Kingdom of Cambodia

Nation - Religion - King

Low-Cost Experiments for Physics Education

Part 2

Chapter 4: Pressure

Chapter 5: Optics

Chapter 6: Electromagnetism





Teacher Training Department 2012

Physics Experiment Manual: Part 2

Chapter 4: Pressure

Chapter 5: Optics

Chapter 6: Electromagnetism

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Prologue

The main objective of this manual is to enable science teacher trainers and teachers to introduce practical activities to their students, thus improving their critical thinking and problem solving skills. All experiments are designed with low-cost and easy-to-find materials.

This manual is complementary with other learning materials developed by the Ministry of Education, Youth and Sport, in cooperation with VVOB. These include a manual on student centred approaches for science education, science posters and boxes with low-cost learning materials for all science subjects.

To ensure an effective use of the experiments in this manual, we suggest the following:

1. Prepare all materials for the experiment before the start of the lesson.
2. Allow students to think, to predict, to observe and to explain during the practical activity. In this way, they will grow familiar with the scientific method.
3. Allow as much as possible hands-on time for students.
4. Revise student understanding after doing the experiment and adjust your lesson plan if necessary.

The Ministry hopes that you all will make the best use of the materials to improve the quality of science education.

Phnom Penh, 21 September 2012

H.E Nath Bunroeun
Secretary of State
For Minister

Preface

This manual was developed by the Ministry of Education, Youth and Sport, in cooperation with VVOB and the Regional Teacher Training Centre (RTTC) of Kandal. Its objective is to improve science teacher training by introducing student centred approaches in lessons.

This manual consists of a set of science experiments that will help students to understand the main concepts outlined in the RTTC curriculum. All experiments have been tested by teacher trainers and teachers. Complementary to the manual is a set of DVD's with short movie clips of all experiments in order to help teacher trainers with integrating experiments in their lessons.

For each experiment we include a set of objectives, a link to the relevant lesson in the curriculum, the material needed to do the experiment, a detailed description of the procedure, observations, an explanation and additional questions. Where appropriate we add ideas for variations.
We are convinced that this manual will contribute to an improvement of science education in Cambodia. However, do not hesitate to communicate us your comments and suggestions.

We are looking forward to receiving your comments. We wish you an inspiring experience and many satisfying science lessons with this manual.

The authors,

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Introduction

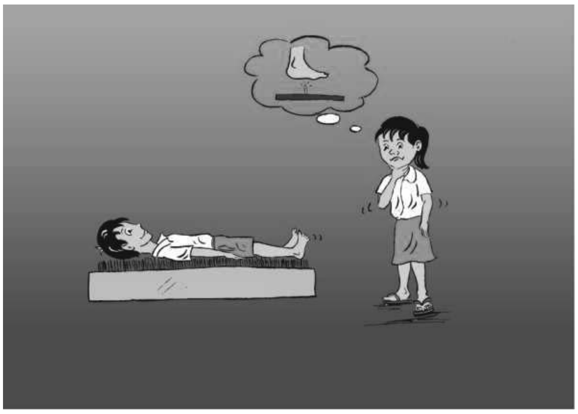
This manual consists of a set of experiments that will help students to understand the main concepts of pressure in solids, liquids and gases. All experiments have been tested. For each experiment we included a link to the curriculum, a list of the material needed, a detailed description of the procedure, observations and an explanation. Where appropriate we added ideas for variations and questions to probe for deeper understanding. Videos of each experiment are also available on YouTube and on **http://krou.moeys.gov.kh**

We are convinced that you will enjoy using this manual. However, no manual is perfect and there may still be mistakes. Do not hesitate to communicate us your comments and suggestions.

Chapter 4: Pressure

Main concepts covered

Pressure: The ratio of force to the area upon which that force is distributed.
Pressure = force / area
The unit of pressure is **Pascal**, 1Pa is the pressure created by a force of 1N on a surface of $1m^2$



Liquid pressure = depth x gravity x density

Buoyant force: The net upward force that a fluid exerts on an immersed object.

Archimedes' Principle: An immersed object is buoyed up by a force equal to the weight of the fluid it displaces.

Principle of flotation: An object floats if its density is lower than that of the fluid it is immersed in.

Pascal's principle: The pressure applied to a motionless fluid confined in a container is transmitted undiminished throughout the fluid.

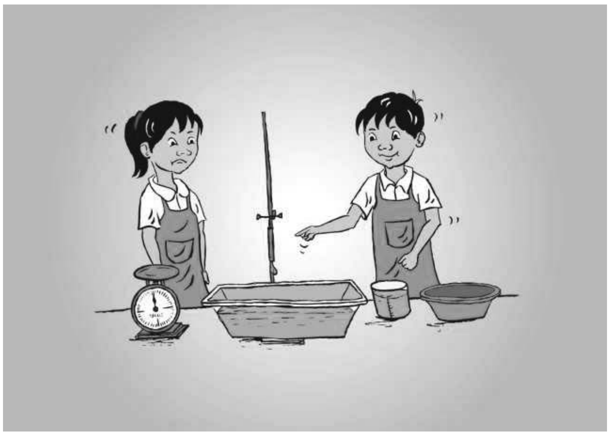
Surface tension: The tendency of the surface of a liquid to contract in area (due to cohesion) and thus behave like a stretched elastic membrane.

Capillarity: The rise of a liquid in a fine, hollow tube or narrow space due to large adhesive forces.

Atmospheric pressure: The pressure against bodies immersed in the atmosphere. It results from the weight of air pressing down from above. A sea level atmospheric pressure is about 101 kPa.

Archimedes principle (for air): An object in the air is buoyed up with a force equal to the weight of the displaced air.

Bernoulli's principle: Where the speed of a fluid increases, internal pressure in the fluid decreases.

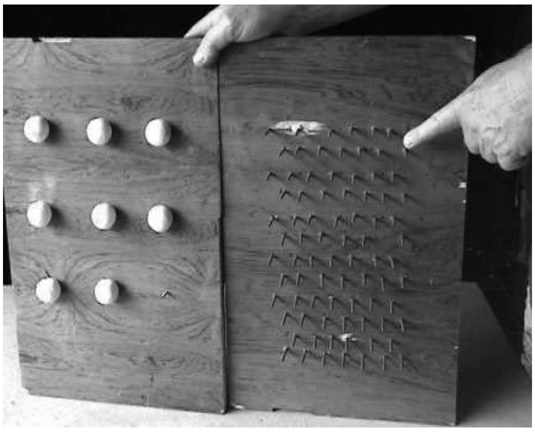


1. Pressure in solids and liquids

1.1 Relation between pressure, force and surface area #1

Objectives

- Students can explain the difference between force and pressure.
- Students can explain why the board with nails is more comfortable than the one with ping pong balls.
- Students can apply concepts of force and pressure to situations in daily life.



Link with curriculum

Physics textbook: Grade 7, chapter 4, lesson 1, published 2009

Material

- Two equally big wooden boards
- 4 polystyrene balls or ping pong balls, cut in half
- Set of nails. The closer the space between the nails the clearer the observations. A space interval of 1 cm between nails is fine.

Procedure

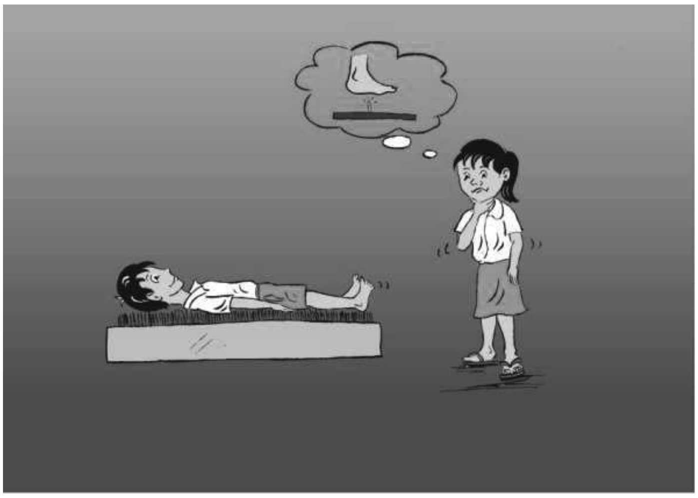
On one board attach three rows of three polystyrene balls. In the other one you hit about 12 rows of 7 nails (the pins point outwards). The more nails and the closer together, the better the effect will be. Use each board as back (of a chair). Describe what you feel; which back feels more comfortable?

Observations

The board with polystyrene balls feels more uncomfortable than the one with the nails.

Explanation

There are only nine polystyrene balls, so nine points of support for your back. Each point has to carry one ninth of the weight of your back. The nails don't push so hard against your back because there are so many. Every nail has to support only a very small part of the weight of your back.
Pressure is the force divided by the area over which the force is exerted.



Conclusion

Pressure is the force divided by the area over which the force is exerted.

1.2 Relation between pressure, force and surface area #2

Objectives

- Students can explain the difference between force and pressure.
- Students can apply concepts of force and pressure to situations in daily life.

Link with curriculum

Physics textbook: Grade 7, chapter 4, lesson 1, published 2009

Material needed

- wooden plate
- approx. 10 toilet rolls

Procedure

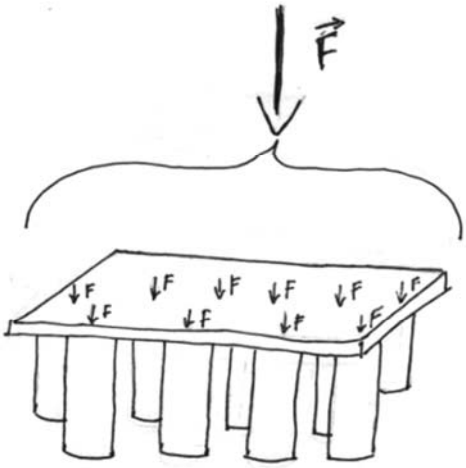
- The teacher asks the students how many toilet rolls one needs to support a person. Normally they pick a high number, like 15. Organize a little class discussion about how the person has to get on the plate. The best way is to stand between two tables so that the person can push himself up and put his two feet at the same time on the plate. Discuss why you cannot just step with one foot on the board.
- Then repeat this experiment after removing one roll. Students have to think how to order the remaining rolls. In the end a person with a mass of 50 kg can stand on 3 rolls!!!!

Observation

How many persons can stand on these cardboard rolls before the set-up collapses? Explain.

Explanation

The force we exert on the board is evenly distributed across the entire surface. Each roll thus has to bear a part of the total force only.
Each roll can bear about 200 N (a mass of 20kg) before it collapses. Ten rolls will thus easily bear the weight of two persons, if positioned right.



Conclusion

Pressure is the force divided by the area over which the force is exerted. Force is not the same as pressure.

1.3 Relation between pressure, force and surface area #3

Objectives

- Students feel what pressure does and which quantities define it.
- Students can explain the difference between force and pressure.
- Students can apply concepts of force and pressure to situations in daily life.

Link with curriculum

Physics textbook: Grade 7, chapter 4, lesson 1, published 2009

Material (2 experiments)

- a pencil per student
- a weight (3kg) with a hook
- an iron thread
- a peace of rope
- a tie

Procedure

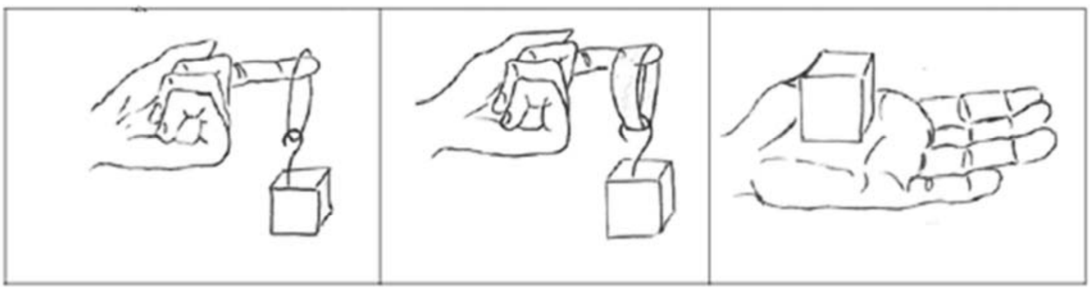
First experiment: Let the students hold their pencil between thumb and little finger. Let them push as hard as they can hold it.
Second experiment: Let a student carry the weight first by the iron thread, than the rope and then the tie. He will feel a big difference. The fourth way, the way with the least pain, is to carry the weight on your hand.

Observation

The students feel that the same force can have a different effect depending on the surface on which the force acts. With both experiments it is possible not only to feel but also to see the effect of the pressure. In the first one the point leaves a little marl. In the second experiment the iron thread leaves a fine line in the palm of the hand.

Explanation

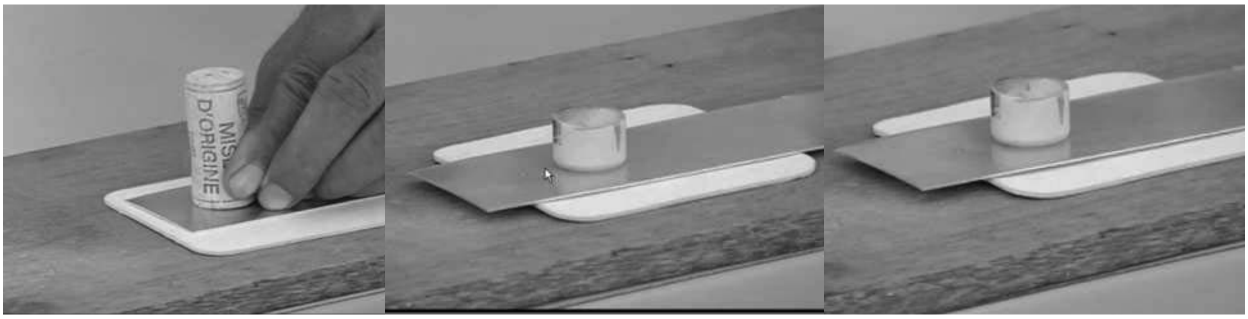
As the pencil is pushed between the two fingers the force is concentrated on the point at one side and is spread over the bases of the pencil on the other side. This results in a different feeling.



1.4 Experiment on difference between force and pressure

Objectives

- Students can explain the difference between force and pressure.
- Students can apply concepts of force and pressure to situations in daily life.



Link with curriculum

Physics textbook: Grade 7, chapter 4, lesson 1, published 2009

Material

- cork
- hammer
- needle
- pair of tongs
- copper or aluminium plate

Procedure

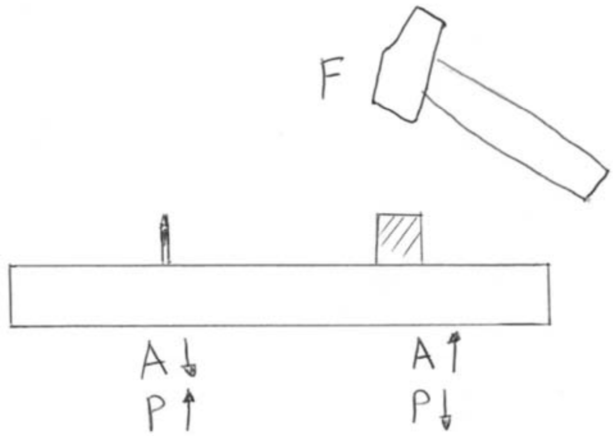
The objective of the experiment is to hammer the needle into the metal plate. We use the cork as support, to hold the needle so it wouldn't break. Put the needle into the cork so the point just doesn't come out on the other side. Remove the top part of the needle that is still sticking out of the cork with a pair of tongs. Place the cork on the metal plate and hit it hard with a hammer.
Also, hit a piece of cork without a needle with the hammer. Show students the different result.
Tell them you hit the plate both times with the same force.

Observation

The needle makes a hole in the plate. The cork without the needle doesn't make a hole, although the force applied was the same.

Explanation

The surface where the needle touches the plate is very small. All the force of the hit is concentrated in this point, so it is a very large force.
Thus: the magnitude of a force does not only depend on the pressure, but also on the magnitude of the surface on which this force is exercised.



Conclusion

Force and pressure are different things. Pressure is affected by the surface over which the force is exerted.

1.5 Experiment on the effect of depth on pressure in a liquid

Objectives

- students can explain how pressure in a liquid depends on the depth
- students can explain pressure in liquids to situations in daily life

Link with curriculum

Physics textbook: Grade 8, Chapter 5, lesson 2, published 2008

Material needed

- large plastic bottle
- tape

Procedure

Use a hammer and nail to poke three holes in the side of the can, one near the top, one at the middle, and one at the bottom.
Use the strip of duct tape to cover all the holes, and then fill the can with water. Hold the can over a sink or outside and quickly remove the tape. Notice how strong the water stream is that comes from each of the three holes in the can. There should be a difference between the results at each hole.

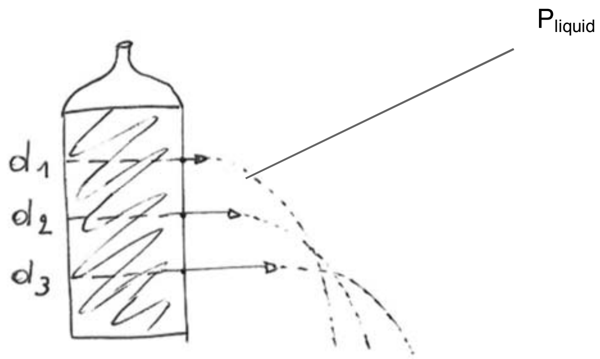
Extension: Do the experiment with two sizes (diameters) of bottles, for example a small water bottle and a big coke bottle. Make holes at the same distance from the top (so that the water levels above the holes are equal)

Observation

We have evidence that the pressure in water increases as you get deeper. You observe that the stream of water from the bottom hole shot out harder than that from the middle hole, which shot out harder from that from the top hole.
The size (diameter) of the bottle doesn't affect the water stream. Only the height of the water column above the hole is important.

Explanation

The higher the pressure (remember that pressure is force per unit area), the harder it pushes on the water as it leaves the hole. Makes sense, then, that the pressure gets higher and the water pushes harder as you get closer to the bottom of the can or deeper in the water.
The liquid pressure pushes the water out horizontally (or perpendicular to the side of the bottle). As soon as the liquid is out the bottle, only gravity acts upon it.



Every 10m you go under water the pressure increases by one atmosphere. This is why submarines and deep sea diving suits have to be so strong to avoid being crushed.
This experiment also explains why hydroelectric dams have to be so high. The deeper the water, the higher the pressure but also the more energy there is to extract.

Conclusion

The higher the pressure, the harder it pushes on the water as it leaves the hole.

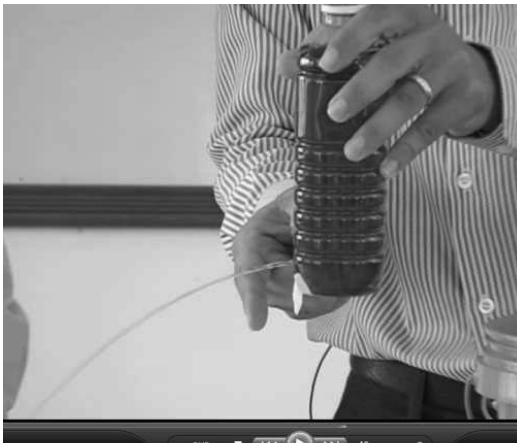
Caution

With this experiment there can be 2 problems.
If you put the top hole to close to the top, the students will not have enough time to observe the 3 streams. And while the water level is dropping the jets change. And they change fast.
You can solve these problems by pouring water into the bottle throughout this experiment. The best way is to keep pouring so that the bottle overflows. In that case the pressure keeps the same during the experiment and the students have enough time to observe the experiment.

1.6 Effect of falling on hydrostatic pressure

Objectives

- students can explain why water doesn't flow out of a falling bottle
- students can explain pressure in liquids to situations in daily life



Pressure = Atmospheric Pressure + Liquid pressure

Free Fall: g = 0

Link with curriculum

Physics textbook: Grade 8, Chapter 5, lesson 2, published 2008

Material needed

- an open plastic bottle filled with water
- the plastic has a small hole in it near the bottom

Procedure

An open plastic bottle filled with water has a hole drilled in it near the bottom.
If the bottle is stationary, the water will flow from it. What happens when the bottle falls? Will it empty faster? Will the water flow less fast?

Observations

When the bottle falls, the water stops flowing out the bottle.

Explanation

Stationary bottle: The water is pushed outside by the hydrostatic pressure at the level of the hole. This pressure is a result of the weight of the layers of water above the hole.

Falling bottle: Falling objects are weightless. The top layers of water no longer exert any pressure on the layers below, since all of them fall at the same speed. The hydrostatic pressure is removed and the water will remain in the bottle.

Conclusion

In falling objects the hydrostatic pressure is removed and the water will remain in the bottle.

Tips

Many students may not see it the first time or be so surprised that they don't believe what they see.
Make sure you have at least three bottles to repeat the experiment.
Try to find a high enough spot so that the bottle can fall long enough.

2. Buoyancy and Archimedes principle

2.1 Experiment on buoyancy #1

Objectives

- Students understand the concept of buoyancy.
- Students can explain why it is easier to submerge a small ball than a large ball.

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 3, published 2008

Material needed

- A bowl of water
- 2 plastic balls, as light as possible, different in size

Procedure

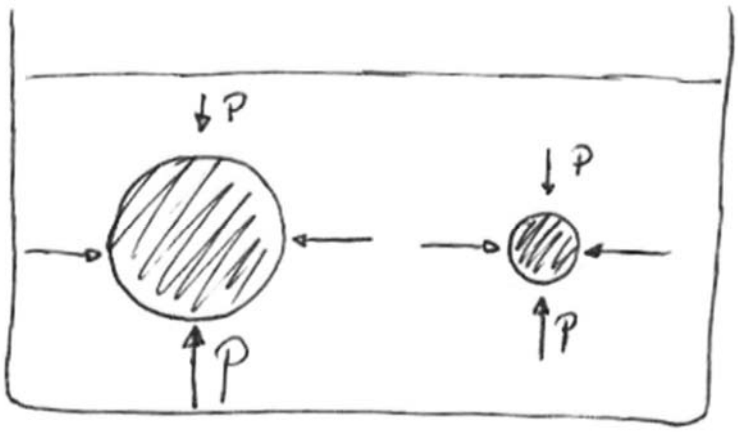
Let the students try to submerge the two balls.

Observations

The water resists when you try to submerge a ball. The bigger the ball is, the harder you need to push to submerge it.

Explanation

The more the water is displaced, the bigger the buoyancy force it creates.
You may repeat the experiment with 2 balls of different weight, but with the same size (made from different Material). Submerging them will require an identical force, illustrating that the upward force is independent of the weight of the submerged object. The heavier the ball the more gravity will help you to win over the buoyancy force and the less you have to push.



Conclusion

The buoyancy force is determined by the volume of the displaced object. That's why it is more difficult to submerge a bigger object.

Questions

Why is it harder to submerge the big ball? Since it is heavier, it should be easier, no?
(The big ball is harder to submerge because it experiences an upward force proportional to its volume. The magnitude of the upward force is equal to the weight of the displaced water.)

2.2 Experiment on buoyancy #2

Objectives

- Students can explain the expression of "volume of water displaced".

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 3, published 2008

Material needed

- A bowl of water (or graduated cylinder)
- A stone or other irregularly shaped object

Procedure

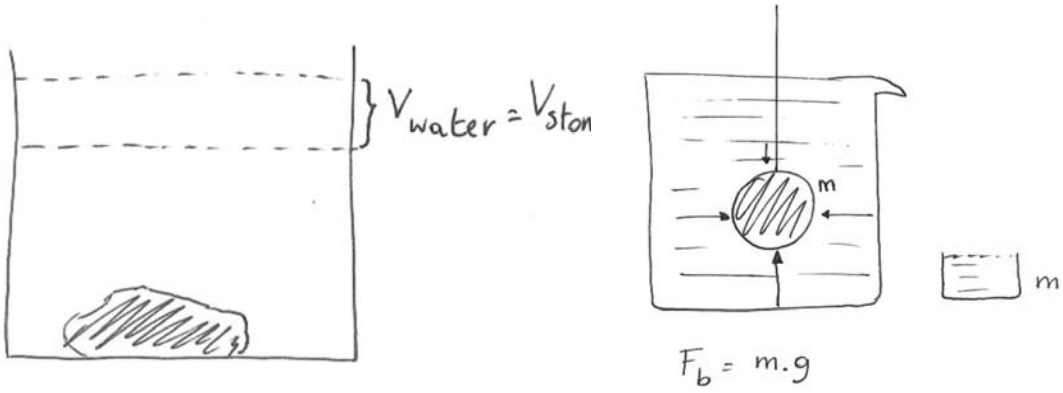
Ask students how they can determine the volume of an irregularly shaped object such as a stone. Present them with the necessary material.

Observations

When you submerge the stone in the water, the water level will rise by exactly the same amount as if a volume of water were poured in that equals the volume of the submerged object.

Explanation

The volume of the stone is equal to the volume of the water displaced. You need this concept to understand buoyancy and the Archimedes principle.



Conclusion

The volume of the stone is equal to the volume of the water displaced.

Question

How could you measure the volume of a floating object? (First, measure the volume of a (sufficiently large) stone, and then measure the volume of the stone, attached to the floating object. Subtracting the two yields the volume of the floating object.)

2.3 Experiment on buoyancy #3

Objectives

- Students can illustrate the variables that influence the buoyancy force.
- Students can recognize applications of the buoyancy force in daily life.

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 3, published 2008

Material

- Bowl or bucket with water
- dynamometer (e.g. 10 N)
- weight of approx. 1 kg such as a big stone
- piece of cord
- if it is possible, 2 blocks with the same size, made of different Material

Procedure

First experiment

- put the cord around the stone and hang it on the dynamometer

- measure the weight of the stone
- submerge the stone in water and measure the weight again

Second experiment

- Repeat this experiment but submerge the object very slow.

Third experiment

- Once totally submerged, lower the object more

Fourth experiment:

- Repeat the first experiment with two blocks (different Material) of the same volume.
- Measure the weight of both blocks before and after they are submerged.

Observations

First experiment: the weight of the stone decreases as you submerges it in the water. The water pushes back.

Second experiment: the more the object is immerged, the less it weights
Third experiment: the dynamometer doesn't change

Fourth experiment: the weight and the weight when submerged is not the same. The difference between the two is the same.

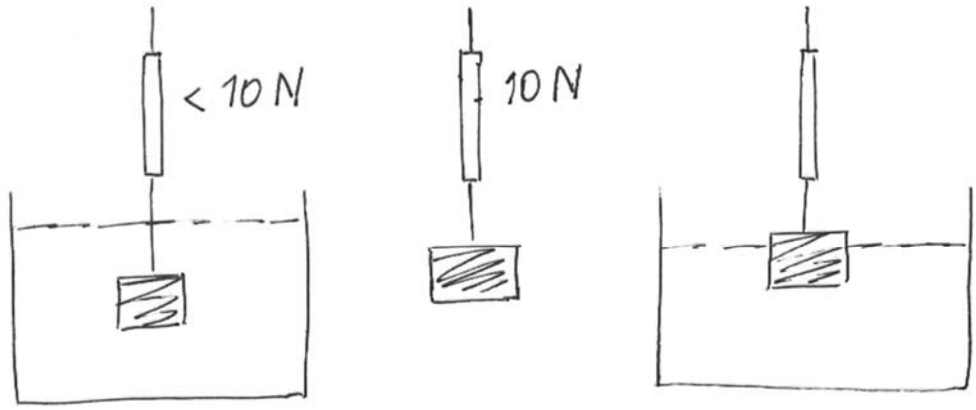
Explanation

First experiment: the buoyant force on an object is the difference between its weight and its weight when submerged.

Second experiment: the buoyant force is influenced by the amount of water that has to get aside. This in turn is determined by the volume of the object (not its mass!!).

Third experiment: once submerged, the magnitude of the buoyant force is not influenced by the depth of the object. Once submerged, the force doesn't change anymore, unless the density of the fluid changes (for example due to temperature changes).

Fourth experiment: the buoyant force is not influenced by the composition (density) of the object.



Conclusion

The strength of the buoyancy force is determined by the volume of the displaced liquid, so not by its weight.

Questions

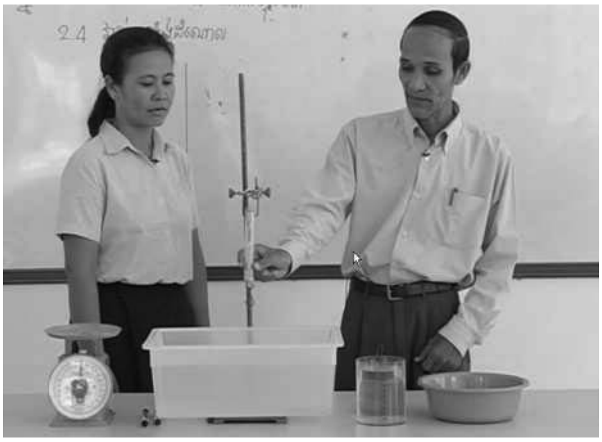
1. Two blocks of identical size are submerged in water. One block is lead and the other is aluminium. Upon which is the buoyant force greater? (The force is the same on each block because they displace the same volume of water. The buoyant force is only determined by the volume of water displaced, not the object's weight. The buoyant force is not influenced by the density of the immersed object)

2. As a boulder thrown in the sea sinks deeper and deeper into the water, does the buoyant force upon it decrease or increase? (The buoyant force stays the same because the displaced volume of water doesn't change. The buoyant force is not influenced by depth.)

2.4 Measuring the buoyancy force

Objectives

- Students can illustrate the variables that influence the buoyancy force.
- Students can recognize applications of the buoyancy force in daily life.



Link with curriculum

Physics textbook: Grade 8, Chapter 5, lesson 3, published 2008

Material

- Bowl or bucket with water
- dynamometer (e.g. 10 N)
- weight of approx. 1 kg such as a big stone
- piece of cord
- balance

Procedure

- put the cord around the stone and hang it on the dynamometer
- measure the weight of the stone
- submerge the stone in water and measure the weight again

- extension: partially submerge (immerge) the stone and measure its weight
- extension: measure the weight of the water with the balance. Try to have 10N of water. This makes it easier to make calculations. What happens with the total weight as you submerge the stone?

Extension

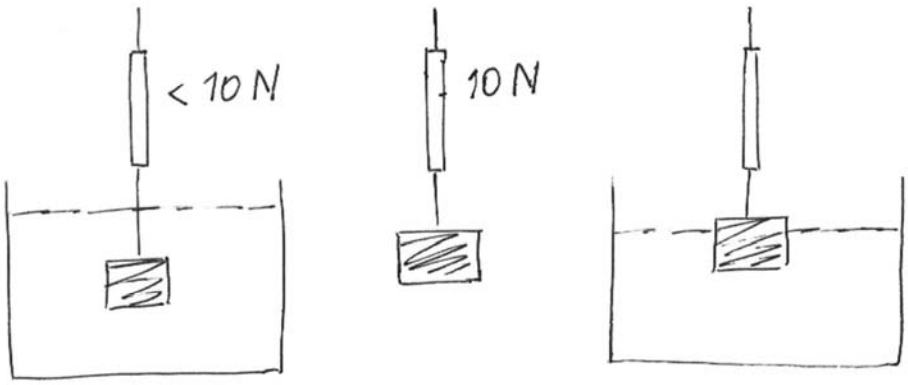
Another way to demonstrate the Archimedes effect is to use a bowl which allows you to collect the overflowing water. Fill the bowl completely with water. Then hang a dynamometer on an object and submerge it in the bowl. Collect the overflowing water in a small bowl. Use a second dynamometer to measure the weight of the water. The second dynamometer should indicate a weight that is equal to the difference between the original weight of the object and the weight when it is submerged. The buoyancy force is equal to the weight of the displaced liquid.

Observations

- The weight of the stone decreases when you submerge it in the water.
- The total weight on the balance is the weight of the water plus the weight of the stone minus the amount of the buoyant force.

Explanation

Submerging the stone causes an upward buoyant force equal to the weight of the water displaced. This reduces the weight of the stone. The bigger the volume of the stone the higher the buoyant force will be.



Conclusion

The strength of the buoyancy force is determined by the volume of the displaced liquid, so not by its weight.

Questions

1. What is the buoyant force on the rock? (The weight of the rock before submerging minus the weight of the rock after submerging)
2. What is the scale reading when the rock is suspended beneath the surface of the water? (This depends on mass of the stone)
3. What is the scale reading when you release the rock and it rests at the bottom of the container? (Same answer as in 2)

2.5 Experiment on buoyancy #4

Objectives

- Students can apply the concepts of buoyancy, density and the Archimedes principle.
- Students can recognize applications of the Archimedes principle in daily life.

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 3, published 2008

Material

- Shirt button, small stone, raisin, rice grain or similar small object. It is important to select an object with the right weight: if it's too light, it will float all the time and if it's too heavy it won't rise to the surface.
- Drinking glass
- Carbonated soda

Procedure

Fill a glass with carbonated soda. A clear soda is probably best because you can see through it easily. Drop the button into the glass. If it floats on top of the soda, give it a tap with your finger and send it to the bottom of the glass.

Observations

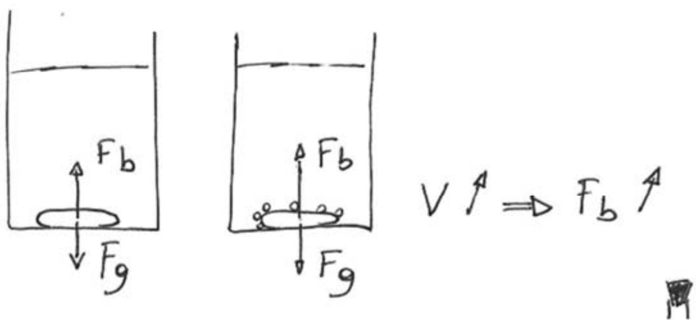
Small bubbles begin to form around the button.
Suddenly the button rises to the top of the glass. If necessary, give it a tap to knock the little gas bubbles off and it will sink to the bottom again. This will go on as long as the soda is fizzy. You can have several buttons rising and falling in the same glass.

Explanation

The gas bubbles are carbon dioxide, which is what gives soda its “fizz”. When the bubbles attach to the button they give it enough lift, or buoyancy, to make it rise.
The attached bubbles cause the volume of the button to increase, so that the buoyant force also increases. On the other hand the weight of the object remains the same, so that the net force on the object becomes an upward force

Conclusion

The gas bubbles increase the total volume of the button, thus increasing its buoyancy force. If the buoyancy force is greater than the gravity force, the object will raise to the surface.



2.6 Effect of the liquid on buoyancy

Objectives

- Students can explain the effect of the density of the liquid on the buoyancy force.
- Students can recognize examples where the density of the liquid affects the buoyancy force in daily life.

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 3, published 2008

Material needed

- egg
- glass
- water
- salt

Procedure

Place an egg in a bowl of tap water. Then dissolve salt in the water until the egg floats.
An alternative way to do this experiment is to do present the students with 2 bowls, one where the egg is floating and the other where egg sinks to the bottom. Ask students to come up with a hypothesis that explains their observations.

Variation 1: you can do a similar experiment with a can of coca cola and a can of energy drink. The coca cola will float in the water, whereas the energy drink will sink. Let your student try to find an explanation for this observation. (The density of the energy drink is higher due to a higher concentration of sugar).

Variation 2: it is possible to find the salt solution where the eggs float in the solution. It's not so easy, you need a steady hand and a lot of patience, but it can be done.

Variation 3: try to find a rotten egg. End the experiment with this extension. Put the rotten egg in the tap water and it will float. Let the students discuss and find the solution.

Observation

First the egg sinks. When enough salt is dissolved, it rises to the surface and floats.
How does the density of an egg compare to that of tap water? And to the density of salt water?

Explanation

By adding salt to the water you increase the density of the water. As a result the buoyant force will increase.

Conclusion

The buoyancy force depends on the density of the displaced liquid.

2.7 The “Cartesian Diver”

Objectives

- Students can explain the up and down movement of the ‘Cartesian diver’ applying concepts of density and the Archimedes principle.
- Students understand that floating and sinking are not related to the mass of an object but to the volume of liquid it displaces.

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 3, published 2008

Material needed

- Empty plastic water bottle
- Plastic pen cap with small weight attached to it (small stone, piece of clay, small nail). A transparent cap gives the best results for explaining.
- Some paperclips attached to it to make it heavier

Procedure

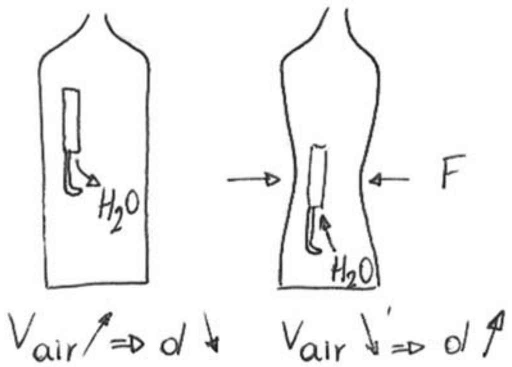
Fill the bottle full with water. Attach some paperclips to the pipette. The pipette or diver floats because there is a bubble of air in it. Make sure the bottle is closed well. Push softly with both hands on the sides of the bottle.

Observations

The diver sinks deeper into the bottle.
If it doesn't sink the diver is too light. Attach some paperclips to make it heavier. However, the diver should still float when you're not squeezing the bottle.

Explanation

The pressure in the bottle increases, when you press the bottle. The air in the pipette is squeezed together so more water can get into the pipette ($V_{air}\downarrow$ because $p\uparrow$ and $p.V$ is constant). It becomes heavier and sinks. When you stop pressing, the air bubble is allowed a bit more space again. Some of the water leaves the pipette and it can float again.
Another explanation: As the air in the pipette is squeezed, less water is pushed aside by the diver so the buoyant force decreases. If the cap is transparent, the students can see that the water goes into the cap.



Submarines use this principle to go up and down. When the space between double walls of the submarine is filled with water, it goes down. When air under high pressure is pumped in between the double walls, the water is pushed out and the boat goes up.

Conclusion

Pressing the bottle alters the amount of air inside the 'diver', thus affecting its density. When the density increases, the 'diver' sinks to the bottom of the bottle.

2.8 Air and buoyancy force

Objectives

- Students can explain their observations in this experiment.
- Students can apply concepts of density and buoyancy to situations in daily life.

Link with curriculum

Physics textbook: Grade 8, Chap 5, Lesson 3, published 2008

Material needed

- 2 glasses
- water container
- water

Procedure

Lower two glasses in water, mouths downward above the air-filled glass. Slowly tilt the lower glass and let the air escape, filling the upper glass.

Observations

You will be pouring air from one glass into another! You can see the air travel from one glass to another.

Explanation

When glass A is pushed into the bowl, it will contain air. When it is tipped on the side, the air will bubble out and the cup will fill with water. When glass B is above glass A the air will bubble into glass A because air is lighter than water.

All objects experience an upward force when submerged in a fluid. This force, called the buoyancy force, is equal to the weight of the fluid displaced by the object. For an object that floats, the upward buoyant force is greater than the object's weight. In fact, the buoyancy force allows low-density objects to not only float, but also causes them to resist being forced under water and to rise quickly to the surface when they are released. Air experiences a powerful upward force when placed under water. When air bubbles are released, they respond to this force and race quickly to the surface.

Conclusion

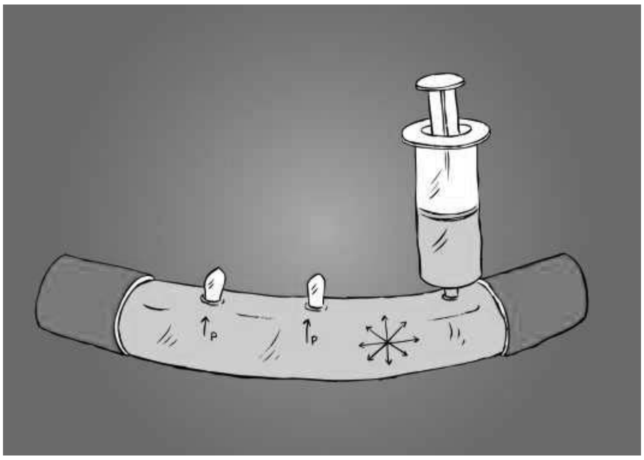
The buoyancy force allows low-density objects to not only to float, but also causes them to resist being forced under water and to rise quickly to the surface when they are released.

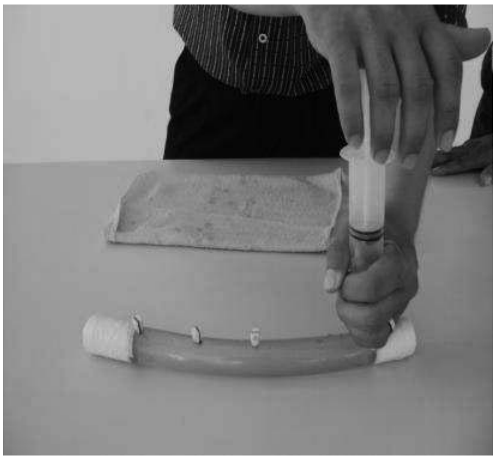
3. Pascal's principle

3.1 How is pressure transmitted in a liquid? (1)

Objectives

- Students understand that pressure is transported invariably through a liquid.





Link with curriculum

Physics textbook: Grade 10, Chap 1, Lesson 4, published 2008

Material

- Glass bottle with 2 or 3 openings
- Cork or plastic caps to seal off the openings
- Water
- Hammer

Alternative (when you don't have a glass bottle with multiple openings)

- Plastic tube (e.g. 30cm length) with 4 holes
- 2 plastic bottle caps

- Cork or plastic caps to seal off the 3 holes
- Tape
- Glue
- Water
- Syringe

Procedure

- Fill the bottle with water and put it on a towel
- Seal the openings off with the corks. Don't put the one you're going to hit too deep. You can push the other ones deeper to increase effect.
- Hit well on one cork.

Alternative

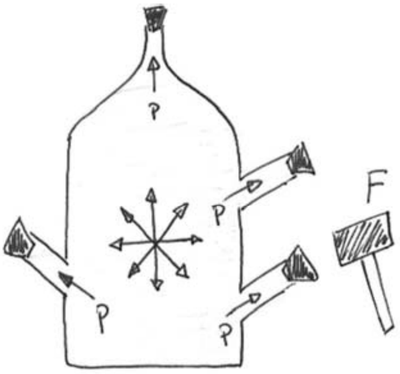
- Make 4 small holes in the plastic tube and seal off the 2 sides of the plastic tube with glue. Use tape to cover the two ends.
- Put small rubber pieces into 3 of the 4 small holes. Make sure that the syringe fits into the 4th hole.
- Fill the tube with water and put it on a towel
- Press well on the syringe.

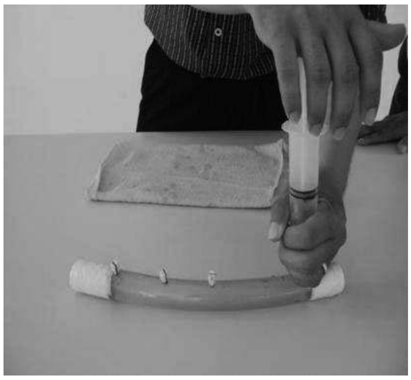
Observations

The other corks or rubber pieces fly away at the same time and with the same speed. The pieces furthest away from the syringe fly away at the same speed as the pieces closest.

Explanation

A force is applied by the hammer or syringe, generating pressure on the liquid. Then the pressure is transported through the liquid. The liquid exerts pressure on the other corks.
Make sure to distinguish correctly between force and pressure!





Conclusion

Pressure is transmitted invariably within a liquid.

Questions

- What is needed to let the cork fly away?
- Where does this force come from? Or is it pressure?
- Does the hammer exert a force or a pressure? On What?
- What does the water do with the pressure?

3.2 How is pressure transmitted in a liquid? (2)

Objectives

- Students understand that pressure on a liquid travels in all directions.

Link with curriculum

Physics textbook: Grade 8, Chap 5, Lesson 2, published 2008

Material

- Small plastic bag
- Water
- Small needle

Procedure

- Fill the bag with water and close it off. Leave some air in the bag.
- Prick small holes at various places. Let your students make suggestions.
- Exert extra pressure on the liquid by squeezing the air in the bag. Do it quickly.
- Repeat if not all students could observe the effect.

Observations

By squeezing the bag the water flows faster out of all holes.

Explanation

Pressure on a liquid is felt everywhere in the liquid in the same amount. Explain that you exert pressure on a liquid, but afterwards the pressure comes from a liquid.

Conclusion

When pressure is exerted on a liquid, this pressure is felt everywhere within the liquid in the same amount.

Questions

- Can I make a hole somewhere in the bag so the water does not flow out?
- Why does the water flow out the bag before I start squeezing it?
- Did you see a hole with no water flowing out?

3.3 How is pressure transmitted in a liquid? (3)

Objectives

- Students understand that the pressure increase is the same in all directions.

Link with curriculum

Physics textbook: Grade 8, Chap 5, Lesson 2, published 2008

Material

- Plastic bottle in which you make holes of different sizes.
- Straw and plastic tubes of different sizes that fit into the holes. The result should resemble the figure below.

Procedure

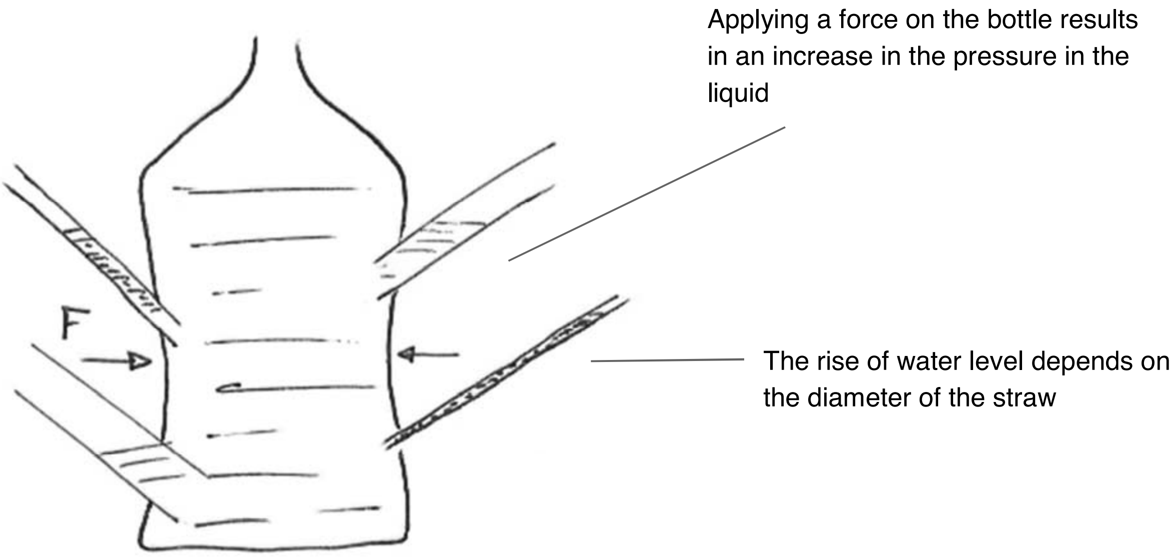
- Exert a small pressure on the bottle <u>above the water surface</u>. Keep it pressed.
- You can start the experiment with a small underpressure. Unscrew the cap. Then, press the bottle a lit, screw the cap back on and release the pressure on the bottle. Make sure the underpressure is no too high.
- Explain that the height of the water depends on the pressure of the water itself. During this experiment we will only observe how much the level increases.
- Press the bottle and gradually increase the force you exert. What do you observe?

Observations

- How much does the water level rise?
- Does it rise equally high in all straws/ tubes?

Explanation

Pressure is applied equally and invariably through the liquid. The higher the diameter of the straw/ tube the lower the increase in water level. However, the increase in pressure is the same everywhere.



Conclusion

The pressure within the liquid is the same everywhere, but the bigger the diameter of the tube the lower the increase in the water level inside the tube.

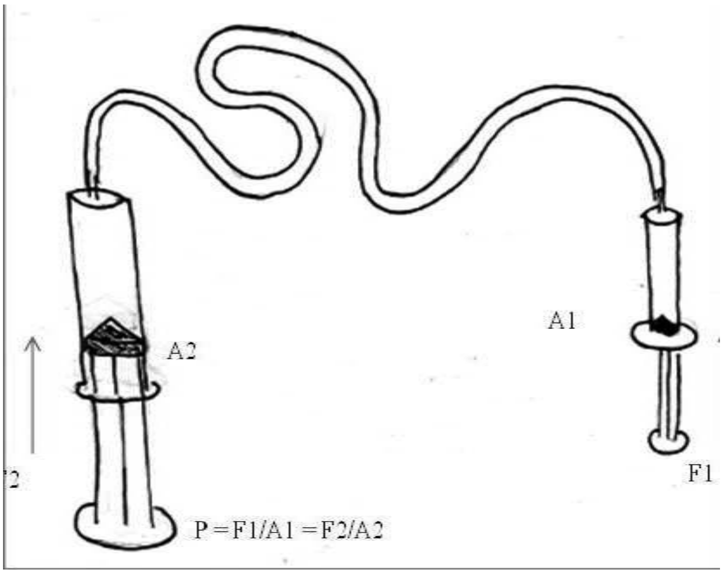
Questions

How much did the pressure increase? Did it increase in all tubes/ straws equally?
Can you combine this and the previous two experiments into one conclusion?

3.4 Experiment to illustrate principle of hydraulic press

Objectives

- Students can apply Pascal’s principle to the functioning of a hydraulic press.
- Students can recognize applications of Pascal’s principle in daily life.



Source: Arteveldehogeschool

Link with curriculum

Physics textbook: Grade 10, Chap 1, Lesson 4, published 2008

Material needed

- 2 syringes of different sizes, the bigger the area of the pistons differ, the better the result.
- Plastic tube connecting them
- it’s best to make one set for every two or three students
- If you can find one really big syringe, make a set with it and let one student (the more sceptical the volunteer, the better) come forward and try to move the pistons.

Procedure

Press each syringe gently one after another. Press both syringes without moving the pistons. Don't press too hard, otherwise everything will get loose.

Observations

On the smallest piston you don't need to push hard. The bigger one is more difficult to move.
With the set with the very big piston it's sometimes impossible to move the big one. Then you have to pull the little one a bit.

Push the piston into the large syringe until you have displaced 10ml of water. Now do the same with the small syringe. What is the difference?
The small syringe requires a slight force only, the large syringe needs to be pressed harder (F1<F2)

Explanation

F1 exercises pressure on a small surface A1, F2 on a large surface A2. Both cause the same pressure p in the water:
p = F1/A1 = F2/A2

A small force can resist a large force, because its surface is much smaller.
However, for the small syringe it is necessary to push the piston further to displace the same volume of water. You don't get something for nothing (Law of Conservation of Energy)

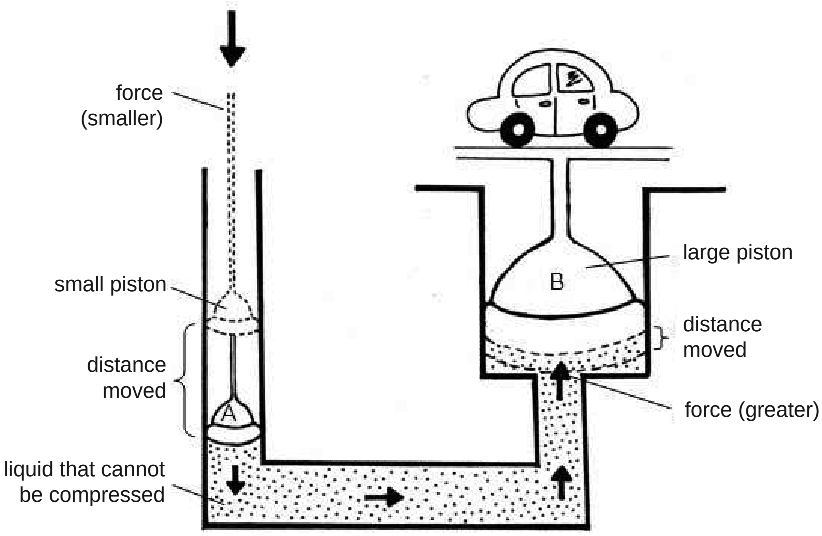
A change in pressure at any point in the fluid at rest is transmitted undiminished to all points in the fluid. This principle can be used to multiply forces such as done with a hydraulic press. By increasing the area of the larger piston (or reducing the area of the smaller piston), we can multiply force, in principle, by any amount. However, the hydraulic press does not violate energy conservation because a decrease in distance moved compensates for the increase in force.

Conclusion

Although the pressure inside the liquid is the same everywhere, the force exerted on an object depends on the surface. By increasing the area over which the pressure is exerted, we can also increase the force. This is compensated by a decrease in the displacement.

Questions

Afterwards present the students with a picture of a hydraulic press (like the one below) and ask them to explain how it works (first leave out the explanation). Students should see the link between Pascal's principle and the way a hydraulic press works.



4. Surface tension

More experiments on surface tension can be found in the chemistry activity manual

4.1 Experiment on surface tension #1

Objectives

- Students can explain the concept of surface tension.
- Students can recognize applications of surface tension in their daily life

Link with curriculum

Physics textbook: Grade 11, Chap 1, Lesson 8, published 2009

Material

- drinking glass
- water
- lots of straight pins (or paperclips)

Procedure

- Put the glass on a kitchen counter or in the sink. Add water until the glass is full to the brim.

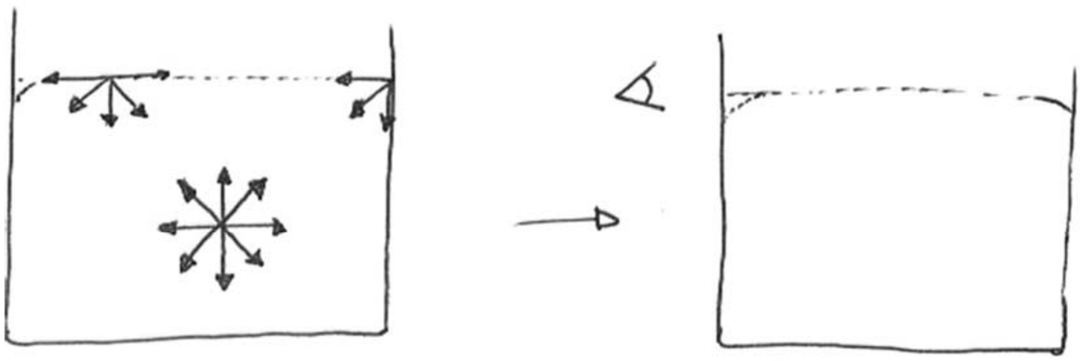
- Ask students how many pins they can add before the water spills over.
- Carefully hold a pin over the glass so its point just touches the surface of the water.
- Let go of the pin so it slides into the water. Add another pin and then another until the water finally runs over.
- You can organize a competition with this experiment. Let every student put a paperclip in the glass. The student that makes the glass flow over has to clean the whiteboard during the class. It can happen that the glass doesn't overflow after all the students put a clip in the water. In that case, continue with the first students again. If it takes a long time with paperclips, you can also use bigger objects like marbles to do the experiment with.

Observations

You'll add more pins than you believed possible. Look sideways at the glass and you'll see the level of the water is above the edge of the glass.

Explanation

Surface tension keeps the water from overflowing long after it seems possible for the glass to hold any more pins.
Make a drawing on the whiteboard indicating that the water surface resembles a stretched elastic membrane preventing water from spilling over.



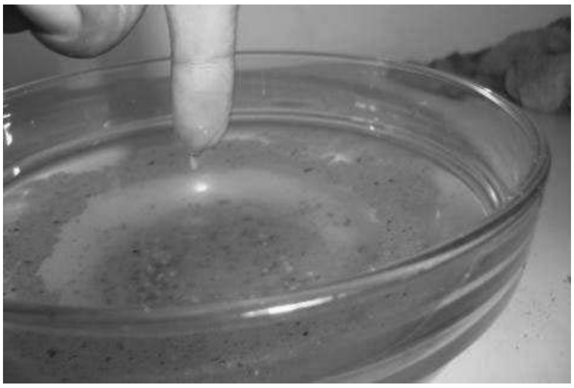
Conclusion

Surface tension, caused by intermolecular forces between water molecules, enables light objects with a large surface to float on the water.

4.2 Experiment on surface tension #2

Objectives

- Students can explain the concept of surface tension.
- Students can recognize applications of surface tension in their daily life



Link with curriculum

Physics textbook : Grade 11, Chap 1, Lesson 8, published 2009

Material needed

- Pepper
- Water
- A deep plate
- Dish washing liquid

Procedure

1. Clean the dish well with water.
2. Put a thin layer of water in the dish.
3. Put a bit of pepper on your hand and throw it carefully on the water.
4. Put some dish washing liquid on your finger and push it in the middle of the dish in the pepper.
5. Stir gently one or twice.

Observations

After adding the dish washing liquid the pepper moves toward the edge of the plate. Upon stirring, the pepper sinks to the bottom.

Explanation

Water consists of molecules. At the top of the water, the molecules are at rest and form a strong layer, called surface tension. When you add dish washing liquid to the water the surface tension is broken. The pepper is pushed towards the side of the dish, because the surface tension is broken in the middle. You can compare it with two people pulling a rope. When the rope breaks the two people will fall backwards.
Upon stirring the dishwashing liquid is spread, reducing surface tension everywhere. The destroyed surface tension (like a broken membrane) causes the pepper to sink.

Conclusion

Surface tension of water can be reduced by adding dish washing liquid or another oil to the water

4.3 How soap works

Objectives

- Students can explain the concept of surface tension.
- Students can recognize applications of surface tension in their daily life

Link with curriculum

Physics textbook: Grade 11, Chap 1, Lesson 8, published 2009

Material needed

- water bottle
- some oil
- some soap or shower gel

Procedure

Put some oil in the water bottle and shake. Then add soap and shake again. What do you observe?

Observations

Water and oil mix as long as you're shaking but when you stop they quickly separate again.
The soap makes a fine film around each oil droplet and a longer time is required for the oil to coalesce again after you stop shaking the bottle.

Explanation

Soap greatly weakens the cohesive forces between water molecules. It breaks down the surface tension around the dirt particles so that water can reach them easily and surround them. The dirt is then carried away in rinsing.

Conclusion

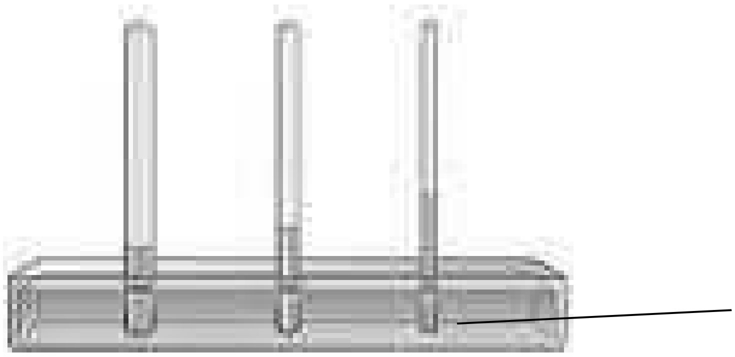
Soap greatly weakens the cohesive forces between water molecules.

5. Capillarity

5.1 Experiment to illustrate capillarity

Objectives

- Students can explain the concept of capillarity.
- Students can recognize applications of capillarity in their daily life



The smaller the tube, the higher the water level due to capillary action.

Material needed

- drinking glass
- water
- bowl
- 2 paper towels

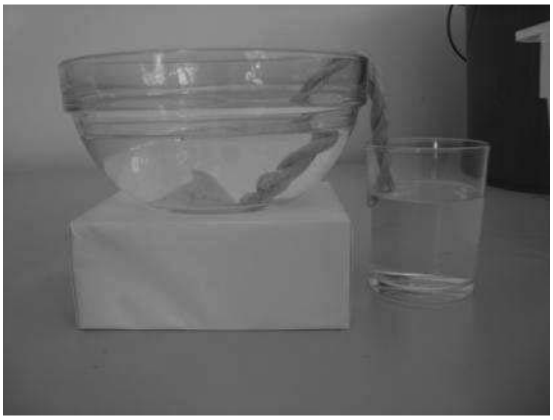
Procedure

- Fill the bowl nearly full of water. Put it next to the glass. Just in case there’s a leak it’s good idea to do it in a sink or outside.
- The objective is to have the water move up and over the rim of the bowl and down into the glass. To do this you need a wick through which the water can travel. A wick is a tight roll of paper or cloth that will absorb water. Just as a candle wick carries melted wax up to the flame, your water wick will carry water along its length.
- Twist the paper towels together fairly tightly to form the wick.

- Bend the wick in the middle. Then place one end in the glass. Be sure the other end reaches into the glass.

Observations

- The wick gets wet as water begins to travel along it.
- After a few minutes water will appear in the bottom of the glass.
- Water won't flow from the bowl into the glass. Instead of flowing, it sort of oozes. Check back once in a while to see how it is coming.
- When the water level in the glass is as high as the level of the water left in the bowl, the water stops moving. If you set the bowl on something higher than the glass you get most of the water out of it.



Explanation

There are thousands and maybe millions of tiny spaces between the fibres of the paper towel. Water moves into these openings and advances along the twisted material. Its movement is known as capillary Procedure. Moisture moves from plant roots into the rest of the plant in this same way. Capillarity finds its origin in the adhesive forces between the water molecules and the sides of tubes (plastic, wood…). When adhesive forces are greater than the cohesive forces between the water molecules they will crawl upwards. This effect is counteracted by the weight of the water column. The smaller the water column the smaller the weight of it and the stronger the capillarity effect will be.

Conclusion

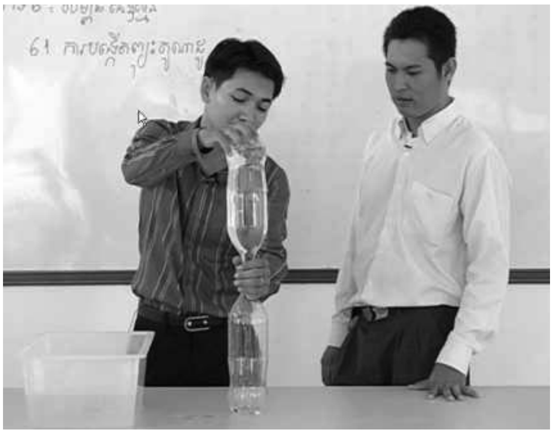
When adhesive forces are greater than the cohesive forces between the water molecules they will crawl upwards.

6. Pressure in Gases

6.1 Simulate a tornado

Objectives

- Students understand that gases, including air, exert pressure.
- Students can explain how air and water pressure cause the ‘tornado’ in the experiment.



Link with curriculum

Physics textbook: Grade 7, Chap 4, Lesson 4, published 2008
Physics textbook: Grade 8, Chap 5, Lesson 4, published 2009

Material needed

- Two clean, empty plastic bottles
- picture (or video) of tornado
- photo roll box

Procedure

- Make holes in the caps of the two plastic bottles. Glue the caps into a fitting tube (for instance the box of a photo roll).

- Fill one bottle with water and screw the glued construction on it. On top of this, you put the empty second bottle. Turn everything upside down. When the water is in the lower bottle, turn everything around again and give the full upper bottle a good spin.
- You can present this experiment as a game.
- Extension: an alternative way is to take two full bottles of water and ask two students to empty it as fast as they can. Which is the fastest way of doing it? The fastest way is to hold the bottle upside down and give it a good spin. In this way a whirlpool is created allowing air to flow in and water to flow out the bottle.

Observations

At first the water has a difficult time moving from the upper to the lower bottle. It even stops moving. When you give the full bottle a thorough spin, a (water)tornado appears and it can move more easily.

Explanation

The ‘empty’ bottle is in fact filled with air. When water comes in, air is pushed out. The air has to move through the same hole as the water. When you don’t spin the bottle, the water and the air cannot pass through the opening at the same time. When the bottle is spun, the water moves close to the edges of the bottle and in the middle an opening is made through which air can pass. You have made a whirlpool.

Most of the destruction done by tornadoes is caused by the lowered air pressure – you need Bernoulli’s Law to explain this - , not by the whirling winds. Explain that the experiment is a simplified version of a tornado.

Conclusion

Air is not nothing. When water flows into a bottle, the air in the bottle needs to find a way to escape. A tornado is the most efficient structure to get water in and air out of the bottle at the same time.

Question

Would this experiment work on the Moon? What would happen? (There is no air pressure on the Moon, so all the water would flow out directly. There is no air that simultaneously wants to enter the bottle.)

6.2 Blow a balloon inside a bottle: experiment on air pressure #1

Objectives

- Students understand that gases, including air, exert pressure.
- Students understand that gases can easily be compressed.

Link with curriculum

Physics textbook: Grade 7, Chap4, Lesson 4, published 2008
Physics textbook: Grade 8, Chap 5, Lesson 4, published 2009

Material needed

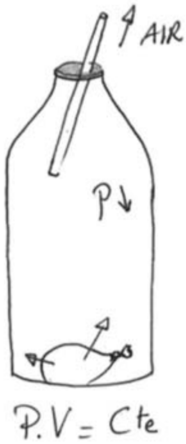
- A glass bottle with a wide opening
- A vacuum pump with accompanying rubber cork (if not available: use a straw and clay to create a tightly sealed bottle from which you can suck the air out.)
- balloon

Procedure

Blow a tiny bit of air in the balloon and make a knot. Put it in the bottle.
Close the bottle with the rubber cork and use the vacuum pump or the straw to blow out the air.

Observations

The balloon grows bigger.



Explanation

By sucking air out of the bottle, the air pressure inside the bottle decreases. Since there is less air in the bottle surrounding the balloon, the pressure to which it is subjected is lower than the air pressure inside the balloon. This enclosed air can now take more space in the bottle because the surrounding air doesn't push so hard anymore.
In the end a new equilibrium is achieved and the pressure inside and outside the balloon are equal again.

Conclusion

Decreasing the air pressure around the balloon, results in the balloon blowing up, as the air inside the balloon expands to reach a new equilibrium.

6.3 Blow a balloon inside a bottle: experiment on air pressure #2

Objectives

- Students understand that gases, including air, exert pressure.

Link with curriculum

Physics textbook: Grade 7, Chap 4, Lesson 4, published 2008
Physics textbook: Grade 8, Chap 5, Lesson 4, published 2009

Material needed

- A plastic bottle (large)
- Balloon

Procedure

1. Blow a little air into the balloon. Try to push it into the bottle.
For the first experiment the way you blow up the balloon is crucial: not too much so that the students still think it is possible and give it really a try but enough so that it's not possible. Sometimes it's enough to tie the balloon without blowing air into it. Just work with the air already in the balloon.

2. Put the empty balloon over the bottleneck and try to blow it up like this.

Observations

1. The balloon cannot be pushed into the bottle in this way.
2. Also this method doesn't work.

Explanation

In the first case, there is air in the balloon. You can give the balloon all the shapes you like, it will not go easily in the bottle. You have to take the gas in the balloon in count.
In the second case there is air in the bottle. This prevents the balloon from getting into the bottle.
Thus air (gas) is not nothing!
A little trick is to make a small hole in the bottom of the bottle. Now try the second method again. Now you can blow up the balloon. When you blow, the air in the bottle is pushed out through the hole so the balloon gets enough space to become bigger. You can first let a student try and blow up the balloon, then you take the bottle with a little hole and blow it. Let students try and find the explanation!

Conclusion

Air is not nothing. Air inside the bottle prevents you from blowing the balloon.

Question

Why can't the balloon in both cases be pushed into the bottle?

7. Atmospheric Pressure

7.1 Functioning of a drinking straw

Objectives

- Students can explain how differences in pressure create movement.
- Students can apply differences in pressure to situations in daily life, including the use of a drinking straw.

Link with curriculum

Physics textbook: Grade 7, Chap 4, Lesson 4, published 2009
Physics textbook: Grade 8, Chap 5, Lesson 4, published 2008

Material needed

- drinking straw
- glass of water
- plastic water bottle with cap

Procedure

- Make a hole in the plate the size of the drinking straw. Make sure the straw fits exactly in the hole.
- Suck up water with a drinking straw
- Try to suck up water with the cap screwed on the bottle and the drinking straw pushed through the hole in the cap.

Explanation

Strictly speaking, you don't suck up the liquid when you use a straw. What you do is releasing the pressure in the straws and allowing the weight of the atmosphere to press the liquid up into the straw. You create a region of low pressure inside the straw due to the pressure has been "absorbed" to the mouth. When the pressure of our surrounding (atmospheric pressure) is higher than the pressure inside the straw, it will push the fluid towards the inside of the straw, by this the fluid will eventually reaches the mouth of the person.

On the other hand if you try to blow the straw, the pressure inside the straw will increase and hence when the inside pressure is higher than our surrounding pressure (atmospheric pressure) the air inside the straw will be forced to gush out and effervescence will occur
When the cap is screwed on air can't press the liquid up the straw.

Conclusion

A drinking straw is based on creating an underpressure inside the straw, which makes the water flow into the straw.

Questions

Could you drink soda through a straw on the Moon? (No, there is no atmospheric pressure on the Moon, so there would be no pressure that can press the liquid up.)

7.2 Using a drinking straw as a pipette

Objectives

- Students can explain how differences in pressure create movement.
- Students can apply differences in pressure to situations in daily life, including the use of a drinking straw.

Link with curriculum

Physics textbook: Grade 7, Chap 4, Lesson 4, published 2009
Physics textbook: Grade 8, Chap 5, Lesson 4, published 2008

Material needed

- Thin plastic tube or drinking straw
- Glass of water
- Plastic bowl

Procedure

Place the straw or tube vertically in the glass filled with water so that water enters it.. Next seal off one end of the tube with your finger and pick it out of the glass. Next, hold it above the bowl and release your finger from the tube.

Observations

No water should come out of the tube or straw until you release your finger from it.

Explanation

The reason is that the atmospheric pressure at the bottom of the tubing is enough to offset the pressure of the weight of the water trying to pull the water out of the tube or straw. When you release your finger, atmospheric pressure at the top and bottom are approx. the same so that the net force is the weight of the water.

Conclusion

You can use a straw as a pipette using differences in atmospheric pressure between the top and bottom of the straw.

7.3 The crushed aluminium can

Objectives

- Students can explain how atmospheric pressure affects our environment.
- Students can apply differences in pressure to situations in daily life.

Link with curriculum

Physics textbook: Grade 7, Chap4, Lesson 4, 2009
Physics textbook: Grade 8, Chap5, Lesson 4, 2008

Material

- empty aluminium can from soft drink (make sure to have some spare ones because the effect is so sudden that a lot of students don't see it the first time. If available the effect with a big aluminium can, the effect is even more spectacular.
- water
- large bowl of water
- a pair of tongs large enough to hold the can
- a stove

Procedure

Put half a glass of water in the can and hold it over the flame of the stove. Wait until the water inside the can starts to boil. When you see a lot of steam coming out of the can, remove the can from the heat and immediately turn it upside down in a large bowl of cold water and hold it there.

Observations

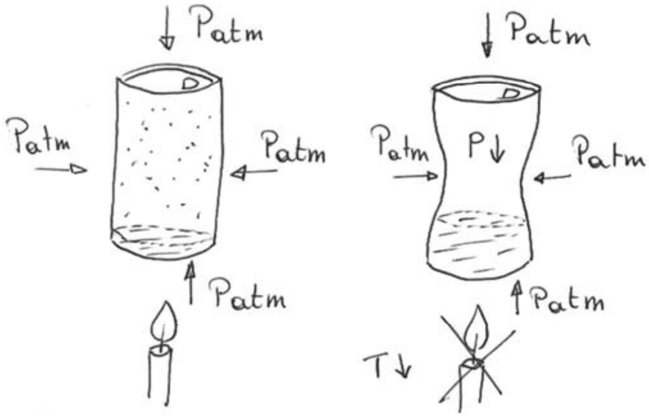
The can gets crushed symmetrically and immediately.

Explanation

When you heat the small amount of water inside a can it starts to boil. The water vapour pushes almost all the air out of the can. Air leaving the can (certainly not all of it) leads to very little air inside the can compared to what's outside the can. Once you put the can in cold water, the vapour condensates. Inside the can there is less air left, but the vapour is gone so the pressure inside the can is much smaller than the atmospheric pressure. So you get regular atmospheric air pressure (due to the weight of the air above you and the can) on the outside and little air pressure on the inside. The dramatic collapse of the can is an indication that the air pressure around us is pretty large. In fact, the atmospheric air pressure a sea level is around 100,000 newton per square meter.

Conclusion

So you get regular atmospheric air pressure (due to the weight of the air above you and the can) on the outside and little air pressure on the inside.



Questions

1. What would happen if you put less water in the can? (It will collapse less dramatically or it doesn't collapse at all).

2. What would happen if you put the can full of water? (no collapse since there is not enough air in the can to cause a large pressure difference)

7.4 Card and glass experiment

Objectives

- Students understand how atmospheric pressure affects our environment.
- Students can apply differences in pressure to situations in daily life.

Link with curriculum

Physics textbook: Grade 10, Chap 1, Lesson 4, published 2008

Material needed

- a glass with water
- a sheet of paper or card

Procedure

- Fill a glass up to the rim with water. Place an index card over the top.
- Over a sink (just in case the trick doesn't work), quickly turn the whole contraption upside down, holding on to the index card as you do. Then release the card.

Observations

The card doesn't fall.
Ordinarily, you would expect the weight of the water to push down on the index card hard enough that the card falls off and the water follows. If you water the whole thing carefully, though, you'll notice that a

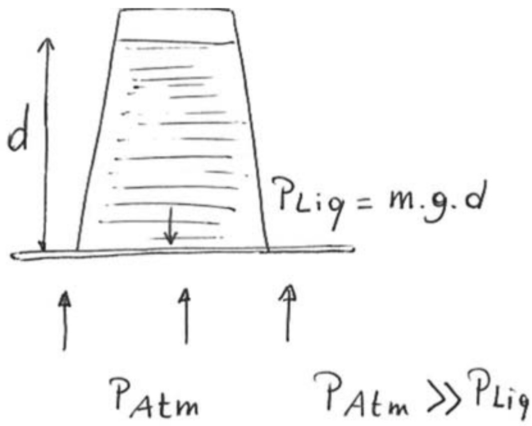
small “air” space forms in the top (formerly the bottom) of the glass when you turn the glass over.

Explanation

There is very little air in that space in the glass. Unless you turn the glass over very slowly, and don’t hold tightly onto the card, there isn’t a chance for much air to get into that space. With very few air molecules in that space, you have very little air pressure. There is so little air pressure in that space, in fact, that the difference between the outside air pressure and the small air pressure in that space is enough to hold up the weight of the water in the glass. Therefore, the water stays where it is. Actually, the explanation above only covers part of the story. If you repeat the experiment with the glass only half filled, it also works. This is because water pressure in general is relatively low compared to atmospheric pressure – atmospheric pressure corresponds to the pressure of a water column of approx. 10 meters.) Since the air in the glass can only expand a little bit (because of the water, Law of Boyle-Marriott), there is still a sufficient underpressure to keep equilibrium.

Conclusion

This experiment illustrates the strength of the atmospheric pressure, in this case higher than the pressure of the water.



Questions

- Turn the glass around very slowly. What happens and why?
- What happens if you keep the glass sideways? Why?
- Does the experiment work if you put sand in the glass instead of water? Why not?
- Does the experiment work if you put less water in the glass? How far can you go? (for advanced students)
- If you take a longer glass? Will it still work? (The glass may be as deep as 10 m)

7.5 Inverted glass experiment

Objectives

- Students understand how atmospheric pressure affects our environment.
- Students can apply differences in pressure to situations in daily life.

Link with curriculum

Physics textbook: Grade 10 Chap1, Lesson 4, published 2008

Material needed

- Glass
- Bowl of water
- Cork
- Drinking straw

Procedure

- Hold a glass under water, allowing it to fill with water.
- Turn it upside down and raise it, but keep its mouth beneath the surface.

Extension: put a cork on the surface of the water. Make sure this cork is in the glass. As you pull out the glass, not only the water, but also the cork rises in the glass.

Extension: hold the glass mouth down in the water but make sure there is still a lot of air left. Put one end of a straw in the air bubble inside the glass and suck out the air. You'll see the water rising.

Extension: Same as original experiment but now use the straw to blow air in the glass. The water level will drop, even under the water level.

Observations

The water does not flow out of the glass.

Explanation

Atmospheric pressure against the water surface in the bowl is greater than the water pressure in the glass.

Conclusion

Differences in atmospheric pressure cause the water to stay in the glass.

Questions

How tall would a glass have to be before water began to flow out? (At a height of 22,4 m atmospheric pressure would equal water pressure.)

8. Bernoulli's Principle

8.1 Lifting paper

Objectives

- Students can explain Bernoulli's principle
- Students can relate Bernoulli's principle to real world phenomena, such as the wings of an airplane.

Link with curriculum

Physics textbook: Grade 11, Chap1, Lesson 8, published 2009

Material needed

Sheet of paper, the lighter the better

Procedure

Hold a sheet of paper in front of your mouth. Blow above and along it.

Extension

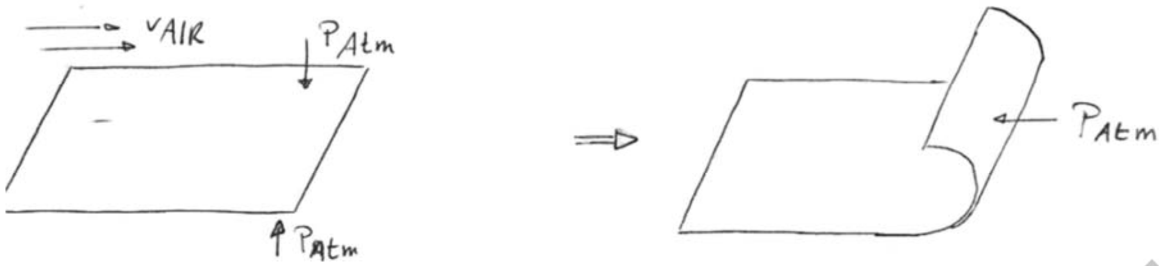
Take two sheets and hang them on a distance of 7 cm from each other, blow between those two papers and they will move towards each other.

Observations

When you blow across the top surface, the paper rises.

Explanation

That’s because the internal pressure of the moving air across the curved top of the paper is less than the atmospheric pressure underneath it. This causes the paper to be pushed upwards.



Conclusion

The fast moving air above the paper causes an underpressure. This is the Bernoulli effect.

8.2 The paper bridge

Objectives

- Students can explain Bernoulli's principle
- Students can relate Bernoulli's principle to real world phenomena, such as the wings of an airplane.

Link with curriculum

Physics textbook: Grade 11, Chap 1, Lesson 8, published 2009

Material needed

- Filing card or piece of thick paper

Procedure

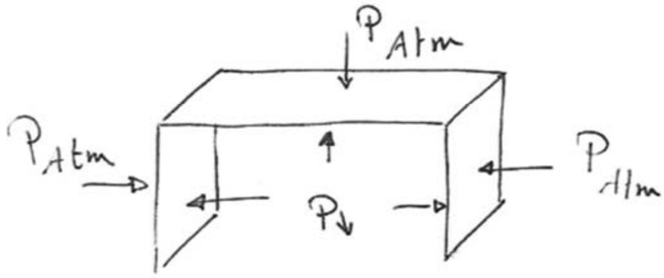
Fold the paper down to make a little bridge or tunnel. Place it on your table and blow across the top through the arch.
Next fold the same piece of paper in half, making a tent, and place it on the table with smooth surface. Predict what will happen when you blow through the tent?

Observation

No matter how hard you blow you will not succeed in blowing the card off the table (unless you blow against the side of it!).

Explanation

The moving air under the card causes a decrease in air pressure (Bernoulli principle). The surrounding higher air pressure keeps the card in place.



Conclusion

The fast moving air creates an under pressure, illustrating the Bernoulli effect.

8.3 Blowing a small card

Objectives

- Students can explain Bernoulli’s principle, as a relation between moving air, pressure and force.
- Students can relate Bernoulli’s principle to real world phenomena.

Link with curriculum

Physics textbook: Grade 11, Chap 1, Lesson 8, published 2009

Material needed

- Small index card
- Thread spool (or similar, like a wooden cylinder with a hole), the hole in the spool has to be narrow
- a pin or a short needle

Procedure

Push a pin through a small card, tape it fixed and place it in the hole of the thread spool. Try to blow the card from the spool by blowing through the hole.

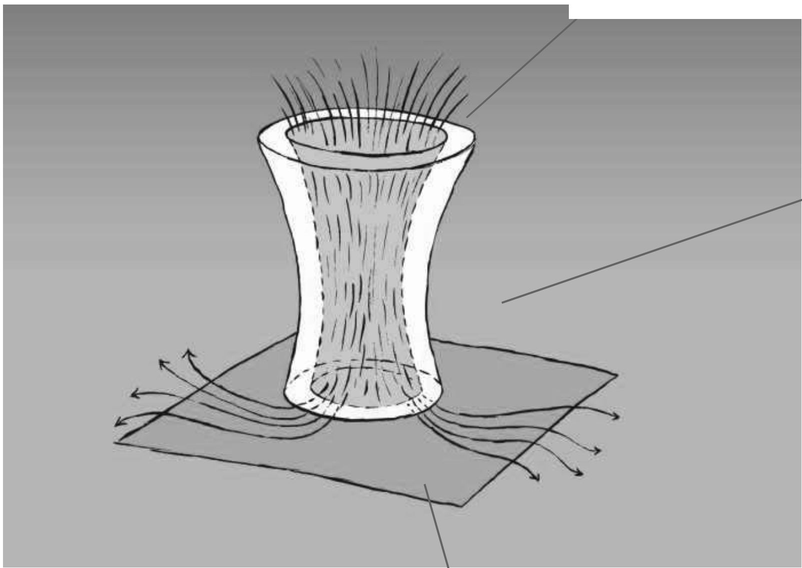
Try it in all directions, also with the card underneath the spool or cylinder.

Observations

It's impossible to blow it away, in EVERY direction. As long as you blow the card doesn't fall. As soon as you stop blowing, it falls on the ground.

Explanation

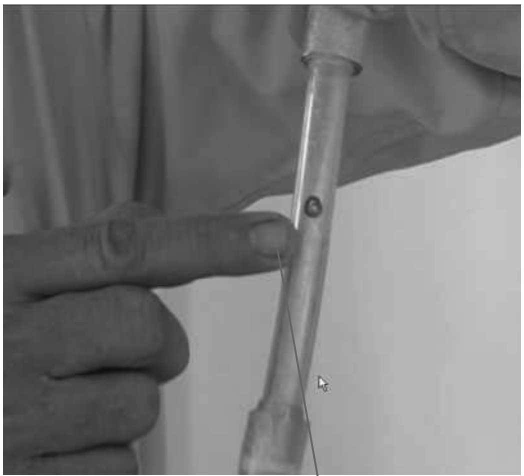
When you blow air through the hole, it moves along the card. On one side there is the atmospheric pressure, on the other side the pressure of moving air. The last one is the smallest, so the atmospheric pressure pushes the card against the spool.

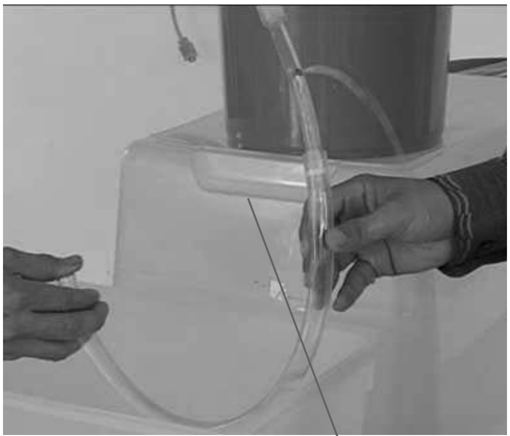


8.4 The tube with a hole experiment

Objectives

- Students can explain how Bernoulli's principle also works in liquids
- Students can relate Bernoulli's principle to real world phenomena,





The water is forced to flow faster in the smaller tube

Hole leaks when no water is flowing through

Link with curriculum

Physics textbook: Grade 11, Chap 1, Lesson 8, published 2009

Material needed

- A bucket filled with water.
- Two tubes of the same size
- One smaller tube

Procedure

Connect the two tubes to each other with the smaller tube. Make a small hole in the smaller tube. Put one end of the construction in the water and suck some water up. Now remove the end from the bucket and let the water run. Do this again, but close the bottom tube with your finger so the water cannot get out.

Observations

The first time, no water comes out of the small hole in the thin tube.
When the end of the tube is closed, the thinner tube starts leaking.

Explanation

The tube with the hole is thinner than the other two tubes. Because of the narrowing, the water starts to run faster. This causes a lower pressure in the thin tube. The pressure is lower than the surrounding air pressure. Because of this, air will come in through the hole. When air comes in, the water cannot get out through the same hole.
When the lower tube is closed, the water stops running. The pressure in the thin tube is now higher than the air pressure, so the water escapes through the hole. You can now clearly see the leak.

Conclusion

The Bernoulli effect is also valid for liquids. An increase in water speed, creates a decrease in pressure.

8.5 Experiment on Bernoulli's Principle for liquids

Objectives

- Students can explain how Bernoulli's principle works in liquids
- Students can relate Bernoulli's principle to real world phenomena, such as two boats passing closely along each other.

Link with curriculum

Physics textbook: Grade 11, Chap 1, Lesson 8, published 2009

Material needed

- Big bowl of water.
- 2 plastic toy boats or similar
- Two cords

Procedure

- Attach the boats to the water bowl as shown in the figure.
- With your hands, increase the speed of the water in between the boats.
- Try to vary the speed of the water. What do you observe?

Observations

When you increase the water speed in between the boats, they are drawn towards each other.

Explanation

Water flowing in between the boats travels faster than water flowing along the outer sides. Streamlines are closer together between the ships than outside, so water pressure acting against the hulls is reduced between the ships. Unless the ships are steered to compensate for this, the greater pressure against the outer sides of the ships forces them together.
Also in real life ships passing along each other need to pay attention not to hit each other as a result of the Bernoulli Principle

Conclusion

The Bernoulli effect is also valid for liquids. The fast moving water in between the boats creates an underpressure and causes the boats to close in.

Chapter 5: Optics

Introduction

This manual introduces 8 experiments on light and optics. The experiments have all been tried out and can be done with low-cost materials.
Some of the experiments are short, providing an engaging introduction to your lesson. Other experiments are longer and can be useful for creating an inquiry-based lesson.

Light and optics were extensively covered by an earlier VVOB programme. A manual with both low-cost and medium-cost experiments is available at VVOB on request.

Main Concepts Covered

Some important features of light are:

- Light is a form of radiation
- Light travels in straight lines
- Light transfers energy
- Light travels as waves
- Light can travel through empty space
- Light is the fastest thing there is
- Light can be visible or invisible to the human eye.

Experiments Optics

5.1 Reflection

Objectives

- Students become familiar with the reflection of light
- Students can explain how the angles of incidence and reflection are related

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Material needed

- Mirror;
- Laser;
- Tape;
- Sheet of paper.

Procedure

- Stick a little mirror on the board. Ask a volunteer in front of the class and give him/her a sheet of paper (you need to see a laser dot through it).
- Now shine almost parallel to the normal on the mirror and ask the volunteer to ‘catch’ the laser beam on the sheet of paper. (The normal = The line perpendicular on the mirror)
- When the volunteer has the laser dot on the paper, move away from the normal and ask the volunteer to keep ‘catching’ the laser beam. She will also have to move away from the normal.
- Now move to the normal and away, and let the students observe what the volunteer has to do to keep the laser dot on the sheet.

Observations

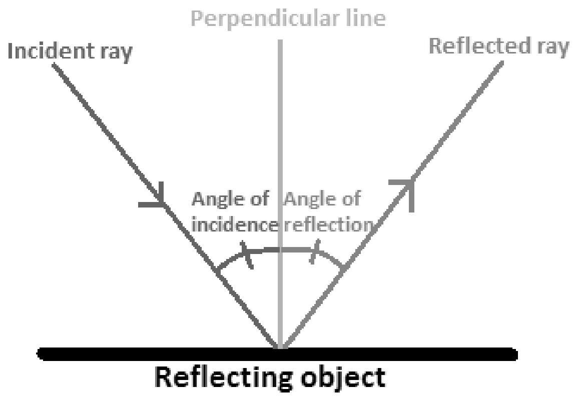
When the teacher increases the angle of incidence, the volunteer will also have to increase the angle of reflection (both moving away from the normal). On the other hand, when the teacher decreases the angle of incidence, the volunteer will also have to decrease the angle of reflection (both moving towards the normal).

Explanation

The reflection of light has some particular properties. When light reaches a reflecting object (a mirror, aluminium foil, glass…) it will be reflected under a particular angle: the angle of reflection. This angle is similar to the angle of incidence, so when we increase the angle of incidence, the angle of reflection will also increase with the same amount of degrees. We measure the angles compared to the (imaginary) perpendicular line on the reflecting object.

Conclusion

The angle of incidence is equal to the angle of reflection, as measured with the perpendicular to the reflecting object.



Questions

1. What happens when the teacher moves away from the normal?

2. How big is the angle of reflection when the angle of incidence is zero degrees?

5.2 Reflection: Build your own periscope

Objectives

- Students apply principles of reflection to explain how a periscope works
- Students can construct a simple periscope themselves with low-cost materials

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Material needed

- A S-shaped plastic tube (see picture)
- 2 small and flat mirrors
- Strong glue or tape

Procedure

- Prepare the periscope before the lesson. Use the scheme below. Be careful to place the mirrors inside the tube under the correct angle. Otherwise, you will not be able to use the periscope.
- Demonstrate the periscope during the lesson. Let a student hide behind a poster and use the periscope to observe what another student is doing.
- Let students try to find an explanation for their observations. Construct a diagram of how the light rays are reflected together with your students.

Observations

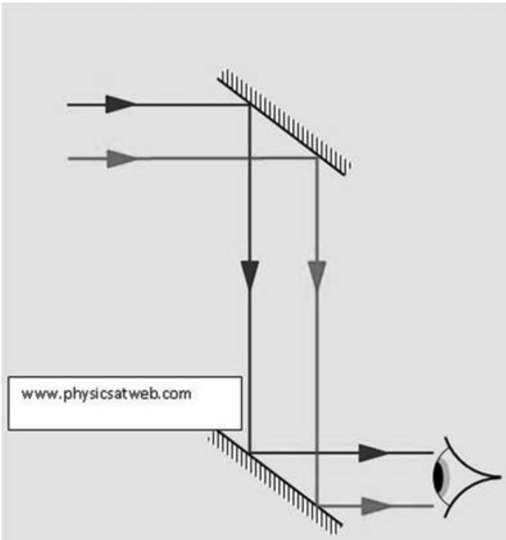
A periscope allows you to see around corners.

Explanation

The observations can be explained with the two laws of reflection. These apply to all types of mirrors.

1. The angle of incidence is equal to the angle of reflection
2. The incident ray, the reflected ray and the normal all lie in the same plane.

In a plane mirror (as in this experiment) the image is always the same size as the object.



Source: Physicsatweb.com

Conclusion

Mirrors have the following common characteristics:

1. The angle of incidence is equal to the angle of reflection
2. The incident ray, the reflected ray and the normal all lie in the same plane.

Questions

Why is the angle of the mirrors in the tube important?
Light travels in a straight line. The mirrors need to be positioned so the light reflecting off the object of interest comes in, bounces off the first mirror, to the second mirror, to the observers eye.

5.3 Refraction

Objectives

- Students can explain refraction in their own words
- Students understand when and why refraction occurs
- Students can illustrate refraction with a simple demonstration

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Material needed

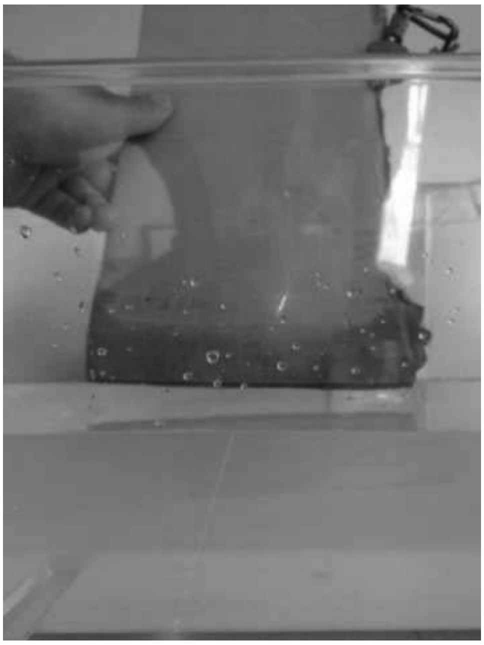
- Laser;
- Transparent bowl
- Water;
- Milk;
- Cardboard.

Procedure

- Pour some milk in a transparent bowl of water, don't add to much milk. The milk will visualize the laser beam. Too much milk will cause diffusion of the laser light.
- Shine the laser in the water. To visualize the laser beam in air you can use a cardboard or some chalk powder.
- Try to shine under different angles, so the students can observe what happens to the angle of refraction when the angle of incidence increases or decreases.

Observations

The laser beam will bend towards the normal when entering the water.



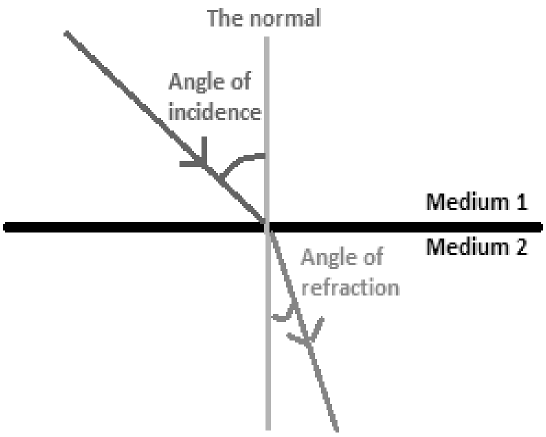
Explanation

Due to the different refraction indices of air and water, light rays will refract when passing the boundary between both mediums. Since water has a higher refractive index than air, the rays will bend towards the normal (the normal is the imaginary line perpendicular to the boundary).
Conversely, when the ray goes from water to air, the ray will bend away from the normal.
The different refraction indices from materials are caused by the different speed of light in these materials.

Conclusion

Optical refraction occurs when light travels from a medium with a given refractive index to a medium with another refractive index, at a certain angle. At the boundary between the media, there is a change in direction of the light ray.

Drawing with explanation:



Questions

What would happen with the laser ray when air and water would have the same refraction index?
→ (see experiment refraction index!)
What happens with the laser beam when you shine parallel with the normal on the water?

5.4 Refraction Index

Objectives

- Students can explain refraction of light
- Students can explain why the cup is not visible when submerged in the oil

Material needed

- Glass cup;
- Oil;
- Marble;
- Pyrex cup

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Procedure

- Take a small transparent cup and try to find oil with the same refraction index, what means you won’t see the cup when it is submerged in the oil. To find the right oil, you will have to try different types of oil, trial and error, or look up the refraction indexes.
- Put a visible object in the oil and put the cup on top of it. Make sure the students haven’t seen the cup on top of it. Now only the object, for example a marble, is visible. Ask for a volunteer and let him try to pick up the marble. He will fail because of the cup on top of it.
- Explain why they don’t see the cup in the oil.

Observations

The cup will be invisible in the oil; you will only see the object underneath it.

Explanation

Because the cup has the same refraction index as the oil, the light rays will not bend and will go straight through the cup. The absence of refraction causes us to only see the object underneath the cup. We only see objects in a medium when it has a different refraction index than the medium (when transparent) or when the object reflects light rays.

Conclusion

Every object has a particular refraction index. We cannot distinguish objects with the same refraction index from each other.

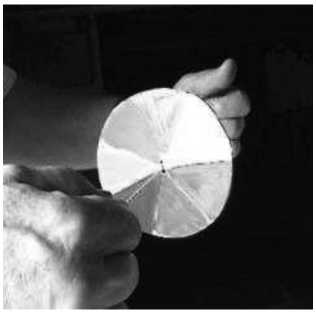
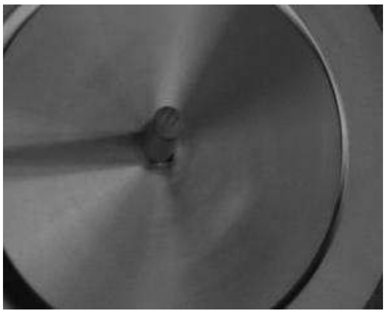
Questions

- Why do we see the object in the oil and not the cup on top of it?
- The cup has the same refraction index as the oil, whereas the object has a different index.
- What would happen when we use a different type of oil?
- A different type of oil would presumably have a different refraction index, making the cup visible.

5.5 The coloured disk

Objectives

- Student can understand that white light is composed of all colours
- Student can conduct experiment the formation of white lights

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Material needed

- A colour disk with in the middle two small holes; lace a rope through the holes (loose)

Procedure

- Swing the colour disk a few times in order to wind the rope.
- Pull (rhythmically) the end of the rope to turn the disk.

Observations

You don't see the colours anymore; you only see a white disk

Explanation

White light is composed of all colours of the spectrum. When the disk isn't moving we notice the different colours of the rainbow (spectrum). We are able to see colours because an object absorbs one or more colours. The colours which are not absorbed, are reflected and enter our retinas.

A white object reflects all colours. A black object absorbs all colours, so no colours enter our eyes. When colours change very fast, as in the moving disk, our brains interpret them as a composition of all colours and we get to see a white disk.

Conclusion

White light is composed of all the colours from the rainbow.

5.6 Making a rainbow

Objectives

- Students can apply the concepts of reflection and refraction to explain how a rainbow 'works'.
- Students can create their own rainbow with low-cost materials.

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Material needed

- an atomiser
- a torch
- soap-suds to blow bubbles

Procedure

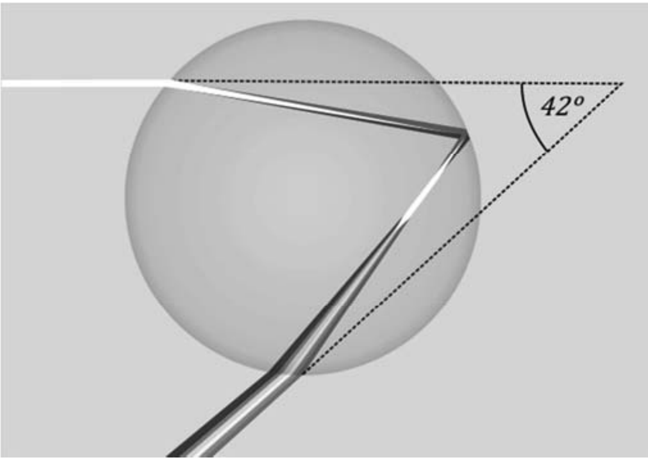
- Spray fine drops of water in the air and shine the torch in a slant way on the drops
- Blow bubbles and shine the torch in a slant way on the bubbles

Observations

You (sometimes) see the rainbow.

Explanation

When these light-rays reflect on the back of the drop, you may see the spectrum. The light is first refracted entering the surface of the raindrop, reflected off the back of the drop, and again refracted as it leaves the drop. The amount by which light is refracted depends upon its wavelength, and hence its colour. This effect is called dispersion. In order to see the colours of the rainbow, you have to turn your back to the sun.



Source: Wikipedia

Conclusion

A rainbow is caused by the different refraction rates of colours, a process called dispersion.

5.7 Constructing a fibre optic bundle

Objectives

- Students can explain how fibre optics uses light reflection as a way to transport information
- Students can perform a simple experiment to illustrate internal reflection within a water bundle.

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Material needed

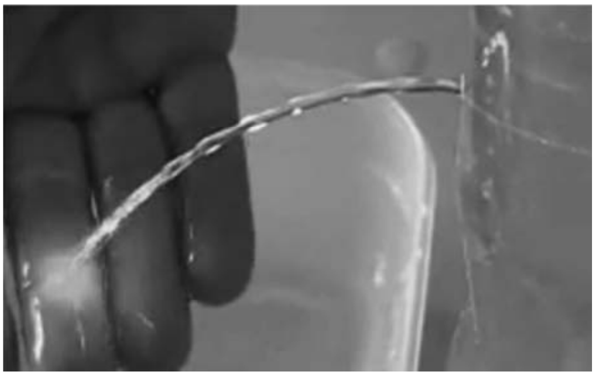
- a plastic bottle of water, with a small hole on the side
- a plastic bowl or bucket to catch the water
- a torch or laser pen
- a bucket

Procedure

- Make a small hole in the bottle
- Fill the bottle with water and screw the lid on.
- Shine the torch through the bottle; see how a light-ray passes through the hole.
- Now unscrew the lid, so that water starts flowing out of the bottle. Use the bowl to catch the water.
- Switch the torch on and off
- Observe how the light ray travels.

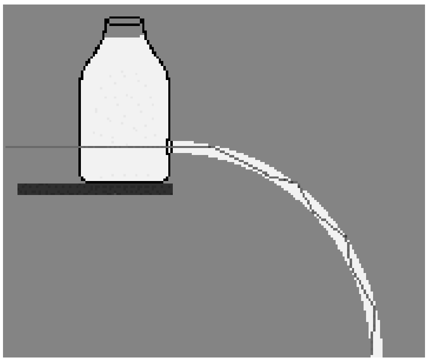
Observations

Usually the light ray shines through the hole in a rectilinear way. When water flows out of the bottle, the light ray is bended and seems trapped inside the curved stream of water.



Explanation

The light-ray is continually reflected by the border of the stream of water.
When light enters a less optically dense medium, it is sometimes reflected along the interface of the media. This phenomenon is called total internal reflection.



The laser beam stays internal to the water, continuously reflecting at each boundary.

Source: Wikipedia

When light is inside the denser medium (water) and heading towards a boundary with a less dense medium (air), it is sometimes reflected along the interface of the media. This phenomenon is called total internal reflection.
This demonstration helps to illustrate the principle by which optical fibres work. The use of a long strand of plastic or glass to pipe light from one end of the medium to the other is the basis for modern day use of optical fibres. Optical fibres are used in communication systems. Since total internal reflection takes place within the fibres, no incident energy is ever lost due to the transmission of light across the boundary.

Conclusion

When light enters a less optically dense medium, it is sometimes reflected along the interface of the media. This phenomenon is called total internal reflection and is used in fibre optics.

5.8 Blue sky

Objectives

- Students can explain why the sky is blue
- Students can do simple experiment to illustrate that shorter wavelengths (blue) are scattered more than longer wavelengths (red).

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Material needed

- a bottle
- water
- some milk
- a torch

Procedure

- Fill the bottle with clear water and shine the torch on it. Which colour do you see in the bottle?
- Add some drops of milk to the water. Shine the torch on the bottle and look at its side and its back

Observations

First, you see white light. After adding the milk, you see red light on the back and blue light on the side.

Explanation

The bottle represents the atmosphere of the earth; the atmosphere contains air, vapour and dust. Vapour and dust diffuse light. Blue light is diffused best of all colours. By day the sky is blue because blue light is diffused. The red wavelengths of the light spectrum are almost not diffused, so we see a red sunset.


Conclusions

Blue light is diffused better than light of other wavelengths by vapour and dust. That’s why the sky is blue and the setting or rising Sun is red.

5.9 Experiment: Pinhole camera (Camera Obscura)

Objectives

- Student can make a pinhole camera
- Student understands how a photo camera work

Material needed

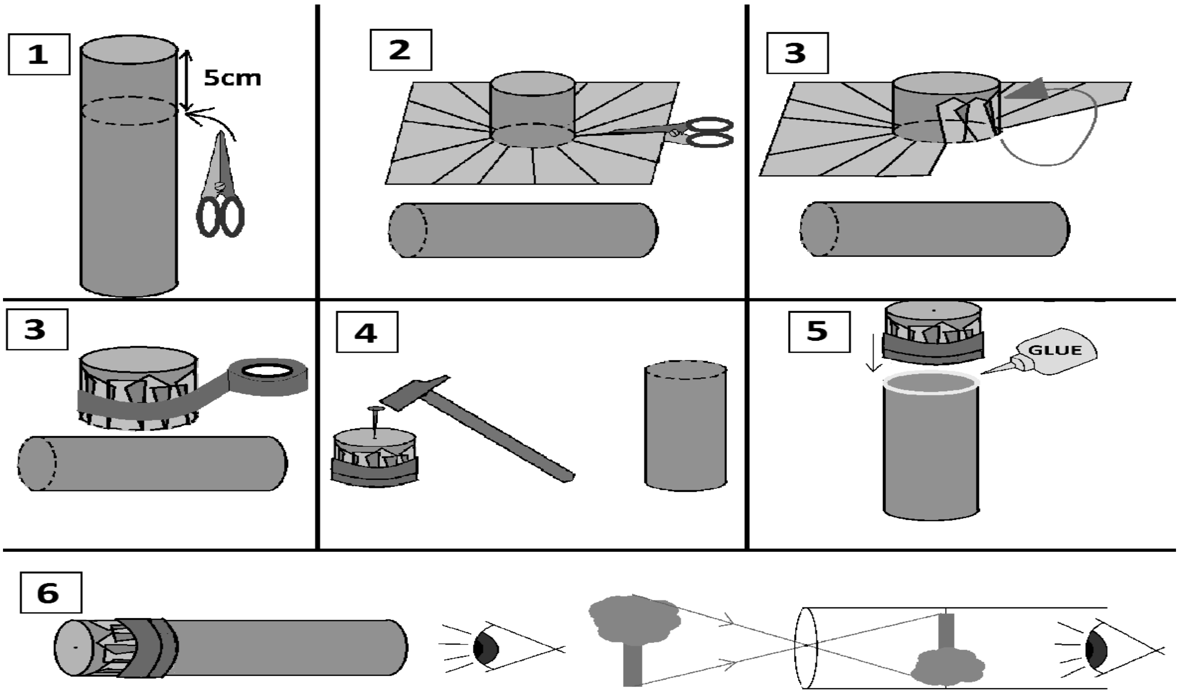
- Pringles (potato chips) Box;
- Glue;
- Tape;
- Scissors;
- Thin paper;
- Hammer and small nail.

Link with curriculum

Physics Textbook: Grade 10, Chapter 4, Lesson 1, published 2009

Procedure

1. Take the Pringles tube, at about 5cm from the metal top cut the box with the scissors. Try to cut as straight as possible. You will need both ends of the tube, so be careful.
2. Place the small piece of the tube on the thin paper, cut into the paper till you reach the tube.
3. Flip the pieces of paper upwards and glue or tape them so they are stuck to the piece of the tube. It's important to focus while doing this, the paper needs to be wrapped tightly around the tube. The paper that covers to hole in the tube will serve as our screen to 'catch' the image later on.
4. Take the hammer and nail. Carefully make a small hole in the centre of the metal top of the tube.
5. Put some glue on the border of the longer part of the tube, which you cut off in step 1. Now attach both pieces of tube back together again.
6. On a sunny day, go outside and aim your tube at a tree for example. Look into the tube. You will see the tree upside down.

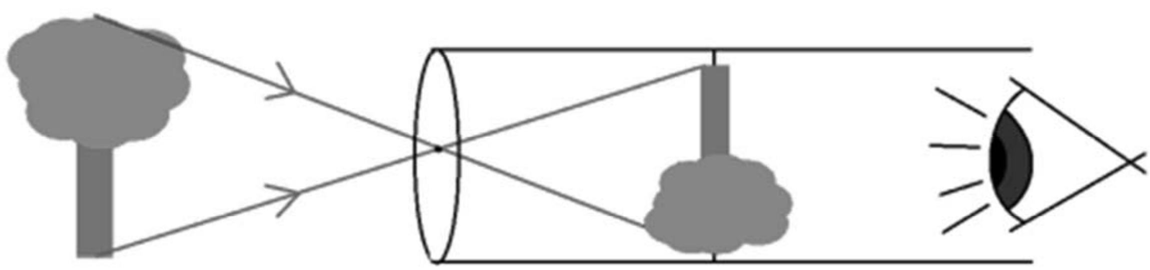


Observations

When looking at an object with your self-made pinhole camera, we see the object upside down.

Explanation

When looking at an object with our eyes, a camera or a pinhole camera, the light reflected by the object goes through the small hole of the pinhole camera. When we extend these light beams on a drawing we can easily understand why we get a reverse image.



Questions

We see a reversed image. Is it only up and down that got switched or did left and right also get switched?
→ Left and right also get switched around, the whole image gets reversed. You can easily show this by using the pinhole camera and ask the students to look at you while you wave your right hand. The students will see you upside down, but also waving your left hand.
When we look at an object with our eyes, we don’t see a reversed image… Why not?
→ The signals our brain receives from our eyes are interpreted by our brain. It’s in our brain the reversed image our eyes actually see is turned around again. That’s why we don’t ‘see’ a reversed image.

Chapter 6: Electromagnetism

Introduction

This sequence provides a set of 9 experiments for teaching electromagnetism. These are conceptual experiments with cheap materials, so teachers can make the experiments themselves. The experiments are put in a logical order and cover the basic principles of electromagnetism. They are best done in the order described in this manual.

This manual also includes didactical suggestions of conceptual experiments. Some general characteristics of **conceptual experiments** are:

- The focus is on explaining basic concepts: the experiments should not be too easy, or too difficult. They may not be complex but simplified so every experiment has a clear objective.
- These experiments can be used as **discrepant events**: by their unexpected outcome, they generate interest and curiosity so students are challenged by asking questions, formulating hypotheses and predict outcomes.
- The experiments help you to find out what learners already know about the concept. They are based on students' misconceptions of basic physics knowledge.
- Learners have to construct their own knowledge, not the teacher!

Every experiment can be done with the same didactical approach, consisting of the following steps:

1. Introduce the experimental setup
2. Ask the conceptual questions
3. Perform the experiments and find the correct answers to the questions
4. If relevant, analyse the wrong answers

Main Concepts

There are attracting and repulsive forces between magnets. The magnetic force acts on distance, no contact is required. The magnetic field is the region around a magnet where another magnet experiences a force. Magnets can only be shielded by magnetic metals like iron and not by other metals, plastics, wood, etc.

The **Curie temperature** or Curie point is the temperature at which a ferromagnetic material becomes paramagnetic; the effect is reversible. An iron magnet will lose its magnetism if heated above the Curie temperature.

The force of **electromagnetism** is manifested both in electric fields and magnetic fields; both are simply different aspects of electromagnetism, and hence are intrinsically related to each other. Thus, a changing electric field generates a magnetic field; conversely a changing magnetic field generates an electric field. This effect is called electromagnetic induction.

A charged particle moving through a magnetic field experiences a force that is at right angles to both the direction in which the particle is moving and the direction of the applied magnetic field. This force, known as the **Lorentz force**, develops due to the interaction of the applied magnetic field and the magnetic field generated by the particle in motion.

A change in magnetic flux (magnetic field strength on two-dimensional surface) will generate a current. The amount of voltage created is equal to the change in magnetic flux divided by the change in time. The bigger the change you have in the magnetic field, the greater amount of voltage. This is called **Faraday's Law of Induction.**

Lenz's Law: "An induced current is always in such a direction as to oppose the motion or change causing it"

Experiments Electromagnetism

6.1 A magical force

Objectives

- Students can identify the attracting and repulsive forces between magnets
- Students can illustrate the forces between magnets with a simple activity.

Link with curriculum

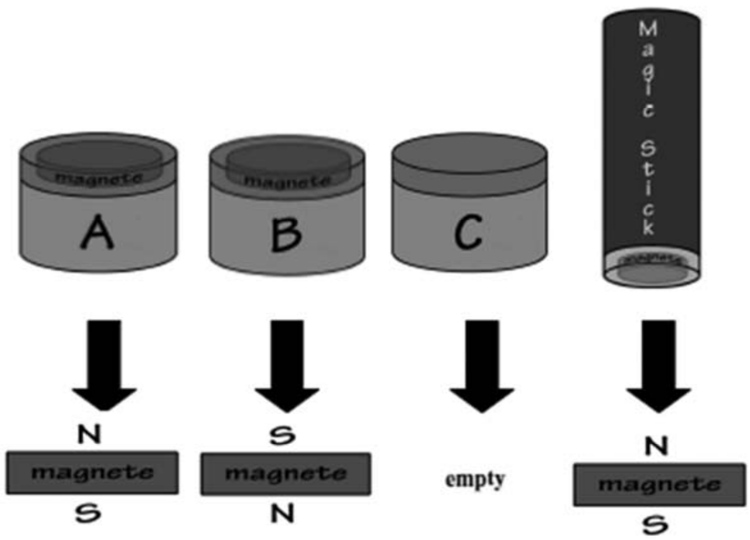
Physics textbook: Grade 8, Chapter 5, Lesson 1-2, published 2010
Physics text book: Grade 10, Chapter 3, Lesson 2, published 2009

Material needed

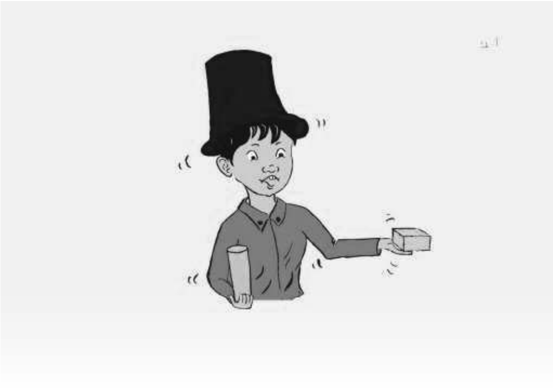
- 3 small boxes (non-transparent) for boxes A, B and C.
- 1 magic box, a bit larger than the boxes A, B or C. It is important that the small boxes precisely can fit in the magic box.
- 1 long box for the magic stick
- 3 magnets. Take care that the magnets are correctly polarized with one north pole up and one south pole down (**www.supermagnete.de** Type S-20-05-N). Magnets of magnetic boards are cheap but have often two north and south poles. Find boxes with correct diameters so that magnets can fit in.

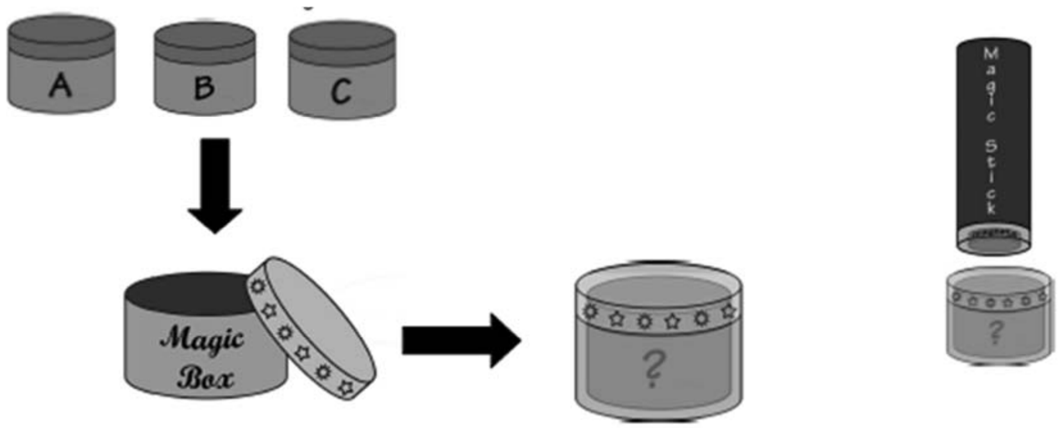
Procedure

- Put the magnets inside the boxes, make sure the magnets are facing the right direction:



- Ask students to put one of the boxes A, B or C in the magic box. Make sure that you cannot see which box is inside the magic box.



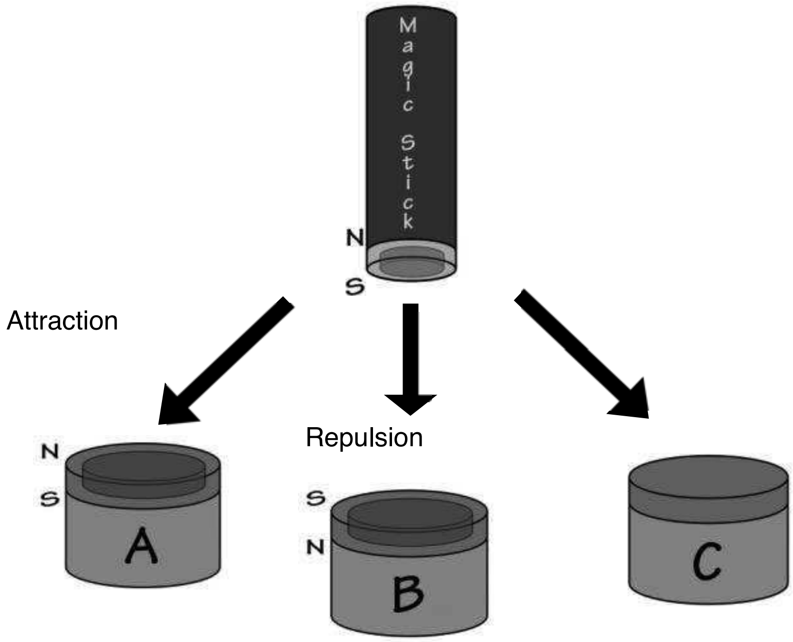


Source: Arteveldehogeschool

- With the help of your magic stick you can find out which box is inside the magic box using attraction or repulsion of magnets.
- Let students try to find out how this magic trick works.

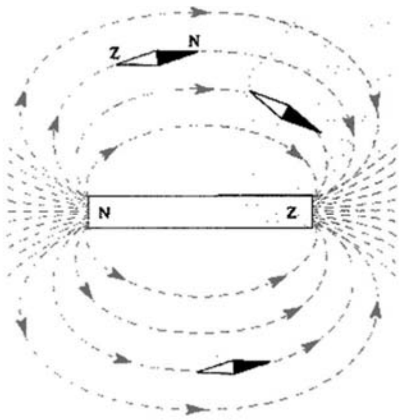
Observations

It depends which box (A, B of C) is inside the magic box.
The magic stick will attract, repel or nothing will happens.



Explanation

According to the position of magnets, there is a repelling or attracting force between magnets. Equal poles (N – N; S- S) will repel and unequal poles will attract (N – S).
Extra: magnetic force is a force that is working from a distance. The concept of magnetic field is very useful here.



Conclusion

Magnets exert a repelling or attracting force. Equal poles (N – N; S- S) repel and unequal poles attract (N – S).

6.2 Can magnets be shielded?

Objectives

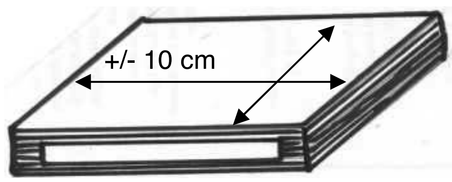
- Students can identify materials that can shield magnets.
- Students can explain what ferromagnetic materials and magnetic fields are
- Students can perform a simple investigation to see which materials can shield a magnet

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 1, published 2010
Physics textbook: Grade 10, Chapter 3, Lesson 1-3, published 2009

Material

- strong magnet
- some paperclips
- materials to try in the slit:
    - Wooden stick
    - Piece of iron
    - Piece of aluminium
    - Piece of plastic
    - (any other materials)
- cardboard slit (made of beer coasters)

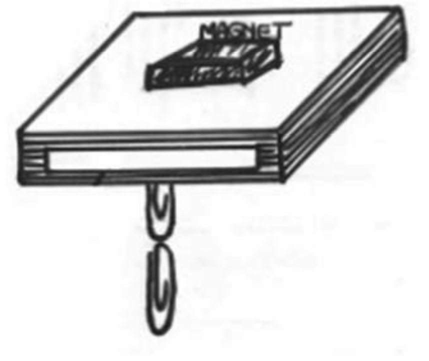


Some instructions for making the cardboard slit:

- Stick 5 beer coasters to each other (two times, so you have 2 sets of sticking beer coasters)
- Cut off the long sides a strip of 1 cm wide (so you have 4 strips of 1 cm wide)
- Glue 2 strips on the long sides of 1 set of coasters
- Glue the second set on top.

Procedure

- Put a strong magnet on top of the cardboard slit
- Put some paperclips below. Because of the magnetic field the paperclips will hang onto the cardboard slit.
- Now put some different materials in the slit. First try with a wooden plate, and then try with glass, aluminium and cupper plates. Finally slide the iron plate in the slit.



- What happens with the magnetic force or field (see previous experiment) when you put the wooden/cupper/iron/… plate in the slit?

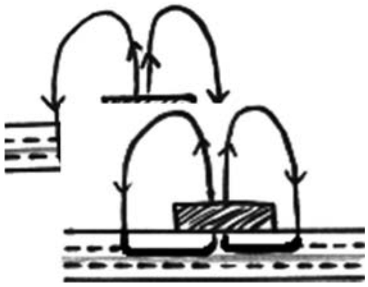
Observations

Let your students predict every observation. For the wooden and glass material, they will be able to predict correctly. If you use copper and aluminium, it will be more difficult.

- Wooden plate → nothing happens
- Glass → nothing happens
- Aluminium, copper → still nothing happens!
- Iron → paperclips fall!

After this clear observation, let you students try to explain.

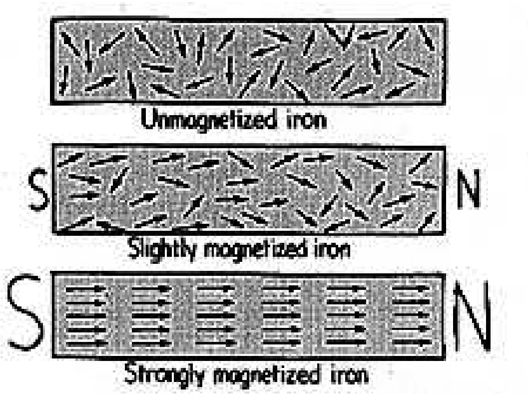
Explanation



We must look at the magnetic field to explain this experiment:
The paperclips are **still hanging** → The magnetic field is not influenced by air, paper, plastic, wood, fabric, aluminium, copper.
The magnetic field lines go through the material, but are not influenced by it.
The paperclips **fall down** → The magnetic field is influenced by: iron Iran is a **ferromagnetic** material: this means that the material inside iron will parallel aligned and become a kind of (non-permanent) magnet. The magnetization (or alignment) happens in small magnetic domains inside the material.

Conclusion

Magnets are not shielded by substances such as air, paper, plastic, wood, fabric, aluminium, copper. However, they are shielded by iron, which is a ferromagnetic material.



6.3 Does heat influence magnetic materials?

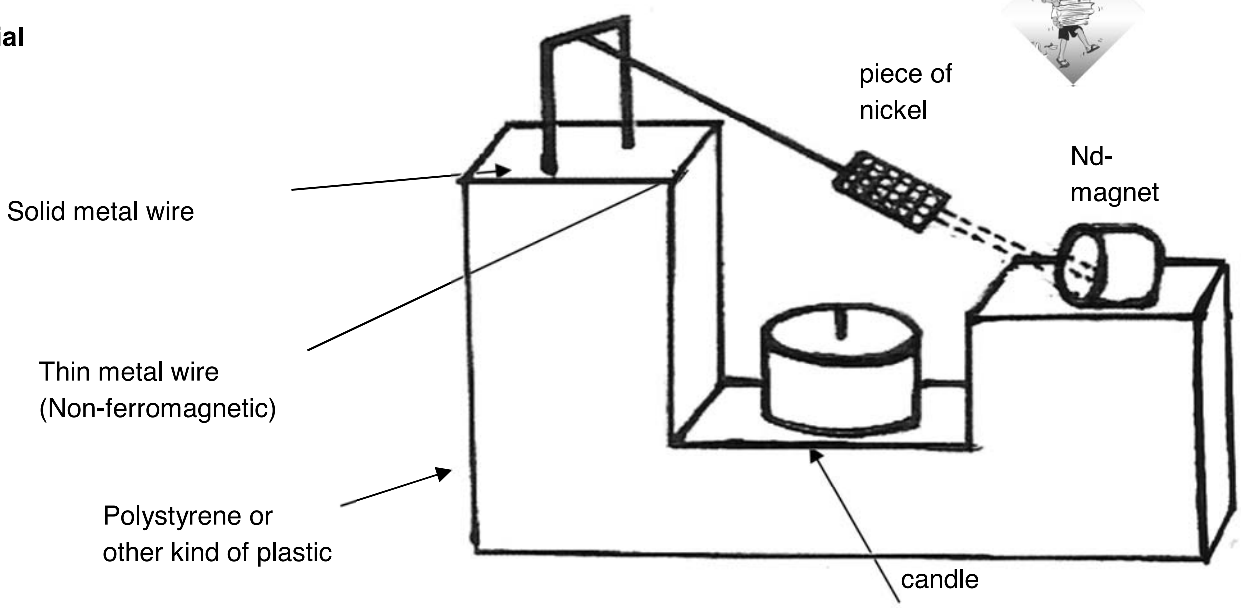
Objectives

- Students can explain how heat affects the magnetic properties of a material.
- Students can set up an inquiry to investigate the effect of heat on an object’s magnetic properties.

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 1-2, published 2010
Physics textbook: Grade 10, Chapter 3, Lesson 1-3, published 2009

Material



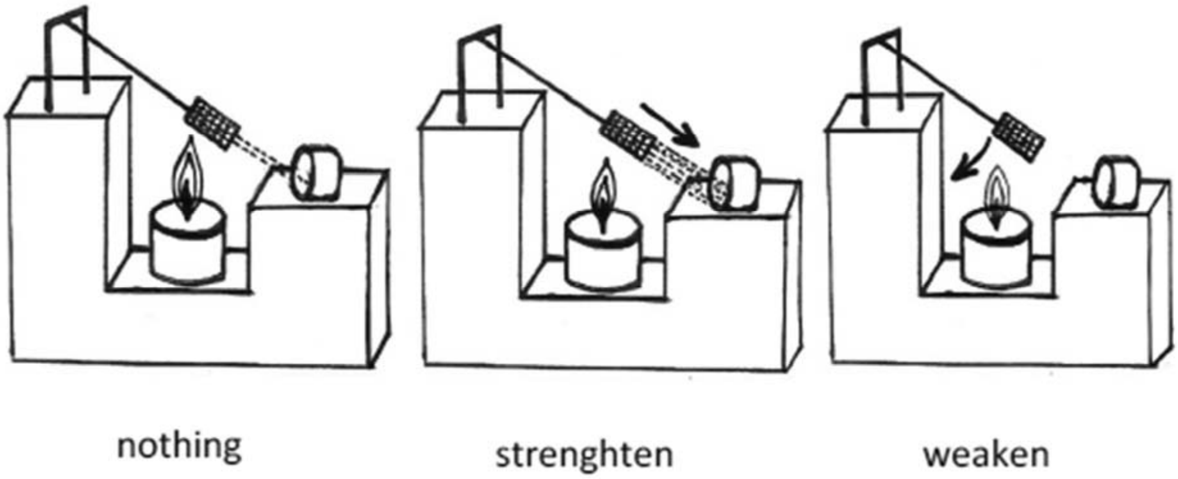
- candle and matches
- very strong magnet
- solid metal wire
- thin metal wire (not iron)
- polystyrene
- pure nickel (not easy to find: e.g. in Nickel - Cadmium battery)

Important tips:

- This experiment does not work with iron! The Curie temperature of iron is 770°C. The flame of a candle does not reach such a high temperature.
- The piece of nickel has to hang into the flame of the candle in order to reach the required temperature of 357 °C.

Procedure

- Place the magnet behind the burning candle.
- The piece of nickel (ferromagnetic material!) will be attracted by the magnet. Make sure that the piece of metal does not touch the magnet but hangs right into the flame! (You will need some exercise to perform this experiment and to search for the right position of candle and magnet).
- What will heat do with the magnetic force?

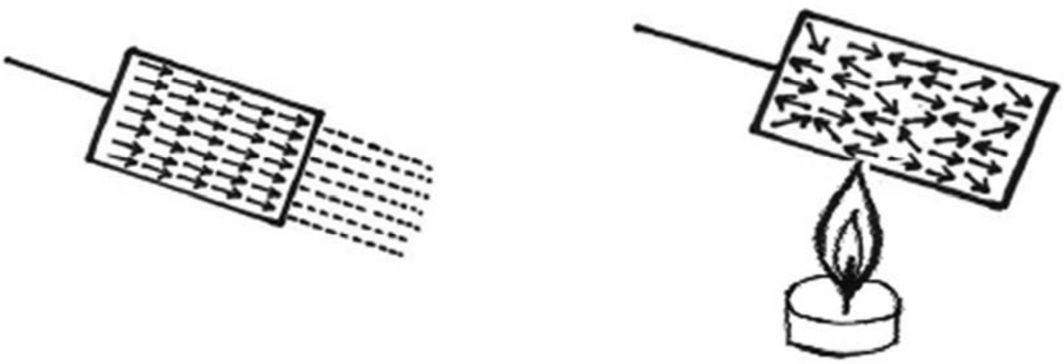


Observations

The magnetic force will become weaker.

Explanation

At the Curie temperature the magnetic force disappears completely. For nickel the Curie temperature is 357°C. Heat has a disordering effect in the magnetic domains.



Below the Curie temperature the magnetic moments are aligned parallel within magnetic domains in ferromagnetic materials and anti-parallel in non-magnetic materials. As the temperature is increased towards the Curie point, the alignment (magnetization) within each domain decreases. Above the Curie temperature, the material becomes non-magnetic so that magnetic moments are in a completely disordered state.

Conclusion

At the Curie temperature the magnetic force disappears completely. For nickel the Curie temperature is 357°C. Each material has a different Curie temperature. Heat has a disordering effect in the magnetic domains.

6.4 How do electric currents and magnets interact? The Electromagnet

Objectives

- Students can explain how a wire carrying a current can become a magnet.
- Students understand how electricity and magnetism are related.
- Students can make a simple electromagnet.

Link with curriculum

Physics textbook: Grade 5, Chapter 1-2, Lesson 3, published 2010
Physics textbook: Grade 10, Chapter 3, Lesson 1-3, published 2009

Material

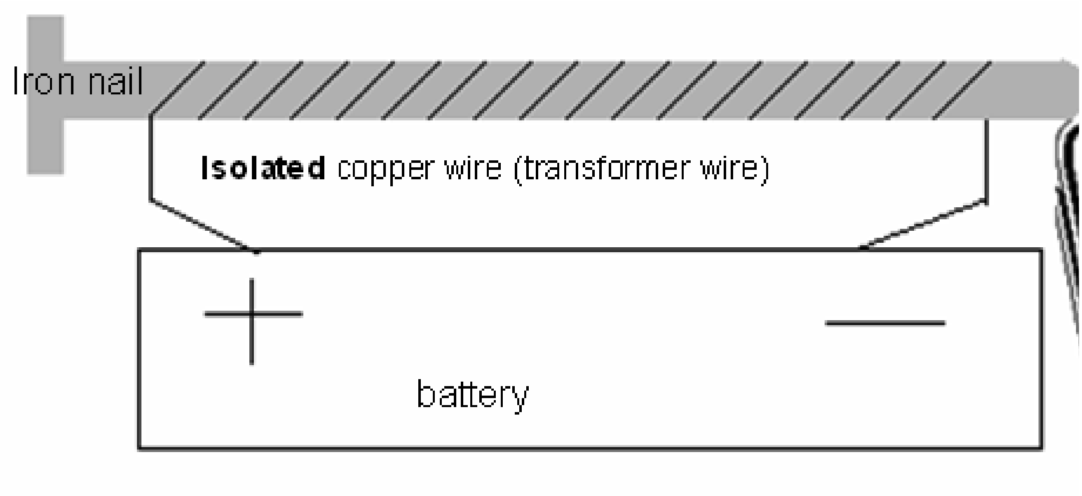
- Battery (9 V)
- Iron nail
- Paperclips²
- <u>Isolated</u> copper wire: the wire must be isolated; otherwise the electric current will flow through the metal (conductive!) nail and not through the coil. In old transformers you find isolated copper wire. Sometimes you cannot see the transparent isolation. With a multimeter you can easily check if there is isolation around the wire.

<u>Important tips</u> when constructing the experiment:

- Do not forget to strip the isolation of the wire at the end to make good contacts with the battery.
- Find the optimal number of windings, the more windings, the stronger the magnet field, but also the higher the resistance of the coil.
- If the current is too big, the battery will be empty very fast (battery will warm up).

Procedure

- Connect the battery with the copper wire.

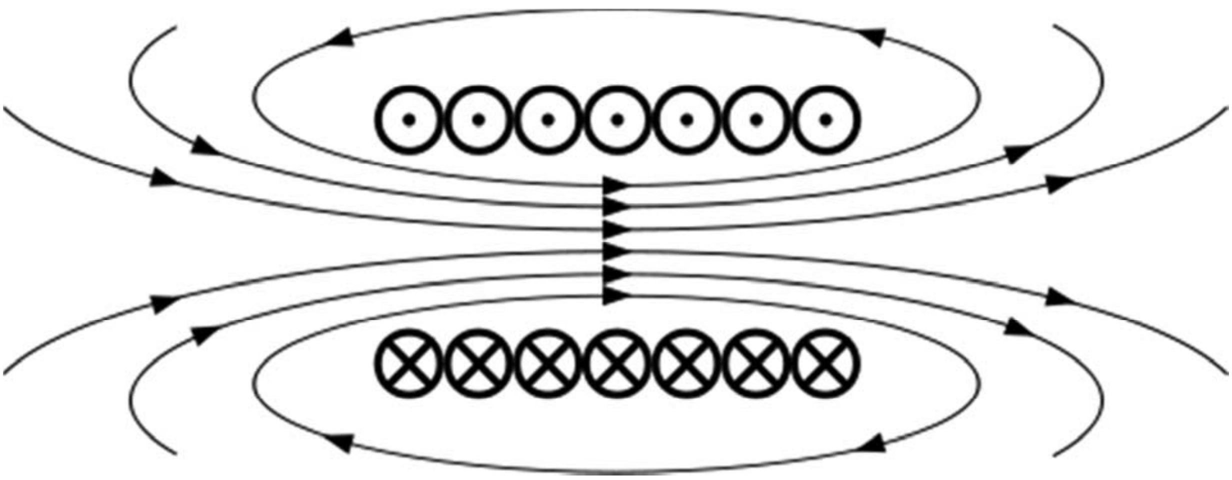


Observations

The paperclips are hanging at the iron nail. The nail becomes magnetic!
A current going through coil results in a magnet (interaction between electricity and magnetism!).

Explanation

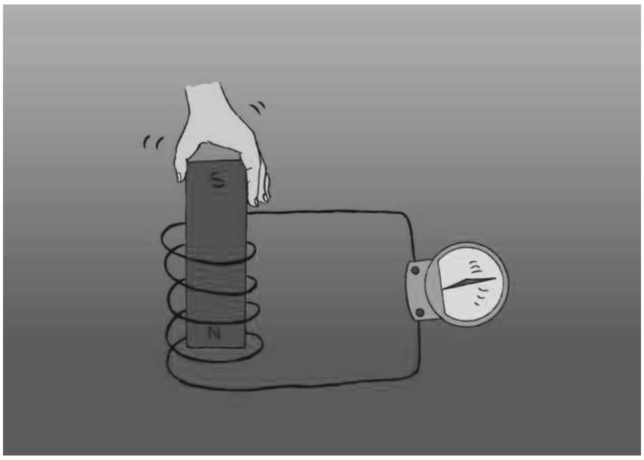
Electric current creates a magnetic field inside the cupper coil. A wire with an electric current passing through it generates a magnetic field around it; this is a simple electromagnet.
The strength of the generated magnetic field is proportional to the amount of current.



The direction of the magnetic field through a coil of wire can be found from a form of the right-hand rule. If the fingers of the right hand are curled around the coil in the direction of current flow through the windings, the thumb points in the direction of the field inside the coil.
Iron is ferromagnetic so the magnetic field magnetizes the iron nail.

Conclusion

A wire with an electric current passing through it generates a magnetic field around it. This is a simple electromagnet. The strength of the generated magnetic field is proportional to the amount of current.



6.5 How do electric currents and magnets interact? The Lorentz Force

Objectives

- Students can explain how a wire carrying a current can become a magnet.
- Students understand how electricity and magnetism are related.
- Students can make a simple electromagnet.
- Students can calculate the direction of the Lorentz force

Link with curriculum

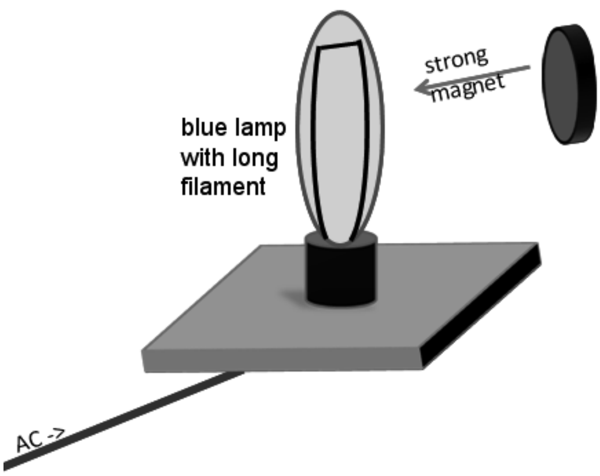
Physics textbook: Grade 8, Chapter 5, Lesson 1-2, published 2010
Physics textbook: Grade 10, Chapter 3, Lesson 1-3, published 2009

Material

- Strong magnet
- Blue Lamp (E27 – 25W) and lamp holder (E27). To create a good visual experiment you must be able to see the filament of the light bulb very well. Because it is not possible to look directly into a normal light bulb, you need a kind of blue lamp. Don’t bring the magnet too close because the filament could break.

Procedure

- Bring the strong magnet close to the lamp



Observations

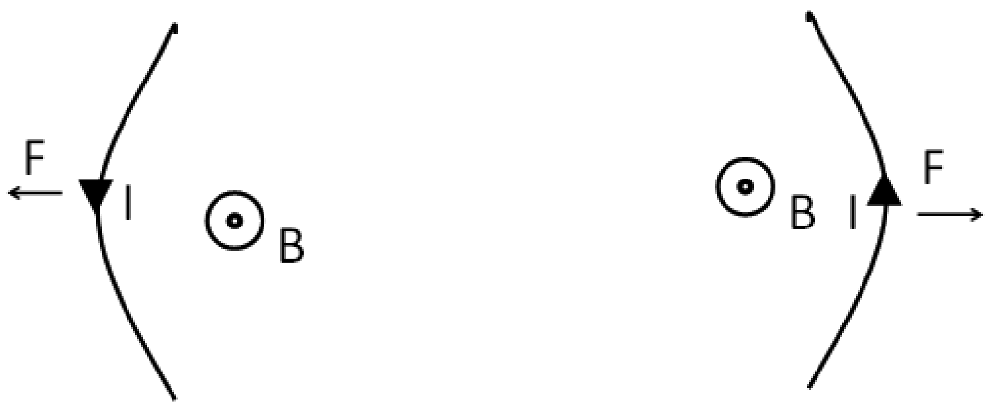
When the magnet approaches, the filament moves back and forward (oscillates very fast).
Can you explain this?

Explanation

You can explain this experiment on a basic and more advanced level, depending on the level of your students.

First level explanation:
The filament is a current-carrying wire so it behaves like a magnet (see previous experiment). This means that this electromagnet can be attracted or repelled by another (strong) magnet.
The current in the filament is an alternating current so the poles of the electromagnet will change rapidly (100 times/s). The filament is alternatively attracted and repelled (100 times/s) and oscillates when the magnet is close.

Second level explanation (Lorentz force):
Magnetic field “B” of the magnet exerts a Lorentz Force “F” on a current-carrying wire.
The direction of “F” is perpendicular to the direction of “B”, but also perpendicular to direction the electric current “I” (right hand rule).
When “I” is reversed, “F” is also reversed



Lorentz force “F” to the left..Lorentz force “F” to the right

“I” changes direction 100 times per second, so “F” will also change 100 times per second, causing the curve of the filament to change 100 times per second.

Conclusion

The filament of the lamp behaves is an electromagnet that can be attracted or repelled by another (strong) magnet. The current in the filament is an alternating current so the poles of the electromagnet will change rapidly and the filament is alternatively attracted and repelled, causing the oscillation.

6.6 Movement out of electricity

Objectives

- Students can explain how a single loop electromotor works
- Students can make a simple electromotor.

Link with curriculum

Physics textbook: Grade 8, Chapter 5, Lesson 1-2, published 2010
Physics textbook: Grade 10, Chapter 3, Lesson 1-3, published 2009

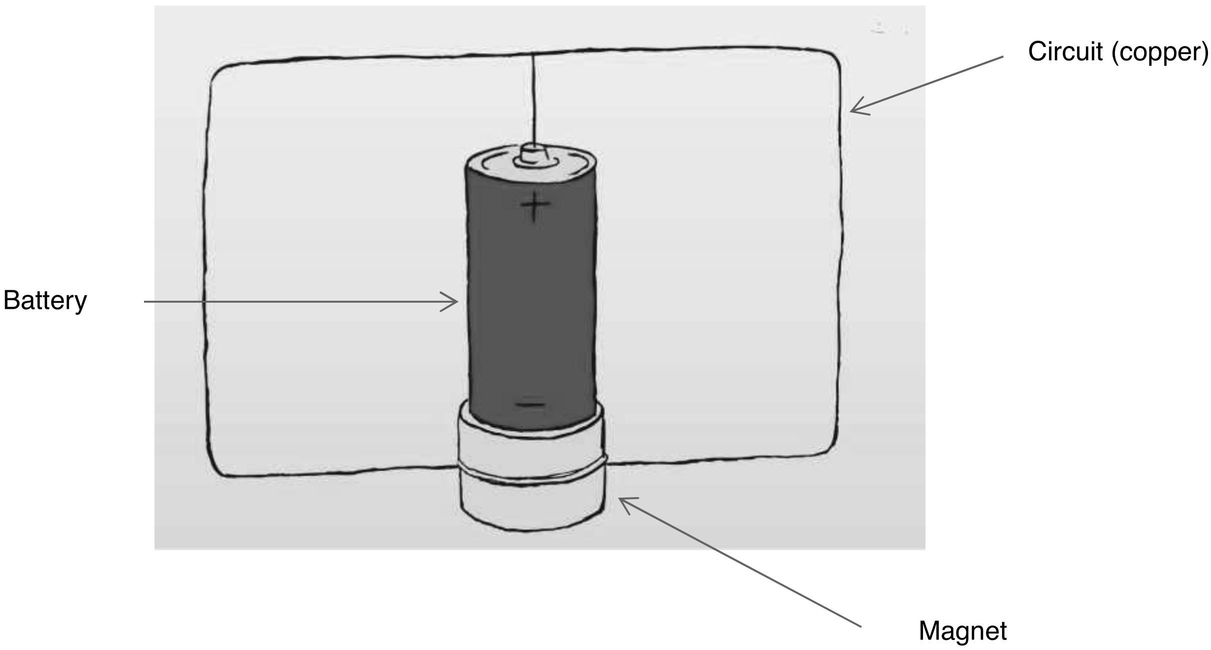
Material

- AA battery
- Strong magnet
- Copper wire. Make sure you use non-isolated copper wire. You can easily strip the isolation from isolated wires.

Important tips:
- Make sure the electric contacts are good (contact with the battery and conductive magnet). If necessary, you need to scrape the copper wire!
- Reduce friction as much as you can.

Procedure

Connect the circuit to the battery.



Observations

The circuit starts to move! We have made a simple electromotor!
Ask following questions during the observation:

- How we can make the circuit turn in the other direction?
- What happens when you turn the magnet?
- What happens when you turn the battery?
- If you cut one side of the circuit, will it still move?

Explanation

You can explain this experiment on different levels (a more basic level and a more advanced level):

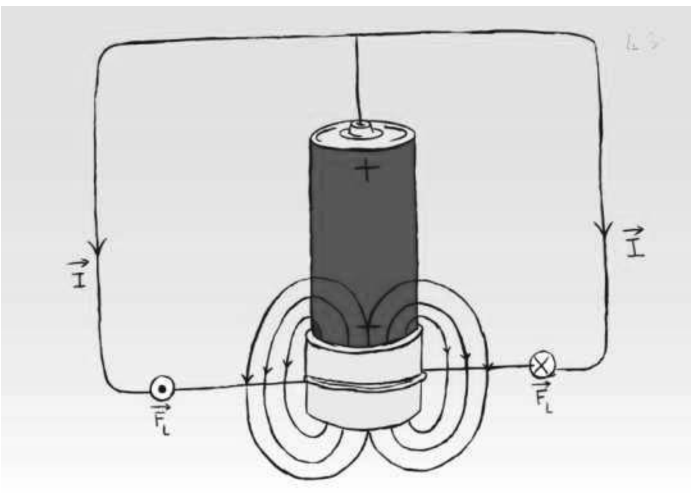
First level explanation:
The circuit behaves like a magnet that interacts with the strong magnet. This means there will be a force that creates movement of the circuit.
In electromagnetism 4 things always appear together: magnet (or magnetic fields), metal wires (mostly copper wires), electricity (electric current) and movement.
Conclusion: If you have 3 of them, you always have the fourth. In this experiment you have a magnet, copper, electricity that creates movement.

Second level explanation: use of Lorentz force, see previous experiment.
Lorentz Force Law:

- electric current “I”
- magnetic field lines “B” (from north to south pole)
  => Lorentz force “F” (use the right hand rule!)

Conclusion

In electromagnetism 4 things always appear together: magnet (or magnetic fields), metal wires (mostly copper wires), electricity (electric current) and movement. If you have 3 of them, you always have the fourth. In this experiment you have a magnet, copper, electricity that creates movement.



6.7 Can magnets induce electric currents?

Objectives

- Students can explain how electric current can be induced from magnets
- Students understand how electricity and magnetism are related

Link with curriculum

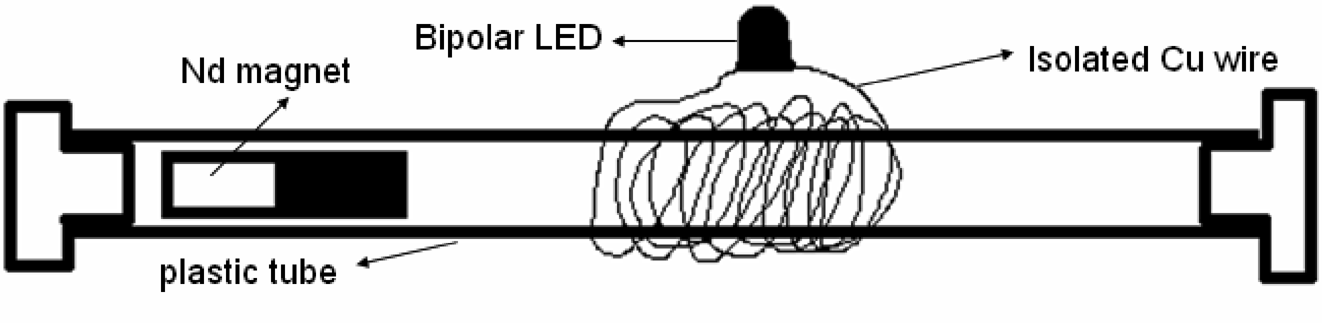
Physics textbook: Grade 8, Chapter 5, Lesson 1-2, published 2010
Physics textbook: Grade 10, Chapter 3, Lesson 1-3, published 2009

Material

- You can always make a coil yourself out of isolated copper wire. It’s easier to use an old transformer to have a copper coil. You can find this in the motor of a microwave oven or other electronic devices with an electromotor.
- Do not forget to strip the isolation of the wire to make good contacts.
- LED (if possible a bipolar LED, which gives more light)
- Strong magnet

Procedure

- Drop a magnet (or shake the tube) so that the magnet inside passes the coil.



- Ask your students what will happen. You can present the question as a ConcepTest, presenting different possible answers.
  a) The LED will light up permanently
  b) The LED will only light up when the magnet passes the coil
  c) The LED will permanently light up but go out when the magnet passes the coil.
  d) The LED will not light up

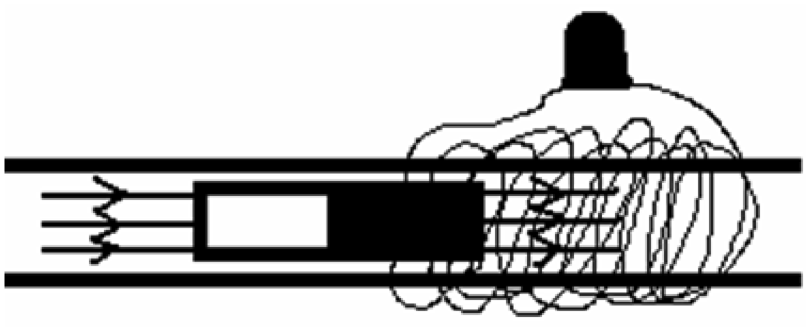
Observations

The LED will only light up when the magnet passes the coil.

Explanation

You can explain this experiment on different levels (a more basic explanation and a more advanced):
First level explanation (see also explanation previous experiment)
In electromagnetism 4 things always appear together: magnet (or magnetic fields), metal wires (mostly copper coil), electricity (electric current) and movement.
Conclusion: If you have 3 of them, you always have the fourth. In this experiment you have a magnet, a copper coil and the movement of the magnet. These 3 create movement.

Second level explanation (Law of Faraday)
Law of Faraday: when the magnetic flux through a coil changes an electric current is been induced.
The magnetic flux = number of field lines going through a surface (cross section of the copper coil).
Only when there is a change of magnetic flux, there will be a current!
When the magnet passes the coil, there is a change of flux. There arises a current (law of Faraday).
The current will lighten up the LED



Conclusion

In electromagnetism 4 things always appear together: magnet (or magnetic fields), metal wires (mostly copper coil), electricity (electric current) and movement. If you have 3 of them, you always have the fourth. In this experiment you have a magnet, a copper coil and the movement of the magnet. These 3 create a current (Law of Faraday).

6.8 Only changing currents induce other currents

Objectives

- Students understand that only a change in magnetic field will create electricity.
- Students can explain why transformers only work with alternating current.

Link with curriculum

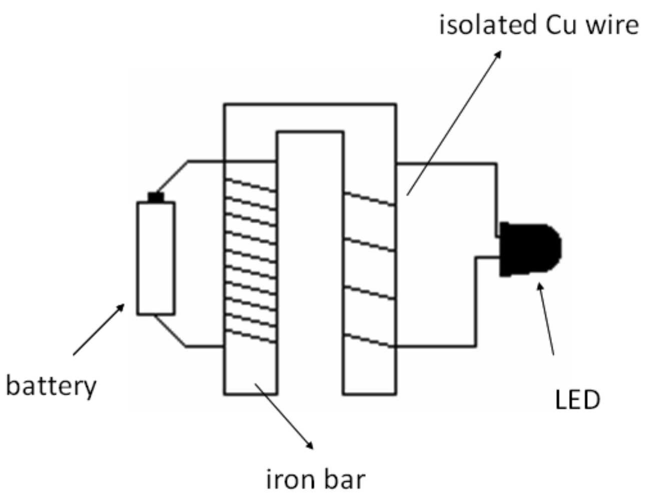
Physics textbook: Grade 5, Chapter 1-2, Lesson 3, published 2010
Physics textbook: Grade 10, Chapter 3, Lesson 1-3, published 2009

Material

- Battery (9 V)
- Instead of the iron bar and two copper wires, you can use a classical adaptor (220 V to 12 V) as transformer. Connect the 220 V to the battery and 12 V to the LED. Big transformers you can find in old microwaves.

Procedure

- Connect and disconnect the battery
- When will the LED light up?



Observations

The LED will only light up when you connect or disconnect the battery (it depends whether you use a normal or bipolar LED).

Explanation

When you connect and disconnect the battery, the magnetic flux inside the second coil will vary.
A change in magnetic flux induce an electric current (law of Faraday) so the LED only blinks during connection and disconnection of the battery
Transformers work only with alternating currents !

Conclusion

Only a change in magnetic field or magnetic flux will create electricity.

6.9 Falling down slowly

Objectives

- Students can explain the Law of Lenz in their own words.
- Students can explain why the fall of the magnet in slowed down in the Cu tube, but not in the Al tube
- Students can perform a simple demonstration illustrating the Law of Lenz

Link with curriculum

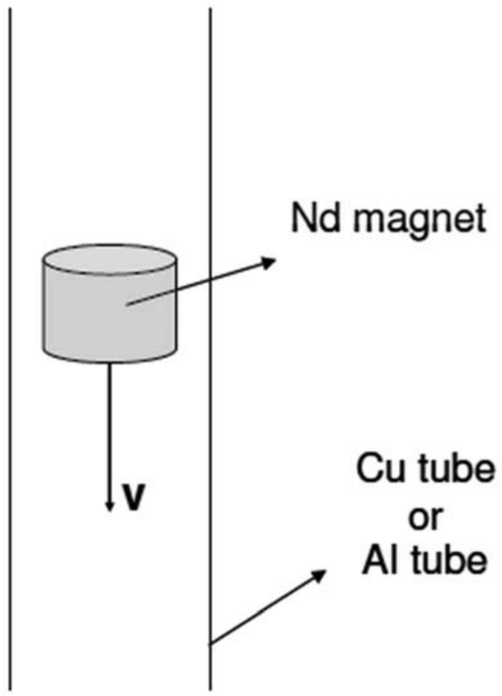
Physics textbook: Grade 8, Chapter 5, Lesson 1-2, published 2010
Physics textbook: Grade 10, Chapter 3, Lesson 1-3, published 2009

Material

- Strong magnet
- Copper tube
- Aluminium tube

Procedure

- Take a copper tube and let an object (not a magnet) fall trough a copper tube. Observe the speed of falling.
- Let a magnet fall through a copper tube. Observe the speed of the falling magnet. Can you find an explanation?
- Try it with an aluminium tube. Is there a difference?



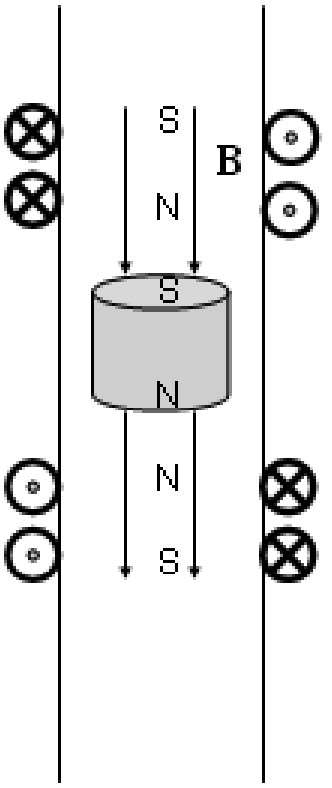
Observations

- The first object will fall like every object falls (acceleration of gravity g).
- The magnet on the other hand falls down slowly (it's like gravity decreases?!)
- In the aluminium tube the also falls down slowly but faster than in the copper tube.

Explanation

You can explain this experiment on different levels (basic explanation and more advanced one):

First level explanation: Law of Lenz
While the magnet falls, there is movement, a magnet and copper (tube). This means that electric current has been induced inside the copper tube (Law of Faraday: change of magnetic flux).
This (newly induced) current creates an opposite magnetic field that slows down the magnet.
This is called the law of Lenz: every current, created by electromagnetic induction, is always in such a direction as to oppose the motion or change causing it. This is in fact an extension of the law of conservation of energy to electromagnetic induction. Every induced current will oppose to the source that causes this current. In this case the movement of the magnet causes the electric current!



Second level explanation
This explanation focuses on the magnetic field (lines) near the magnet.
In the part under the magnet you can see that the magnetic flux increases. According to the Law of Faraday, electric current will be induced below the magnet. These electric currents will work against this increase of flux (Law of Lenz) and become an electromagnet that repels the falling magnet.
In the part above the magnet you have a similar reasoning: the magnetic flux decreases, which also creates an electric current that will work against this decrease of flux. This upper part becomes an electromagnet that attracts the falling magnet.
The induced currents inside the aluminium tube will not be as big as in the copper tube because aluminium has a bigger resistance then copper. This means that the magnet will also slow down but will still fall faster than in the copper tube.

Conclusion

According to the Law of Lenz every current, created by electromagnetic induction, is always in such a direction as to oppose the motion or change causing it.

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