

Newton's Third Law–Tug-of-War

Mechanics: Newton's Third Law, action and reaction	GLX setup file: tug of war
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Qty	Equipment and Materials	Part Number
1	PASPORT Xplorer GLX	PS-2002
2	PASPORT Force Sensor	PS-2104
1	1.2 m PASCO Track	
2	GOcar	ME-6951
1	Hooked Mass Set	SE-8759
0.2 m	Braided Physics String	SE-8050

Purpose

The purpose of this activity is to determine the forces exerted on two objects in a ‘tug-of-war’ and to compare the forces on each of the two objects.

Background

Newton's Third Law of motion states that whenever one body exerts a force on a second body, the second body exerts an opposite directed force of equal magnitude on the first body.

The third law is sometimes called the ‘action–reaction’ law, and it is sometimes quoted as: “For every action, there is an equal, but opposite reaction”.

In a traditional tug-of-war, the winning team is not always the team that has the strongest, largest, or most massive team members. The winning team is usually the one that has the best traction against the ground. The forces exerted by each team pulling on the rope are equal in magnitude and opposite in direction.



Newton (1642–1727)

Safety Precautions

- Follow all directions for using the equipment.

Preview

Use a pair of Force Sensors attached to carts to measure the force each cart experiences during a ‘tug-of-war’ between the two sensors. Use the Xplorer GLX to record and display the force from each sensor. Compare the magnitude and direction of each force.

Prediction

Predict what the forces will be like in each of the following cases:

Case	Prediction
Equal Masses	
Cart 1: Extra Mass	
Cart 2: Extra Mass	

Procedure

GLX Setup

1. Turn on the GLX (Ⓢ). Open the GLX setup file labeled **tug of war** (check the Appendix at the end of this activity).
 - The Graph screen opens with a graph of force versus time for two force sensors. The file is set so that one of the force sensors sends a positive signal when a pull is applied, and the other sends a negative signal when a pull is applied. The sample rate is set at 20 times per second (20 Hz).
2. Connect the first Force Sensor to sensor port 1 on the top of the GLX. Connect the second Force Sensor to sensor port 2.

Equipment Setup

1. Place the track on a horizontal surface and level the track. (Place the cart on the track. If the cart rolls one way or the other, adjust the track to raise or lower one end.)
2. Put a hook on the end of each sensor and mount the sensors on the two carts. Arrange the carts near the center of the track with the sensors facing each other.
3. Tie piece of string into a loop and put the loop over the hooks of both sensors.

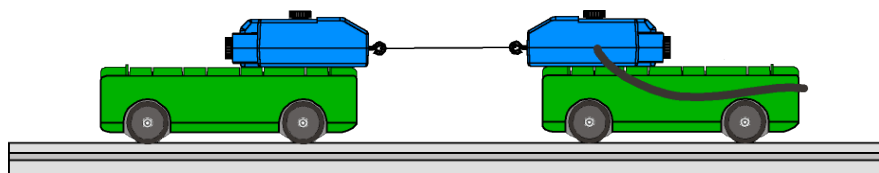


Fig. 1: Equipment setup

Record Data

- NOTE: The procedure is easier if two people handle the two carts and a third person handles the Xplorer GLX.

Part 1: Equal Masses

1. Press the ZERO button on the top of each Force Sensor to zero the sensors.
2. Press Start (▶) to start recording data. Pull the carts away from each other the cart. Try pulling equally hard.
3. Press (▶) to stop recording data after about 10 seconds of pulling.

Part 2: Extra Mass on Cart 1

1. For Run #2, put 500 g (0.4 kg) on the top of one cart
2. Press the ZERO buttons on both sensors. Record data as in the first part.

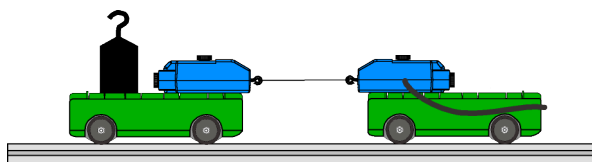


Fig. 2: Extra mass on Cart 1

Part 3: Extra Mass on Cart 2

1. For Run #3, move the extra mass to the top of the other cart.
2. Record data as you did before.

Analysis

Use the Graph screen to examine the forces measured by both sensors for each data run. Compare the force from sensor 1 to the force from sensor 2 for each run.

- The Graph screen shows data from both force sensors. One plot is 'active' and is slightly darker than the other plot.
1. To switch from one plot of data to the other, press $F3$ ($F3$) and select 'Toggle Active Data'. Press \checkmark to activate your choice.
 2. To change the Graph screen to show a specific run of data, press \checkmark to activate the vertical axis menu.

Press the cursor arrow keys (\uparrow) to move to 'Run #' in the upper left hand corner or upper right corner. Press \checkmark to open the menu, select the data run in the menu, and press \checkmark to activate your choice. Repeat the process to select the same run of data for the other sensor.

3. You can use the 'Smart Tool' to determine the value of the force at a specific time. Press $F3$ ($F3$) to open the 'Tools' menu. Use the up-down arrow keys to select 'Smart Tool' and press \checkmark to activate your choice.
- The 'Smart Tool' shows the coordinates of a data point.
4. Describe the results for the forces measured by both sensors for each data run in the Data Table of the Lab Report section..

Record your results and answer the questions in the Lab Report section.

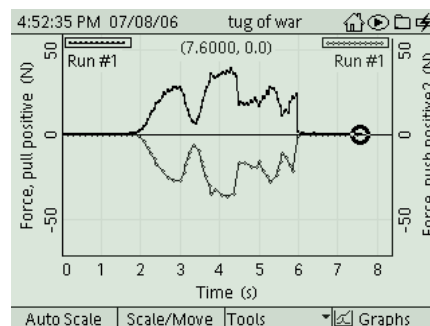


Fig. 3: 'Active' data is bold

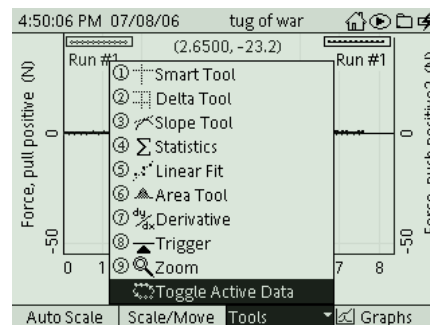





Fig. 4: Select 'Toggle Active Data'

Appendix

Opening a GLX File

To open a specific GLX file, go to the Home Screen (press ). In the Home Screen, select Data Files and press the Activate () button. In the Data Files screen, use the cursor keys to navigate to the file you want. Press **F1** () to open the file. Press the Home button to return to the Home Screen. Press **F1** to open the Graph screen.



Data Files Icon

RAM		Flash	
RAM: Size = 11.8 MB, Free = 11.5 MB			
tug of war	[Open]	7 KB	[Modified]
2nd law mass		21 KB	07/05/06
2nd law a data		13 KB	07/05/06
BREATH		8 KB	10/08/05
first law data		16 KB	06/29/06
free fall data		16 KB	06/29/06
free fall		4 KB	06/28/06
Open	Save	Delete	Files

Lab Report – Activity 8: Newton's Third Law

Name _____ Date _____

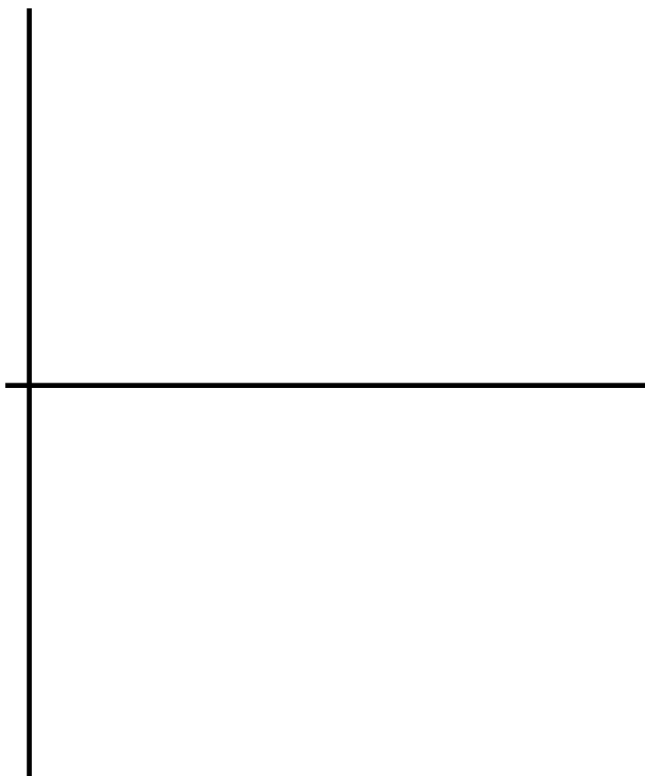
Prediction

Predict what the forces will be like in each of the following cases:

Case	Prediction
Equal Masses	
Cart 1: Extra Mass	
Cart 2: Extra Mass	

Data

Sketch a graph of force versus time for one run of data. Include labels and units for your y-axis and x-axis.



Data Table: Tug-of-War Results

What were the forces like in each of the following cases?

Case	Results
Equal Masses	
Cart 1: Extra Mass	
Cart 2: Extra Mass	

Questions

1. How did the shape of the graph for the first force sensor compare to the shape of the graph for the second force sensor during the first run of the tug-of-war?
2. What happened to the forces measured by the two sensors when extra mass was put on top of cart 1 or cart 2?
3. If two forces are equal and opposite, what should the sum of the forces be?
4. From your data, how close are the forces to being equal but opposite?
5. During a tug-of-war, how does the force on one force sensor compare to the force on the other force sensor?