Fun experiments in astronomy at school

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1. The Curve of the Shadow

_Aim: To measure the movement of the shadow and to understand the rotation of The Earth._

Build the experiment shown in this picture. 
Draw the position of the shadow every half hour. Write the time on each position. In the afternoon draw the curve of the shadow of the motion during the whole day. 
Why does the shadow move?
Which way does The Sun move?
Why is The Sun moving in that direction?

Do this experiment at different times of the year.
How does the curve change with the seasons?
2. A Model of the Moving Shadow

*Aim: To understand the rotation of The Earth*

A projector casts light at a globe. A bended paper clip is placed on the globe casting a shadow.

Place the globe into this position.

It shows the northern Europe at noon. The Sun is in the south. The shadow of the paper clip is pointing to the north.

Rotate the globe a bit to the east.

The shadow of the paper clip will be pointing towards the north-west.

Now the shadow of the paper clip shows where the sun is in the afternoon.

Rotate the globe more to the east.

The shadow of the paper clip will be pointing to the west.

Now it shows where it is in the evening.
Time Zones

This map from NASA shows the time zones. Every hour the earth moves 15 degrees to the east.

When you fly 15 degrees to the east you must set your clock to one hour ahead. When you fly 15 degrees to the west you must set your clock to one hour back.

All the countries on the same longitude should have the same time.

Yet some countries have changed their time zone to get the same time as their neighbouring countries. As an example: Spain is on the same latitude as United Kingdom. Yet Spain has chosen to have the same time as France and Italy. So in Spain they have got “late” sunsets and sunrises.

Find more examples of this.
3. Why does The Earth have Seasons?

*Aim: To learn the reason why there is a change of seasons*

*Goal:* After this activity the pupils will be able to explain:
- Why the southern hemisphere has got the opposite seasons than the northern hemisphere
- The consequence of the Sun height for the temperature
- The seasons on Mars and Uranus

Some people think that it is summer when the sun is closer to us. But why does Greenland have summer whilst Antarctica has got winter? No, the reason is quite different.

**Try this experiment:** Have a globe rotate around a lamp in a dark room. Tip the globe so the axis of the globe is 23.5 degrees from vertical.

| --- | --- |

| The light from the lamp hits the floor vertically. The light spot is small, so the heat is concentrated in a small area. The temperature will be high. | Tip the light of the lamp so the beam hits the floor from the side. The spot of the light is larger and the heat is spread in a much larger area. The temperature will be lower. |
When the sun is high above your head in the sky the temperature will be hotter, because beam of light is heating a smaller area and because the day is longer.

**Seasons on Mars and Uranus:**

If you hold the axis of The Earth vertically, you will see that there will be no seasons on a planet like this.
But if the axis had an angle of more than 23.5 degrees to vertical there is more difference between the seasons.

<table>
<thead>
<tr>
<th>If the axis is in level with The Sun you will see extreme difference between the seasons. The whole northern hemisphere will have midnight sun in its summer. At the same time the southern hemisphere will have night and winter.</th>
<th>Half a year later the seasons will be like this. Night and winter in the Northern hemisphere and summer and day in the south.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Planet Uranus behaves like this too</td>
<td></td>
</tr>
</tbody>
</table>

So Uranus has got extreme seasons during its 84 years orbit of The Sun.

The axis of the planet Mars is like the axis of the Earth. Yet the axis of Mars has changed position mush more than the axis of The Earth. So the climate of Mars has been much more unstable.

Why is the axis of the Earth more stable than the axis of Mars. The Moon is relatively big compared to the Earth. So a theory tells us that the pull of the Moon means a more stable climate on The Earth.

**4. The Phases of the Moon**

**Aim:**
- To understand the Phases of The Moon
- To Understand the Tides

**Goal:** After the activity the pupils will be able to:
- Explain the phases of The Moon
- Explain the phases of the tide.
- Understand the influence of the Earth rotation on the tide
- See the difference between the influence on the tide of the Moon and of the Sun
Do like this: In a dark room let a ping-pong-ball on a stick orbit a globe. A projector represents The Sun. Half Moon: The Moon and the Earth reflects the light of the Sun. The side of the globe with shadow represents the night. At a half Moon only half of the Moons day is seen from The Earth. The phases change whilst the Moon is orbiting The Earth. On this picture the light is coming from the left, and The Moon is 90 degrees from the left.
The Moon moves to the left seen from the northern hemisphere. The Moon waxes as it moves away from The Sun, and after half an orbit it wanes as it gets nearer to The Sun. The night on the Moon is allmost invisible from The Earth. But at New Moon you can see the night of the Moons, because of the light from The Earth. Seen from the Moon The Earth is full at new Moon.

**Tide**

The pull of The Moon makes tide on The Earth. When the Moon is in the horizon it pulls the water away from you so you have low tide. When the Moon is highest in the Sky it pulls the see so you have high tide. You also have high tide app. 12 hours later.

When the Earth rotates around its axis, the Moon is seen moving to the west. **After a little more than 6 hours the tide changes from high to low or from low to high.**

At new Moon or Full Moon the pull from The Sun and from The Moon support each other. So in that period there are bigger differences in water levels by the coast.
5. How does a Newborn Star Get Itself Heated?

_Aim: To understand how star formation produces heat_

_Goal:_ After the activity the pupils will be able to:

- Show the experiment with a pump
- Tell about the energy source in the stars
- Find images of star formation in the www.

**Use a pump**

Pump a bike. How does the pump feel – hot or cold?

Try also to pump while holding a finger over the hole of the pump so the air comes out at last.

Stop before you burn yourself.

Compression creates heat.

At star formation the heat is caused by compression of gasses. If the core of the star reaches 10 million degrees C, fusion of hydrogen will start in the core. Here new elements are produced.

When a star is nearly burned out, the pressure from its center will make the star grow in volume. The upper layers of the star are cooled by this. As the volume grows the temperature falls and the colour of the star turns red.

Find pictures of star formation and star deaths at [www.spacetelescope.org](http://www.spacetelescope.org)

Here you can see the M42 the Orion Nebula.

Four gigantic new stars emits so much light to the nebula, that the Orion nebula itself emits light. Because of that astronomers have been able to detect 3000 stars being born inside of the nebula.
6. How did the Planets Come into Orbit Around the Sun?

_Aim:_ To understand how the planets came into their orbits.

_Goal:_ After the activity the pupils will be able to:
- do experiments with pirouettes
- explain how the planets came into orbit

Rotate in the chair with your arms and legs stretched.

Then bend your knees and elbows while rotating.

The sun system made a pirouette like this when it was born.

The speed was highest angular to the rotation axis of the Sun. All the planets were formed there. You see these planets in the 13 constellations in the ecliptic.

The Hubble telescope took this image of a star being born in the Orion Nebula. Its rotation has created a disk of dust and gas. Planets will be made out of this dust and gas.

To the right you see a star formation on the Eagle Nebula.
7. Why are the Planets not Pushed Away from the Ecliptic?

Aim: To understand why all the planets are in the ecliptic

Goal: After the activity the pupils will be able to:
- Find the ecliptic - The orbit of the planets and of the Sun in the sky
- Show the balance in a rotating wheel
- Explain the balance of the Earth

Hold the wheel while a friend is rotating it. How do you feel the balance of the turning wheel?

When the wheel has stopped also try the balance of a stopped wheel.

It’s the rotation that gives the balance. That is why you can ride a bike.

This is also why the axis of the Earth is so stable.

The rotation keeps the planets in the ecliptic. A planet will never pass in front of the Pole Star.
8. A Rocket with Water

*Aim: To learn how to launch a rocket*

**Goal:** After the activity the pupils will be able to:

- launch a rocket
- understand Newton’s 3. law

**Do like this:**

You can buy a rocket-launcher here: [http://www.gamleskole.dk/shop/raketten-legetoej-online-673p.html](http://www.gamleskole.dk/shop/raketten-legetoej-online-673p.html)

Fill water into a plastic-bottle up to ¼. Turn the bottle upside down and press it on the tip of the launcher. Pump air into the bottle until it suddenly launches. Take care not to lean over the bottle. The air will press the water down. As a reaction to this the rocket will shoot upwards. This is an example of Newton’s 3. law. This law explains how every rocket-launching takes place.

9. Roller Skates

*Aim: To learn Newton’s 3. law*

**Goal:** After the activity the pupils will be able to:

- Show Newton’s 3. law with an experiment
- Understand how a rocket can change velocity
Two persons with roller skates throw a heavy ball to one another.

They roll backwards every time they throw. The harder they throw the ball the faster they go backwards.

Why is that so?

In space you change velocity in the same way when firing a rocket.

An astronaut in the middle of a cabin can fly and hit the wall when throwing something in the direction of the opposite wall.

The ISS can go higher by letting its motor shoot gasses backwards. A spaceship can go lower (downwords) by letting its motor throw gasses forwards.
An Extra Experiment with Roller Skates:

They are standing closely together with roller skates pressing their hands against the other person’s hands.

At the same time they both push each other with their hands.

Do the experiment with
1. two equally heavy pupils
2. two pupils with different weight

Why did the smallest go faster?

Explain with Newton 2. law
F= M * A

You see, it is an advantage to be small.

That’s why empty parts of the rocket are thrown off when once the fuel has been used up.
10. Experiment with Falling Coins

Aim: to understand how a satellite can orbit a planet

Goal: After the activity the pupils will be able to:
• show that coins with different velocity forward hit the ground at the same time
• explain how a satellite can orbit a planet

You have probably wondered why satellites and spaceships do not fall to the ground. Many think that gravity does not go through space, but this is wrong. It is because of gravity that the astronauts can return to the Earth.

You can easily do an experiment that shows why satellites can orbit the Earth.

Do like this. Push the coins with the ruler so they fall to the ground. The coin that is the farthest away from the middle will get the fastest push. So this coin will get the highest velocity horizontally.

But listen: The coins will hit the ground at exactly the same time. Vertically they will fall with the same speed. Now, imagine that the speed of one of these coins will be so fast that it won’t be hitting the Earth but it will fall beside the Earth. Then its starting point must be more than 200 km above the Earth and have a speed of 8 km/s. It will be outside the atmosphere and will not be stopped by the air pressure. The coin will just continue falling.

A spaceship could be falling like this for months. The astronauts will be nearly weightless. But as long as a rocket is fired the astronauts will feel gravity. With the help from the force from a rocket the spaceship can be lifted into a higher orbit or lowered down into the atmosphere so that it can land.

The ISS
The ISS moves vertically with 28000 km/h 400 km above the Earth. The gravity up there is only a bit less than on the ground. But it is falling, so you do not feel the gravity. A tiny pressure of air lowers the orbit of the ISS over months. Sometimes the astronauts use a rocket to gain altitude. When the rocket is working they can feel gravity.
11. Gravity

_Aim: to understand that gravity keeps a satellite in its orbit_

**Goal:** After the activity the pupils will be able to:
- show this experiment
- explain that gravity from the Earth also has an effect in space
- show how a spaceship can land
- show how a spaceship can travel to the Moon or another planet

<table>
<thead>
<tr>
<th>Put a strong fishing line through a hollow plastic stick. Fix a cork in the upper end of the fishing line. Fix a weight in the lower end. Rotate the cork so that it does not fall. If you rotate the cork faster it will be lifted into a higher orbit. If you rotate slower, then the cork will fall into a lower orbit. If you change to a heavier weight, the cork must be faster to stay in orbit.</th>
</tr>
</thead>
</table>

This model experiment is very much like an orbiting satellite. The rocket supplies with energy if you wish to gain altitude. The rocket can take energy away if you wish to land on the ground.

The experiment is also a model of the Earth orbiting the Sun. If the Sun was heavier, it would demand a higher speed of the Earth to keep in orbit. You can calculate the mass of the Sun by measuring the orbit of the Earth.

Astronomers can calculate the mass of a black hole, by measuring the orbiting radius and orbiting time of an orbiting star.

Yet this model experiment does not show how gravity changes with distance.
12. How do you Become Weightless?

**Aim:** to understand that the water is weightless during a free fall

**Goal:** After the activity the pupils will be able to:
- show this experiment
- explain that anything in a free fall is weightless
- understand that the laws of nature are the same in space and on the Earth
- understand that you are weightless when you jump
- explain that gravity from the Earth also has an effect in space

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The water is sprinkling out because of the weight and the pressure.  

The water is weightless and doesn’t press.

<table>
<thead>
<tr>
<th>A water can with holes.</th>
</tr>
</thead>
</table>
Out on the lawn you hold a can with water. Drill small holes in the side of the can in various distances. The water will spurt out, the strongest from the hole near the bottom of the can, because the pressure is harder in deep water.

Everyone, who has tried to dive, knows that the pressure increases the deeper you dive. The reason being the weight of the water. You are carrying all the weight of the water above you. In the same way you feel the pressure of the air on the surface of the Earth.

Now it is easy to make the water in the can weightless for a short moment by letting the can fall down onto the lawn. What will happen to the squirts of water during the fall?

If you jump down from a bench with a can full of holes in your hand, you’ll observe the same – you’ll experience a little of what an astronaut in orbit does.
You can also try to throw the water can upwards making it follow a curved course as a parable. When ascending no squirts will be coming out of the holes, because the water is weightless. It is in a free fall in a curved course.

The „Zero G“ airplane climbs precipitously when it aims at weightlessness. The contents in the plane are weightless while the plane follows a curve as a ball being tossed (the parable-course). Both going up and going down there is weightlessness.

But when the plane is brought back after the fall, and when the engine takes off for the next parable, the passengers experience double weight. They are exposed to 2 G for about 20 seconds.

Photo (Novespace).

A student hangs in weightlessness under the roof in ESA’s A 300 “Zero G” plane.

During the weightlessness (microgravity) they can carry out their experiments.

Read about parabolic flights: http://www.rummet.dk/6a72774 and http://www.rummet.dk/6f92774 and

http://www.nf.suite.dk/astro/vaegtloeshed.htm

Try to navigate a parable plane in a simulation: http://www.rummet.dk/40d000c
In the 4th exercise under the section: Weightlessness your task is to navigate a plane in such a way that an egg stays weightless for 30 seconds. The 5th exercise is to navigate a space ship by means of rocket engines, so that you, in doing this, can bring a tennis ball that is flying around in the space ship, to a stop.

13. A Magnet in a Free Fall

Aim: to understand that everything is weightless during a free fall

Goal: After the activity the pupils will be able to:
- build an instrument to show weightlessness
- explain that anything in a free fall is weightless
- understand the laws of nature are the same in space and on the Earth
- understand that you are weightless when you jump
- explain that gravity from the Earth also has an effect in space

In a transparent plastic pipe a magnet is fastened in one end. In an iron screw with a raw plug a string is fastened, so that you can drag the string away from the magnet. A tube in the pipe stops the screw, so that it can only be drawn down to a certain distance from the magnet. The distance is adjusted in such a way that the magnet just cannot lift the screw. The pipe is held with the magnet at the top and the screw drawn down. If you drop the pipe the screw will immediately jump off with a click.

Why? Because the magnet and the screw fall at the same speed. During the free fall both become weightless. The screw is pulled up, because it doesn’t weigh anything during the free fall.

Throw the pipe into the air. The screw is drawn up to the magnet again, because the way upwards is a part of the free fall. Because of the throw the free fall will go upwards in the beginning – in the same way as when you throw a ball – or during a parable flight.
Hold the pipe in the hand and jump. The screw will jump up. It proves that you were weightless during the jump. Your weight was practically zero – the same way as an astronaut in orbit experiences weightlessness or micro-gravitation.

That the astronaut has an insignificant little weight – a micro-weight (micro-gravitation) is due to the fact that the distance to the Earth has a difference of a few meters for the astronaut and the space ship’s centre of gravity.
Teachers from the UK in The Science on Stage were jumping with a small magnetic instrument to show that everybody is nearly weightless during a jump. You could hear a click from each instrument when the screws were drawn up to the magnets while their feet left the ground. Photo: Gitte Hass

14. When do you have to Wear a Spacesuit

Aim: to show that water is boiling when it is in vacuum

Goal: After the activity the pupils will be able to:
- show boiling water in a tube with vacuum
- tell when an astronaut needs to wear a spacesuit
- explain that liquid water cannot be on the surface of Mars.
Get some 50 degrees C water into the tube. Put your finger over the end of the tube. When you pull the water will be boiling.

The water will be boiling in some seconds. It does not feel hot.

In space an on the Moon is vacuum, so liquid water cannot stay liquid. It will boil. So the blood of an astronaut will also be boiling, if he or she is outside in space without a spacesuit.

If you go high in the mountains the air pressure will be lower, and water will be boiling before it reaches 100 degrees C. On Mars the air pressure is so low that water will be boiling at 10 degrees C.


**Aim: to have fun learning about spaceflight**

**Goal:** After the activity the pupils are able to:
- show a video of space flight
- understand teknology
- understand the Solar System

Visit an astronaut from the ISS: http://esamultimedia.esa.int/docs/issedukit/en/html/t04t1.html

16. Make a Rainbow

**Aim: to learn about light and colours**

**Goal:** After the activity the pupils are able to:
- make a rainbow
- explain how a rainbow is made
- tell why astronomers measure the colours of the light from the stars
Stand with your back to the Sun. Make a shower in front of you.

You will see a rainbow. The sunlight is white, but contains different colours put together. When the white light is refracted in a raindrop it is separated into all colours.

The blue colour is bent very much. The red colour is bent less.

Hold a prism at the light. You will then see a rainbow. This is because the colours are bent differently, when the light passes through glass.

The prism is separating the white light into all colours. The astronomers are separating light from a star. Then they can tell which elements are on the star. They can also calculate the velocity of the star, how hot it is and how old. The light reveals incredibly many facts. Sometimes you can also measure if the star has got planets. In the future it might be possible to find out if an exoplanet has got oxygen in its atmosphere just by studying the light it reflects. Until now we have only found oxygen in the atmosphere of The Earth. You can

Raindrops are separating the sunlight into a rainbow.

In the inner rainbow the red colour is on the top, because it is bent less.

In the weak rainbow over it, the colours are opposite because of an extra reflection in the raindrops.
measure the oxygen in the earthshine reflected by the night of the Moon.  

Foto: Randers HF

17. Why is the Sky Blue? Why is the Sunset Red?

**Aim:** to learn how the sky gets colour.

**Goal:** After the activity the pupils are able to:
- explain the blue colour of the sky
- explain the red colour of sunset and sunrise
- explain why space is black

Sunlight is white. The white light contains all colours. The atmosphere spreads out the blue light most. That is why the sky is blue.

When the Sun is at the horizon its light passes a much longer way through the atmosphere. Even the red light is spread out, so the sky will be more red. The Moon is also red when it is low.

If you go over the atmosphere the sky will be black, because no air spreads out the light.

You will be able to see stars and planets in daytime.

Photo: NASA
Here is an experiment where light is spread out just like in the atmosphere.

Put a glass of water on an overhead projector. Pore some drops of milk into the water.

You see that the light is turning blue. The light on the screen is turning reddish.

The white light from the projector contains all colours. The colours are separated by the milk.

The blue light is spread out more than the red light. That is why the glass looks blue.

The red light is spread less. That is why the red light can reach all the way through the milk to the screen.
18. Why is Light from Far Away Galaxies Redshifted?

**Aim:** to understand the expansion of the universe

**Goal:** After the activity the pupils will be able to:
- explain redshifting
- explain the theory of the Big Bang

| Draw marks in a balloon | When you blow more air into the balloon the marks will be getting away from one another. Just like that the expansion of space, which will create growing distances between far galaxies. |

When an ambulance is driving away from you, its sound will be heard with a lower frequency. Just like that light from far galaxies shift into a more reddish colour.

Read about the **microwave background** on the web.

Astronomers have measured that the expansion of the universe is accelerating.
19. How can Astronomers Measure the Distance to a Star?

Aim: to understand how astronomers can measure distances

Goal: After the activity the pupils will be able to:
- measure and calculate distances

He is watching with his left eye. He is seeing the image to the left.

When he is watching with his right eye he will be seeing the image to the right.

The stick in the front seems to be moving very much when you change your point of view. Background objects seems to be moving less.

Your brain often is calculating the distance to an object by resembling the differences in angels in the images for the right and for the left eye.

The distance between your eyes is the reason why your brain can get an idea of the distance to the object.
The Earth orbits around the Sun. That means that an astronomer observes a star from different positions during a year. The nearest stars are moving more than the stars farther away. Yet it requires accurate instruments to detect, because of the enormous distances to the stars.

You can do calculations like astronomers do, just at a small scale:
An A4 paper-block is in the left side of the table. You are putting the blue and the white needle in a position so that they will be pointing at a star on the black board. Push the paper block to the right side of the table along the back edge of the table. From there you have to set the red needle in order to get the direction to the “star” through the white needle.
You just have to measure the distance between the red and the blue needle. You must also measure the distance from the red needle to a mark you have made for the first position of the blue needle.
The small distance between the red and the blue needle is the baseline in a small triangle. The big distance between the red needle and the mark for the first position of the blue needle is the baseline of a very big triangle. The very small and the very big triangle have the same angles. The height of the small angle (the papers length) is 29.5 cm.

The small baseline is 5 cm.

The big baseline is 200 cm. So the big triangle is $200/5 = 40$ times larger than the small triangle.
Then the distance to the star on the black board must be $29.5 \, \text{cm} \times 40 = 1.180 \, \text{m}$

You can measure the distance to the black board, and see if you have calculated the right result. But when an astronomer is calculating the distance to a star, she or he cannot do this control!

Tycho Brahe was a very accurate astronomer, but he could not measure such a small angle. So he could not prove that the Earth is moving. Much later astronomers could measure this with big telescopes in a meridian mount. In this way it is possible to measure the distance to stars up to 300 light years away.

If a star is farther away the astronomers calculate how much light that is sent from it. They compare this with how much light from the star that has been received. From this they calculate the distance. If a distance is double you just receive $1/4$ so much light from it.

<table>
<thead>
<tr>
<th>The distance to a star</th>
<th>How much light is received</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 unit</td>
<td>1</td>
</tr>
<tr>
<td>2 units</td>
<td>1/4</td>
</tr>
<tr>
<td>3 -</td>
<td>1/9</td>
</tr>
<tr>
<td>4 -</td>
<td>1/16</td>
</tr>
<tr>
<td>5 -</td>
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<td>9 -</td>
<td></td>
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<td>10 -</td>
<td>1/100</td>
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<td>100 -</td>
<td>1/10.000</td>
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<td>1000 -</td>
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<td>10,000 -</td>
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<td>100,000 -</td>
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<td>1,000,000 -</td>
<td>1/1,000,000,000,000</td>
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</tbody>
</table>

To day the distance to a planet in the Solar system is measured with radar.
20. How does the Braking Distance Depend of the Speed.

Aim: to show that energy depends of velocity * velocity

Goal: After the activity the pupils are able to:
- understand that driving fast may cause big damage
- explain the enormous energy in a meteorite
- explain the energy in a storm

| The ruler with 3 coins at 20 cm 40 cm 60 cm |
| Ready to push with the ruler |
| You have just pushed. The coins were gliding 1 unit 4 units 9 units |
One coin is at 20 cm – another coin is at 40 cm. Press the ruler against the table at the end (zero cm) Turn back the ruler and push it into the coins. The coin at 40 cm will get the double speed of the coin at 20 cm. So you might think that the coin at 40 cm will glide the double distance than the coin at 20 cm. But its seems that it is gliding 4 times longer. Try again. Did you get the same result?

Why is it so that you will glide 4 times longer, when you are at the double speed?

Try the experiment with an extra coin at 60 cm. This coin will get 3 times the speed. But you will find that it will be gliding 9 times the distance of the coin at 20 cm. Why is that so?

<table>
<thead>
<tr>
<th>experiment</th>
<th>The coin at 20 cm</th>
<th>The coin at 40 cm</th>
<th>The coin at 60 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>gliding distance1</td>
<td>4 cm</td>
<td>16 cm</td>
<td>36 cm</td>
</tr>
<tr>
<td>gliding distance2</td>
<td>- 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 4
- 5
- 6

Teori:
When speed is doubled the car will glide 4 times longer. When the speed is tripled the car will glide 9 times longer.
Energy depends of the velocity in the second power

\[ E = 0.5 \times m \times v \times v \]
m = mass, \( v \) = velocity, \( E \) = energy

<table>
<thead>
<tr>
<th>speed</th>
<th>Braking distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 unit</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>(calculate)</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>10.000</td>
<td></td>
</tr>
<tr>
<td>100.000</td>
<td></td>
</tr>
<tr>
<td>1.000.000</td>
<td></td>
</tr>
</tbody>
</table>
What can car-drivers learn from your experiment?

**Reaction distance** is the distance you are driving from when you see the danger until you hit the brakes.

**Braking distance** is the distance from when begin to brake until you have stopped.

The reaction distance plus the braking distance is the **stopping distance**

Your reaction distance will increase proportionately with your speed.
Your **Braking distance will** increase proportionately with your speed in the second power.
Your braking distance will get very, very long if you drive fast.

Your braking distance will also depend of the materials in the road.
Calculate the braking distances in these examples:

<table>
<thead>
<tr>
<th>speed km/h</th>
<th>Reaction distance at 1 sec.</th>
<th>Braking distance i m</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2,8</td>
<td>0,63</td>
</tr>
<tr>
<td>20</td>
<td>5,6</td>
<td>2,5</td>
</tr>
<tr>
<td>30</td>
<td>8,3</td>
<td>6</td>
</tr>
<tr>
<td>40</td>
<td>11,1</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>13,9</td>
<td>16</td>
</tr>
<tr>
<td>60</td>
<td>16,7</td>
<td>24</td>
</tr>
<tr>
<td>70</td>
<td>19,4</td>
<td>32</td>
</tr>
<tr>
<td>80</td>
<td>22,2</td>
<td>40</td>
</tr>
<tr>
<td>90</td>
<td>25,0</td>
<td>calculate</td>
</tr>
<tr>
<td>100</td>
<td>27,7</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>30,6</td>
<td>80</td>
</tr>
<tr>
<td>120</td>
<td>33,3</td>
<td></td>
</tr>
</tbody>
</table>

**Asteroids og comets** may hit The Earth with a velocity 1000 times larger than the speed of a car. The energy will then be 1000 * 1000 times larger.
Further more the mass of a meteorite may be enormous.
Find images of impact craters on the web.
21. Measure the Diameter of the Sun

*Aim: that pupils can measure the diameter of the Sun*

*Safety: Never look at the Sun*

<table>
<thead>
<tr>
<th><strong>Action</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill a 2 mm hole in the upper end of the large tube. Tape mm paper in the other end.</td>
<td></td>
</tr>
<tr>
<td>Fix the tube to a long stick and set it towards a chair.</td>
<td></td>
</tr>
<tr>
<td>The tube must be pointed at the Sun, but you must not look at the Sun. Move the tube while watching the shadow of it. <strong>When the shadow is smallest the tube will be pointed at the Sun.</strong></td>
<td></td>
</tr>
<tr>
<td>Bend some paper around the lower end of the tube to get more shadow. Look inside but do not look at the Sun!</td>
<td></td>
</tr>
<tr>
<td>Then you will see a light spot on the mm paper. This is an image of the Sun.</td>
<td></td>
</tr>
<tr>
<td>The spot will move, so when it is outside of the mm-paper you must move the tube until the shadow is smallest possible.</td>
<td></td>
</tr>
</tbody>
</table>
This image of the Sun is 7 mm in diameter.

Look inside at the spot, never outside along the tube where the Sun will be. Never look at the Sun.

The angle $v$ is the angle we see the Sun.
The length of the tube is called $r = 0.74$ m for this tube.
The distance to the Sun is $R = 150,000,000$ km.
The diameter of the image is $d = 7$ mm.
\[ d = 2 \times 3.14 \times r \times \frac{v}{360} \]

This means:

\[ v = d \times \frac{360}{6.28 \times r} \]

Here: \( v = 0.007 \times \frac{360}{6.28 \times 0.74} = 0.5 \text{ degrees} \)

So we have calculated that we see the Sun in an angle of 0.5 degrees.

Because we know the distance to the Sun we can calculate the diameter of the Sun.

\[
D = 2 \times 3.14 \times R \times \frac{v}{360} = 2 \times 3.14 \times 150 \,000 \,000 \,000 \times 0.5/360 = 1 \,310 \,000 \,000 \,m
\]

So this calculation: The diameter of the Sun is 1 310 000 km

Astronomers have with much better instruments calculated that the diameter of the Sun is 1.4 mill. km. That is more than 3 times the distance to the Moon.

### 22. Measure the Diameter of the Moon

**Aim:** to measure the diameter of the Moon

You may look at the Moon. But Never Look at the Sun
Do like the boys here. Make a hole in 2 A-4 cardboard. A 120 cm string goes through the holes. A match is tied to keep the string in the hole. In the front cardboard is a hole that is exactly 1 cm wide.

Now the child farthest from the Moon looks at the Moon through the 1 cm hole. The cardboards are taken closer to one another until the Moon exactly fills the hole of 1 cm. Now measure the distance between the cardboards by measuring the length of the string.

You see a small triangle from the eye to the 1 cm hole. A big triangle from the eye to the Moon has got the same angles.

Hole = 1 cm

Distance between the cardboards = a cm

The average distance to the Moon is 384.000 km. (Max. 406.680 km, min. 356.410 km). We use the average distance because our experiment is not very accurate.

\[
\frac{1 \text{ cm}}{a} = \frac{\text{The diameter of the Moon}}{\text{The distance to the Moon}}
\]

\[
\text{The diameter of the Moon} = 384.000 \text{ km} \times \frac{1}{a}
\]

The diameter of the Moon is 3.474 km. This is ¼ of the diameter of the Earth.

What was your result of the diameter of the Moon?

You see a waning moon in the Morning. A week after full moon is a good opportunity to do this experiment at school in the morning.

23. Stellarium a Free Planetary Program

Download from [www.stellarium.org](http://www.stellarium.org)
You can see the sky at any place and time. You can zoom, see names, see fast motion. It is easy.
24. Study the Moon here
http://wms.lroc.asu.edu/lroc_browse/view/wac_nearside

25. Downloads for the Galileoscope
https://www.galileoscope.org/gs/content/downloads

Galileoscope assembly instructions:

Galileoscope assembly instructions (Just pictures):

Galileoscope optics activity guide:

Galileoscope observing guide:

Galileo's Classroom:
http://www.uwyo.edu/caper/info.asp?p=16091

26. Video
http://www.boernafgalileo.dk/galleri.htm

Eyes on the Skies DVD. The history of telescopes
http://www.spacetelescope.org/videos/archive/category/eyesontheskies/

Human spaceflight: Zero gravity
Mission 1: Newton in Space
Mission 2: Body Space
Mission 3: Space Matters
Mission 4: Space Robotics
http://www.esa.int/esaHS/SEMZTFYO4HD_education_0.html

Ingredients for Life: On Earth and in Space
http://www.esa.int/esaHS/SEMU2XP4KKF_education_0.html

Have fun with your experiments.

Thank you very much to Ulla Bitsch-Larsen for improving my English.

April 2011
Kind regards from
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