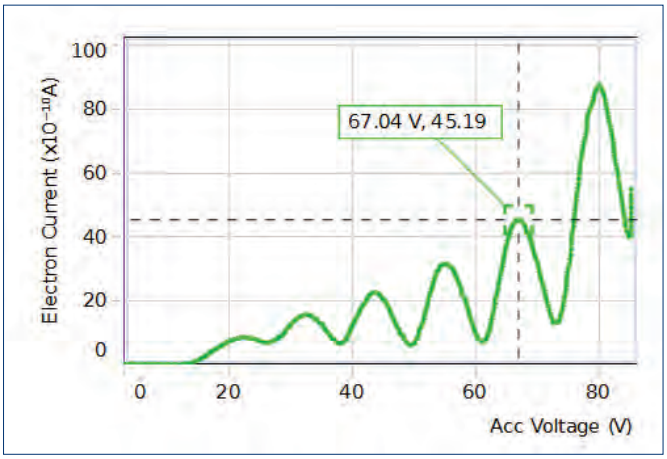
- Demonstrate atomic energy level quantization
- Uses argon gas so no heating is required

As early as 1914, James Franck and Gustav Hertz discovered in the course of their investigations an energy loss in distinct steps for electrons passing through mercury vapor and a corresponding emission at the ultraviolet line (λ= 254 nm) of mercury. They performed this experiment that has become one of the classic demonstrations of the quantization of atomic energy levels. They were awarded the Nobel Prize for this work in 1925.



PASCO Advantage:

With PASCO Capstone, students can collect many more data points compared to manually taking readings from the digital readouts. The peaks and troughs are easily measured using the coordinate tool.

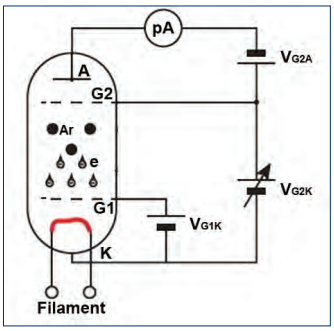


Includes:

• Franck-Hertz Tube Enclosure with Argon Tube	SE-9650A
• DC Power Supply I (Constant Voltage)	SE-6615
• DC Power Supply II (Constant Voltage)	SE-9644
• DC Current Amplifier	SE-6621
• Red and Black Patch Cords	
• Interface Cables (2)	

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**



This diagram shows the internal structure of the Franck-Hertz tube and the wiring diagram.

How It Works:

Electrons are accelerated by applying a known potential between two grids inside the argon tube. When an electron has sufficient kinetic energy to excite one of argon's outer orbital electrons and has an inelastic collision with an argon atom, the electron loses a specific amount of kinetic energy. This loss of electron kinetic energy causes a decrease in the electron current in the argon tube. Within a very short time, the excited argon electron will fall from the excited state back into the ground state level, emitting energy in the form of photons.

As the accelerating voltage is increased, the electrons undergo multiple collisions and the excitation energy of the argon atom can be determined by the differences between the accelerating voltages that cause a decrease in the current. Planck's Constant can be determined.

Order Information

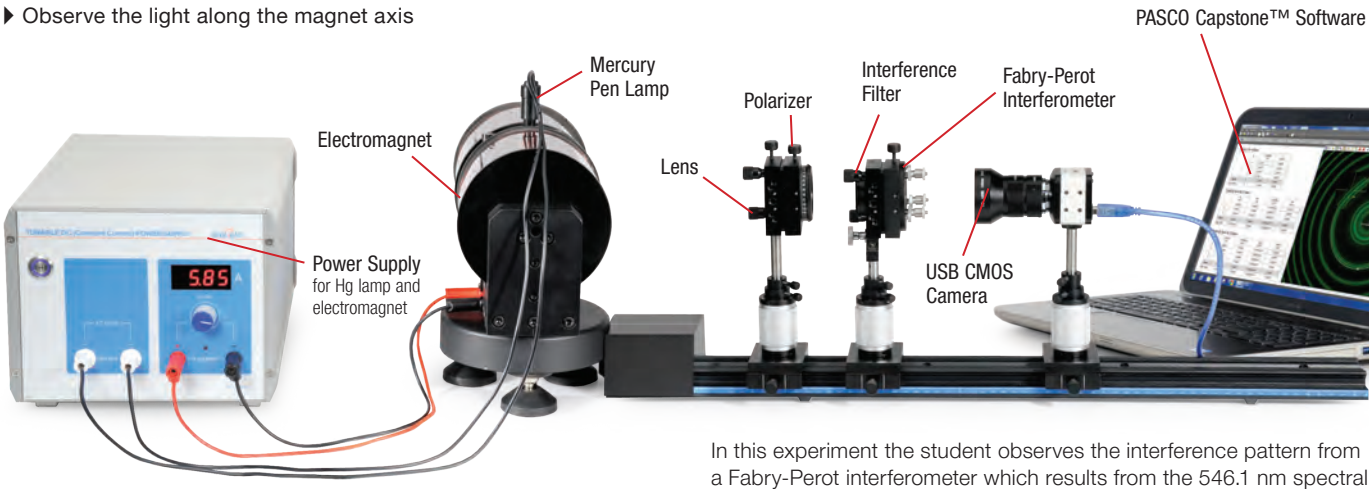
Franck-Hertz Experiment EX-5561
Required:
550 or 850 Universal Interface ..... pp. 26-29
PASCO Capstone Software ..... pp. 84-87

Zeeman Effect Experiment

EX-5562

Concepts:

- Measure the Zeeman Effect with polarization perpendicular and parallel to the field
- Observe the light along the magnet axis



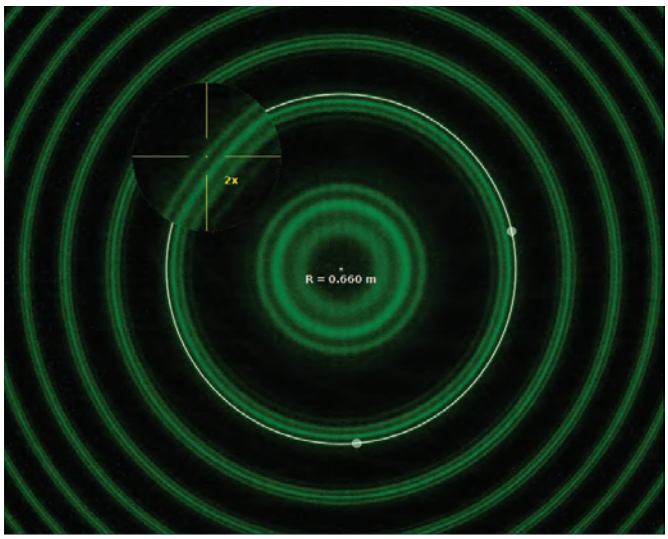
In this experiment the student observes the interference pattern from a Fabry-Perot interferometer which results from the 546.1 nm spectral line of a mercury lamp immersed in a uniform magnetic field. The magnetic field is varied from zero to nearly 1 Tesla.

Initially, the light is viewed along an axis perpendicular to the magnetic field axis. A polarizer is used to show the three lines due to light that is polarized parallel to the field axis and to show the six lines that are polarized perpendicular to the field axis. The pattern may also be viewed along the field axis where the light is circularly polarized.

Finally, the pattern that is polarized perpendicular to the field axis is used to calculate the Bohr magneton. All atomic magnetic moments are integral or half-integral multiples of the Bohr magneton.

End view through the axis of the magnet

Electromagnet produces about one Tesla.



PASCO Advantage:

In PASCO Capstone software, students can use the video magnifier tool to enlarge the region and observe the line splitting in detail. Also, the radius tool needs only three points to define the circle, so even rings that are partially out of view can be measured.

Includes:

- Electromagnet
- Power Supply
- Optics
- Tesla Meter
- PASCO Capstone Single User License UI-5401

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at **www.pasco.com/CapstoneExperiments.**

Order Information

Zeeman Effect Experiment EX-5562
Required:
PASCO Capstone Software ..... pp. 84-87
(No interface required.)

Part Number Index

— A —

— B —

– C –

C

— F —

— G —

– M –

P

S

– T –

– U –

– V –

V-Z

– W –

– X –

– Y –

– Z –

2023 Summer Institutes

Join us in sunny California for a 2023 PASCO Summer Institute! These three-day events offer a unique opportunity to extend your professional skills, connect with like-minded educators, and explore new approaches for engaging students in STEM learning.

You'll also enjoy exclusive access to the PASCO facility, including a behind the scenes tour of how our solutions are made. Meet the passionate people behind our products, share your thoughts and ideas, and get a sneak peek at what's to come.

Interested in attending?
If you're interested in attending a 2023 PASCO Summer Institute, we highly recommend securing your seat early. For more information and registration details, visit us at:

pasco.com/institutes

SPARKvue Institute
July 12-14, 2023
Intended for teachers of all science disciplines.

PASCO Capstone™ Institute
July 19-21, 2023
Intended for physics teachers.

Terms and Conditions

The PASCO Promise of Learning (90-day Satisfaction Guarantee)

We are confident that PASCO solutions will help your students achieve more in science. Within the first 90 days, if you are not satisfied that your students are more engaged and learning more effectively, return your purchase for a refund. We don't want you spending precious budget dollars on something you don't use. (We are sorry but we must exclude non-PASCO software that has been opened, radioactive products and products that contain perishables.) See instructions for Returns below.

PASCO 5-Year Limited Warranty for Education

PASCO products are built to survive. PASCO-manufactured products are covered by a limited warranty for a period of 5 years from delivery date against defects in material and workmanship. This warranty is valid for educational institution customers and only for educational use of these products. The PASCO warranty does not extend to any product, including touch screens, which have been subject to abuse, neglect, accident, improper installation or application, or products that have been repaired or altered outside of our factory. Consumables and limited-life products (such as pH probes, membranes, fast response temperature probes, batteries, chemical solutions, some light sources, printed materials, etc.) are excluded.

Other Warranty Terms

The SPARK LXi2 datalogger carries a limited warranty for a period of 3 years from delivery date against defects in material and workmanship. This limited warranty applies only to hardware components of the SPARK LXi2 that are not subject to accident, misuse, neglect, fire, or other external damage. This warranty can also be voided by unauthorized use, alterations, or repair. This warranty is valid for education institution customers and only for educational use of these products.

Products manufactured by anyone other than PASCO are subject to the conditions of the warranty supplied by the manufacturer (generally 1 year). Additional warranty information on our products is available upon request.

Free Teacher and Technical Support

We want teachers to be successful with PASCO solutions. Please contact our support team with any questions via phone or email: +1 916-786-3800 or support@pasco.com. We are here to help.

SPARKvue Licenses

SPARKvue software may be purchased as a Single License for use with one computer or as a Site License for use on all computers on a K-12 campus or in a college/university department.

SPARKvue for iPad®, Chromebook™, or Android™ tablets is licensed separately and is free through the App Store, the Chrome Web Store and Google Play. See pasco.com for more information.

PASCO Capstone Licenses

PASCO Capstone may be purchased as a Single License for use with one computer, or as a Site License for use on all computers on a primary and secondary campus or in a college/university department.

e-Book Licenses for Essential Chemistry and Essential Physics

For complete information on our e-book licenses, go to **pasco.com/essentialchemistry** or **pasco.com/essentialphysics**.

Shipping

Items in stock will normally be shipped in less than five working days from receipt of the order. Specific requests for air shipments or special carriers will be honored at an additional cost.

Returns

Please contact the authorized PASCO representative in your country for assistance in returning equipment for repair. PASCO's International Customer Service team can be reached at +1-916-786-3800 or at intlcustserv@pasco.com. Out-of-Warranty products must be shipped prepaid, door-to-door. Returns for credit or exchange must be in new condition and packaged in original shipping cartons or packaging sufficient to prevent damage during international transport.

Trademarks

PASCO, PASCO scientific, PASCO Capstone, EcoZone, ezSample, MatchGraph!, MultiMeasure Sensors, ScienceWorkshop, SPARKscience, SPARK Element, SPARKvue, SPARKvue HD, SPARKlab, SPARKlink, PASPORT, STEM Sense, AirLink, //code.Node and Tension Protractor are trademarks or registered trademarks of PASCO scientific in the United States and/or in other countries. All other brands, products or service names are or may be trademarks or service marks of, and are used to identify products or services of, their respective owners. For more complete information visit pasco.com/legal.

More Product Information

Designed for education. PASCO products are designed for education; they are not intended for use in graduate research or industry, and should not be used in any apparatus involved with life support, patient diagnosis, or industrial control.

PASCO reserves the right to change the specifications of any product without prior notice. If a product is no longer available, PASCO reserves the right to substitute a product of equal, or higher, value and functionality.

FCC

Where appropriate, electrical products are marked to indicate that they conform to Federal Communications Commission (FCC) standards. Most commonly, FCC Part 15, Class A.

CE MARK

Where appropriate, products carry the CE marking, which indicates that they conform to the applicable European standards. This almost exclusively applies to products that are designed to meet the following applicable directives:

2014/30/EU	EMC Directive
2014/35/EU	Low Voltage Directive
2015/863	RoHS3
2014/53/EU	Radio Equipment Directive

Other Regulations May Apply

Local, national, and international regulations may restrict the purchase, storage, transport, use or disposal of certain products such as chemicals, radioactive sources, and specialty products and wireless transmission devices. Please consult your local regulations to ensure compliance.

Unless Otherwise Specified:

– Operating Temperature Range: 0°C to 40°C (32°F to 104°F)
– Maximum Altitude (Operational): 10,000 feet
– Recommended Storage Temperature: 10°C to 27°C (50°F to 80°F)

Quality

PASCO scientific meets the highest quality standards, and our quality management system is registered to ISO 9001.

PASCO and the Environment

PASCO is committed to being in compliance with all laws and requirements in the countries in which our products are sold. PASCO is a responsible steward of the environment and as such, continually seeks to minimize the impact that our manufacturing, distribution, and consumption practices make on the planet's natural resources.

Miscellaneous

RoHS

European Union Restriction of Hazardous Substances. EU Directive 2015/863:

- All applicable electrical products supplied by PASCO to the EU meet the requirements as specified in the RoHS directive either by substance limits or by product exemptions.

EU WEEE

Waste Electrical and Electronic Equipment. EU Directive 2012/19/EC:

- All applicable products supplied by PASCO to the EU meet the requirements as specified in the WEEE directive and are marked with the WEEE symbol.

WEEE-Product End of Life Disposal Instructions (Reference):

Electronic products are subject to disposal and recycling regulations that vary by country and region. It is a user's responsibility to recycle electronic equipment per local environmental laws and regulations to ensure that equipment is recycled in a manner that protects human health and the environment. To find equipment recycling drop-off locations, please contact your local waste recycle/disposal service or the product representative.

The European Union (EU) WEEE (Waste Electrical and Electronic Equipment) symbol on our products and packaging indicates that this product must not be disposed of in a standard waste container.

EU REACH

Registration, Evaluation and Authorization of Chemicals:

- PASCO has reviewed the REACH SVHC list and, according to our current knowledge, cables supplied with some products may contain certain phthalate plasticizers at greater than 0.1% by weight
- Regarding the other SVHC's, to the best of our knowledge, none are present in PASCO products (articles) at concentrations of greater than 0.1% by weight

Battery Replacement and Disposal Instructions (Reference):

Batteries contain chemicals that, if released, may affect the environment and human health. Batteries should be collected separately for recycling, and recycled at a local hazardous material disposal location adhering to your country and local government regulations. To find a battery recycling drop-off location, please contact local waste disposal service or the product representative.

The battery or batteries used in PASCO products are marked with the European Union symbol for waste batteries that indicate the need for separate collection and recycling. For small batteries, the symbol is printed on the packaging.

EU Battery Directive

EU Directive 2006/66/EC on Waste Batteries:

- The European Union (EU) battery directive aims to reduce the environmental impact of waste batteries and accumulators.
- According to our specifications, all products supplied by PASCO scientific into the EU that contain batteries meet the battery directive requirements, and are marked with the battery symbol.

PASCO has been supporting educators in over 100 countries around the world since 1964.

ISO 9001 Certified

Global Coverage & World-Class Support

PASCO

PASCO's global network of factory-trained partners are science specialists, who are knowledgeable about PASCO solutions. Contact our team today to see how PASCO can update your labs and provide value for years to come.

Find Your Local Representative
pasco.com/support

Follow PASCO:

Live Contact Hours:
M–Th: 7:00 am–4:30 pm
F: 7:00 am–2:00 pm
Pacific Time

Phone:
+1 916.786.3800 (outside US)
800.772.8700 ext. 1004
(inside US)
Fax: 916.786.7565

Mail:
PASCO Scientific
10101 Foothills Blvd.
Roseville, California
95747-7100 USA
ISO 9001:2015 Certified

Email:
support@pasco.com

Web:
Get quotes and
order online
pasco.com

Chat on pasco.com

Providing educators worldwide with innovative solutions for teaching science.

PASCO
10101 Foothills Blvd. • Roseville, CA 95747-7100
+1 916 786 3800 www.pasco.com

NEW! PASCO Wave Driver

PASCO Wave Driver Create amazing wave demonstrations that students can easily see with our new, heavy-duty Wave Driver. (Page 272)

CT-IPHY