Physics is Fun:
Why do objects fall?

Grzegorz Karwasz
Didactics of Physics Division
Nicolaus Copernicus University
Toruń, Poland

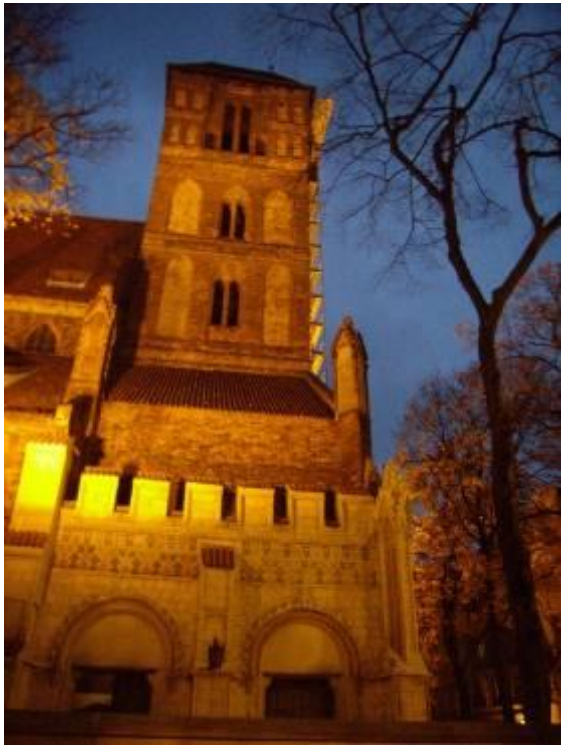
송미영
선임 연구원
플라즈마물성데이터 센터
플라즈마물성연구팀 / 원천기술연구부/

플라즈마기술연구센터 /국가핵융합연구소

Toruń – medioeval city (*1227)

Established by German religious order

Toruń – city of cathedrals

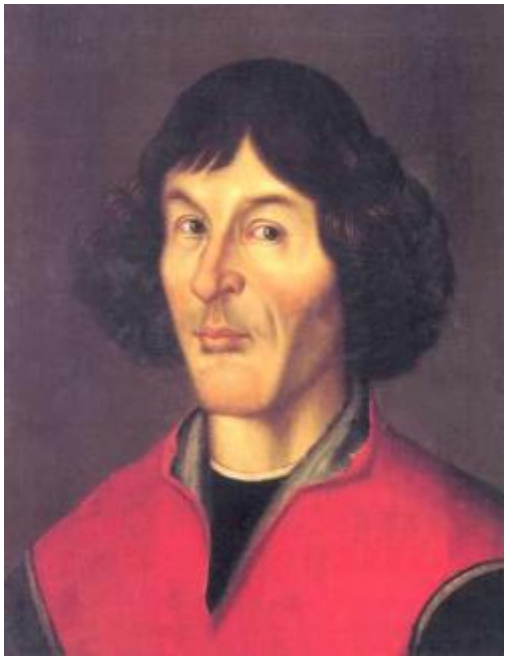


Church S.S. John's

Church S. Mary
(Ascension to Heavens)

Church S. James

Toruń – Nicolaus Copernicus born (1473)



N. Copernicus (1473-1543)

House of Copernicus father, rich merchant

Lucas Watzenrode (Nicolaus' uncle, Bishop)

What happened in Poland/ Europe?

Poland 1466:
war between German order and Poland finished (peace in Toruń)

Europe 1453:

Constantinopole (=Instabul) conquered by Turks

(=end of Bizantine Imperium)

Nicolaus Copernicus – laborious student

Kraków (1492-1496)

S. Mary Church

Bologna (1496-1500)

Tower of Donkeys

Padova (1501-1503)

S. Antonio Basilica

Look into sky: Moon and planets are moving!

Jupiter, Venus and Moon
Bamberg, Germany, 25.03.2012

Trento, Italy, 26.03.

Ptolemeus (151-212): Sun and stars are moving

Katedra Wniebowzięcia NMP w Toruniu

Ptolemeus (151-212): Sun and stars are moving

Katedra Wniebowzięcia NMP w Toruniu

Ptolemeus (151-212): Sun and stars are moving

Katedra Wniebowzięcia NMP w Toruniu

Ptolemeus (151-212): Sun and stars are moving

Katedra Wniebowzięcia NMP w Toruniu

Nicolaus Copernicus: Earth is moving

„He stopped Sun and Heavens,

he moved Earth”

Terrae motor, solis caelique stator

Copernicus Monument
Toruń

Copernicus system: planets move around Sun

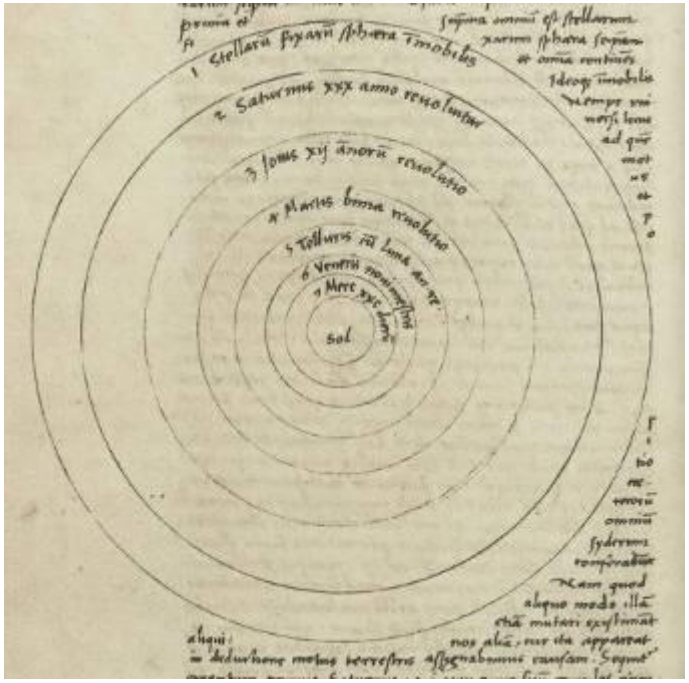
Mercury: - 1 orbit in 90 days

Venus: - 1 orbit in 9 months

Mars: - 1 orbit in 2 years

Jupiter: 1 obrbit in 11 years

Saturn: 1 orbit in 30 years



Copernicus system: everything in movement

Earth: - 1 rotatation in 24 hours (=1 day)

- 1 orbit in 365 days (=1 year)

Moon: - 1 orbit in 28 days (≈ 1 month)

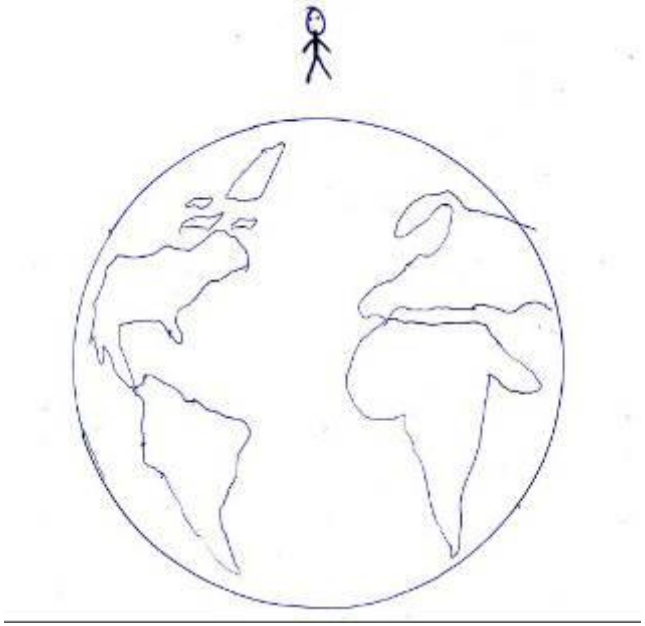
- rotation in 28 days

Sun: - 1 rotation in 25 days

Whole Solar systems flies 400 km/s towards *Leon* constellation

Why do all objects fall down on the floor?

Because there is gravity!



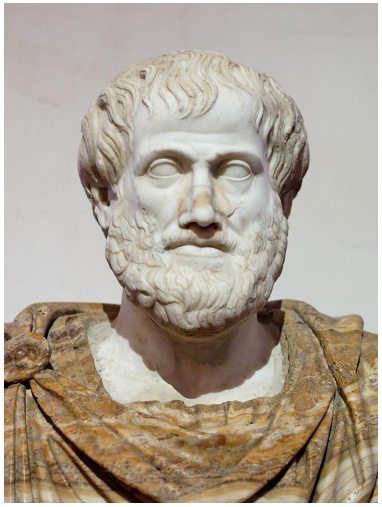
What is gravity?

It is Earth's attraction

What is Earth's attraction? It is gravity

This is *tautology*: Rice is made of rice

Aristotle (384-322 BC)



Objects fall, because they are heavy,
and the *natural* place of heavy objects is the center of Earth

So objects fall, in order to go to the center of Earth

Let's try it!

Let's try it again!

Yes! Objects go to the center of Earth!

Can the ball jump up?

http://dydaktyka.fizyka.umk.pl/nowa_strona/?q=node/171

And what about jumping up?

Have a look on this film!

And again...

No! it was a trick. The film was inverted...

Can objects jump up?

Let’s think all together: Jump up!

(It is called tele-kinesis, and some people believe it)

It does not work. Is everybody really thinking „jump up?”

or somebody says: „do not jump!”

Let’s try it again!

It does not work. The ball can not jump up!

I have a magic ball

I will make a magic, and the ball will go up

Magic, magic: go up!

Now come back!

Go up! Come back!

Have you seen it? it’s magic. Isn’t it ?

Now I will tell to this rubber ball,

jump up to the roof! (Be careful)

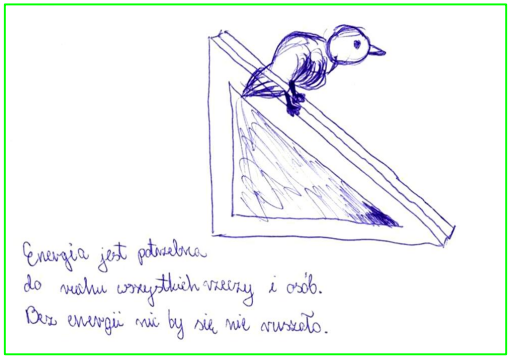
We learned it.

Now we can jump all together!

Why?

We have energy!

This is „energy” which makes things move



What do I feed these birds with?

Balls? No! With energy!

Why do these hens walk?

Because I gave them energy

We do work, to give energy

This puppet goes down, because he got energy

This Santa Claus climbs, because I give him energy

We work, to give energy

Objects jump (and move, and fall) because they have energy

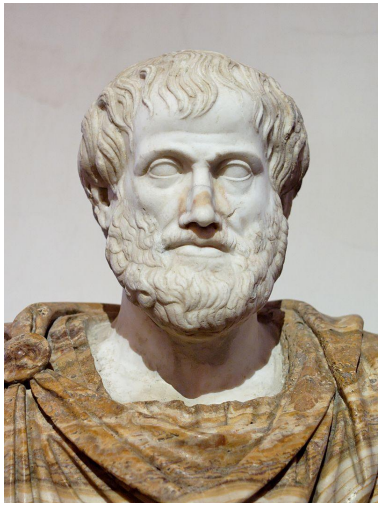
This is another magic ball

I will work on it (put energy)

Now this ball will jump. Tell it: jump!

This woodpecker will knock, if I rise him

How do objects fall?



Now we know why do objects fall.

Let us ask, how do they fall.

Do heavy objects fall quicker?

Aristotle says: Yes!

Which cart is quicker?

Who thinks that the heavier cart is quicker?

Who thinks that the ligther cart is quicker?

Let’s try it!

Which cart is heavier?

Which cart is quicker?

We start with the lighter car

The heavy should joint it.

No! It did not work

So try with the light one.

It does not work either!

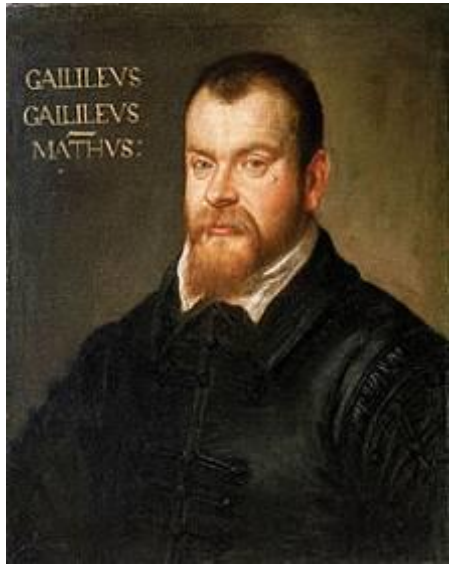
The only explanation is that they descent with the **same velocity**!

Galileo (1564-1642)

All objects fall with the same „velocity”

Maybe he made objects fall from the Tower in Pisa

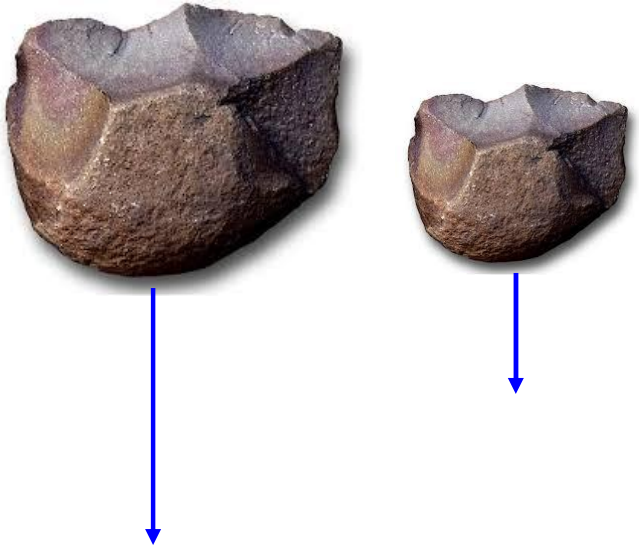
The Tower was leaning already in that time



Galileo Galilei:

„What will happen if we make

fall a heavy stone and a ligth stone?”



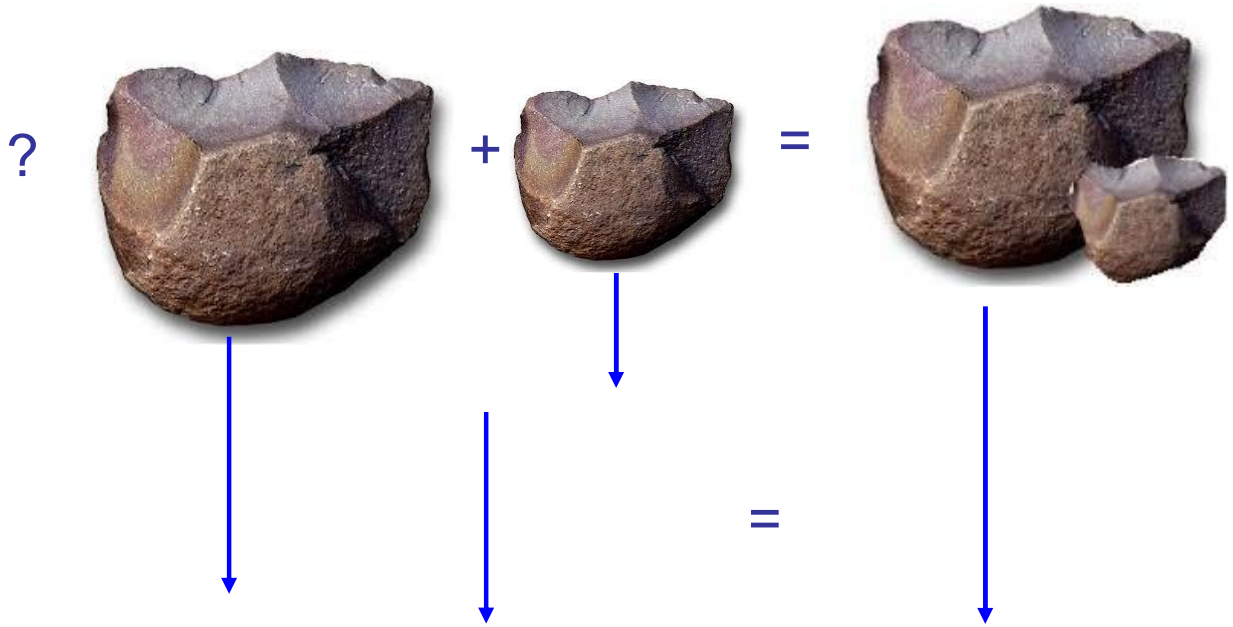
Heavier will fall quicker

and light slower?

Galileo Galilei:

„What will happen if we connect the

heavy stone and a ligth stone?”



Heavy and light fall together!

Now, we try two balls:

heavier and lighter ball

?

Shut your eyes!

This is heavy, and this is light

Now, together:

Listen carefully!

Which was first?

Open you eyes!

They fall together!

All objects fall with the same „velocity”!

Now, try it again

Look carefully!

The heavier is quicker!

Why?

We try two pieces of paper

One is ball, one is paper sheet

This is the air which makes the difference!

Let’s make experiment without air

There is no air on Moon, but we can’t go to Moon

But we have a film

This is a tube with a feather and a coin

We check what fall first – coin or feather?

Clear! coin is first!

Now we pump out air from tube

This is a pump, we wait untill air goes out

And we try again!

Now, coin and feather are together

This is the air which makes the difference!

Now we make experiment on Moon

Apollo 17 (1971)

„This is an old experiment by Galileo

He said that all objects fall
with the same velocity

This is a hammer and this is a feather

Let’s try which falls first!

They fall together. Galileo was rigth!”

What is absence of gravity?

Like in the space

Eating in Space Station

Gagarin, first man in space (12.04.1961)

We can make it here

This is our space ship and pilot

Will he jump out?

No! he falls together

The bear is in absence of gravity

We check it again

Now water flows out

No! water and the cup fall together!

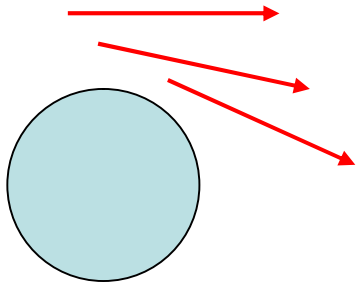
Water in the cup is in *absence of gravity*

But spaceship on orbit?

It goes around, not falling?

Yes, it goes around

but it is constant falling



How do objects fall?

Now listen to this ball

Close your eyes and listen

How does the ball move?

It goes with constant *velocity*

Listen again

Now, it starts slowly and goes quicker and quicker

The ball *accelerates*

Let’s try a bigger *inclined plane*

Listen to the film

At what distance are balls? Equal, rigth?

Now we look at the film

Let’s measure distances

Distances are 1 : 3 : 5 :7, i.e. successive odd numbers

This is the law discivered by Galileo

Successive odd numbers

$s = \frac{1}{2} at^2$ where a is the acceleration

Science Center, Daejon

Laws of conservation (1)

Energy (kinetic and potential):

$E_k = mv^2$, m – is mass, v - velocity

$E_p = mgh$, g – is gravitational acceleration, h – heigth

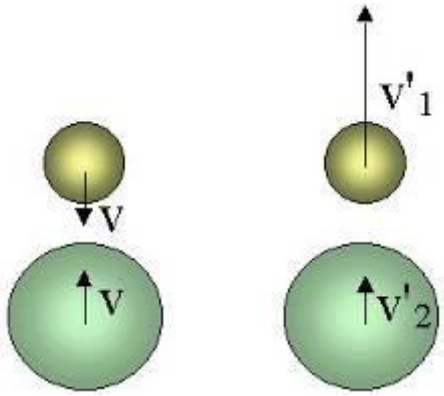
$E_p \leftrightarrow E_k$

Newton's craddle

Laws of conservation (2)

Momentum (*impetus*)

$\boldsymbol{p} = m\boldsymbol{v}$



Experiment on recoil

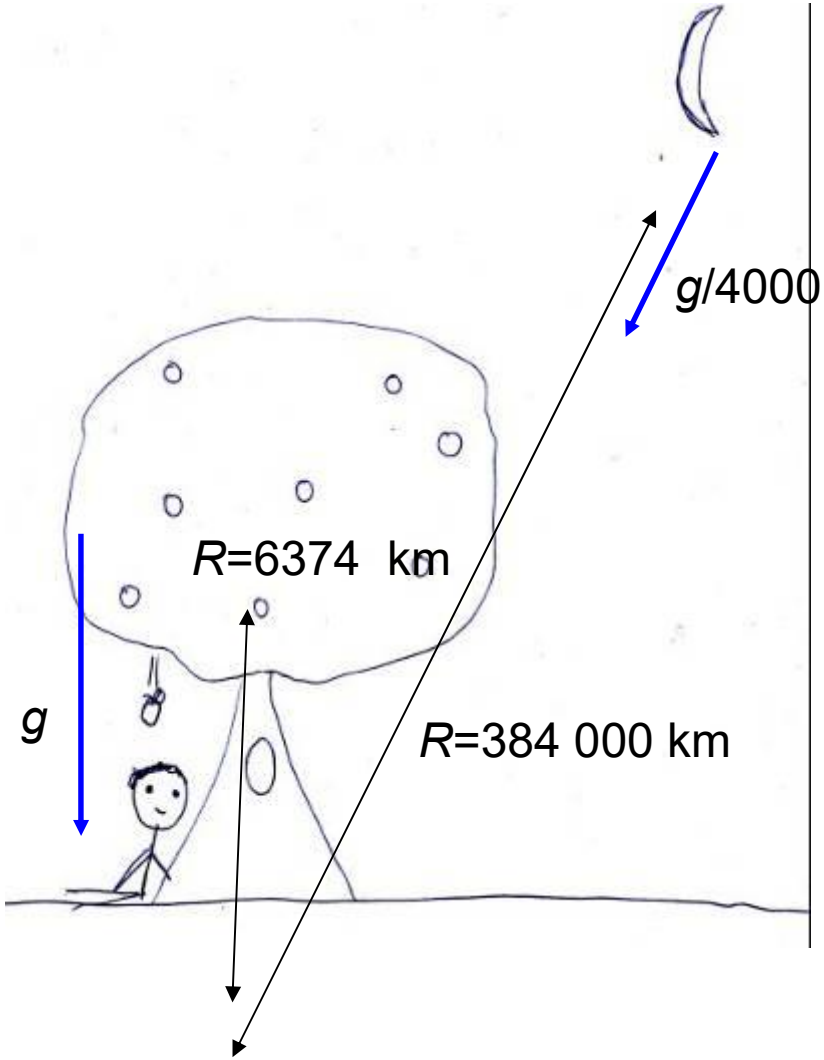
Laws of conservation (3)

Angular momentum

$\boldsymbol{L} = m\,\boldsymbol{r} \times \boldsymbol{v}$

„celtic stone”

Newton: Moon is constantly falling on Earth



All objects (on Earth) fall

with the same *acceleration* g

Moon is more distant

so it falls with g/4000

(one orbit in 28 days)

Physics is Fun!

But physics is also discovery:

Albert Einstein:

How can we recognize real absence of gravity from free falling?

→ General theory of relativity (1915)