

ORDINARY LEVEL SECONDARY  
EDUCATION PHYSICS  
PRACTICALS

**USING LOCALLY  
AVAILABLE MATERIALS**

TEACHER'S GUIDE

# Preface

As the era of Alternative to Practical comes to an end, it is my hope that science teachers nationally embrace the new paradigm, that science lessons should be student-centred, competence-based, activity-oriented, and connect with student's life experience. Every student in Tanzania should perform practical exercises, not just the few tested on national exams, but the wider range of hands-on activities teachers should employ to build a deep understanding in their students.

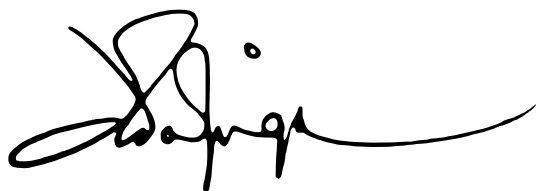
Educational research has identified two obstacles to the universal implementation of hands-on science education. First, many teachers themselves learned in Alternative to Practical schools and therefore lack essential experience with hands-on science. Every effort is already under way to overcome this deficiency. A national in-service training program reaches thousands of educators annually, and a Teachers' Guide has already been written to guide teachers on standard execution of dozens of hands-on activities in Physics.

The remaining challenge is a fallacy rooted in ignorance and complacency: the idea that the materials required for hands-on science teaching are unavailable to most schools. We reject the notion that science education requires expensive, imported materials. Everything required to teach modern science is already available in our villages and towns. The challenge is simply to begin.

Science belongs to Tanzania as much as any country in the world. The law of gravity respects no national boundaries; we all feel its effect and can measure its strength. Those who decry the use of locally available materials as "stone age science" misunderstand the meaning of Science - that it applies universally, in any situation, with any material. Dependence on expensive imported materials teaches students that Science is a foreign concept, to be memorized rather than understood, and that Science lacks application to daily life. Science is the birthright of humanity, as much as Language or Mathematics or Music, and the time has come to embrace what we already own.

This Companion Guide was written to equip teachers with the knowledge

and skills to deliver hands-on science lessons in any school, especially those without standard science laboratories. I hope that this Companion Guide will also inspire school inspectors, examiners, curriculum developers and college tutors to increase their emphasis on the importance of hands-on education, and to reject material deficiencies as an excuse for any absence of practical work. In the same spirit, this Companion Guide seeks to expand the range of approaches to learning Physics and it is my hope that the many stakeholders in science education will embrace alternative methods that enable quality delivery of science education for every student.

A handwritten signature in black ink, appearing to read 'Dihenga', with a stylized flourish extending to the right.

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Permanent Secretary  
Ministry of Education and Vocational Training  
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# Background

## Motivation for Writing this Companion Guide

Quality science education requires students to perform experiments with their own hands. Unfortunately, research on the situation of secondary science education shows that many students do not perform such experiments. This is due to several factors, all of which can be addressed.

First, many teachers themselves do not have enough experience with science experiments, largely due to the absence of practical education when they themselves were students. Teacher training programs and the new Physics Teachers' Guide seek to address this shortcoming.

Second, this lack of experience leads to low confidence for trying new experiments. Science can only be learned through experimentation – just as students must perform activities to truly understand the material on the syllabus, so too must teachers. The teacher using this book is strongly encouraged to perform every one of these experiments to deepen his or her fundamental understanding of Physics.

Third, most schools lack traditional laboratory facilities. Many educators therefore assume that this means hands-on activities are impossible.

To address this misconception, the Ministry of Education and Vocational Training has decided to prepare this Physics Companion Guide. The objective is to ensure that all secondary school Physics teachers can conduct practical work even if they do not have access to a standard Physics laboratory. Specifically, this book demonstrates that many quality hands-on science experiments are possible with very basic materials. The experiments in these pages require materials available in villages or, at worst, in a regional capital. Standard laboratory materials certainly add value to science teaching; this book merely makes it clear that they are not required as a condition for provision of quality education.

## Procedures Followed in Developing the Companion Guide

This Companion Guide builds on the work of the Physics Teachers' Guide. In preparation for the Teachers' Guide, educators and subject experts identified activities for most of the topics on the ordinary level syllabus. To prepare this Companion Guide with Local Materials, a team of secondary school teachers and science experts from TIE devised methods for performing the activities of the Physics Teachers' Guide using low cost and locally available materials.

## Description of the Companion Guide

Practical investigations address specific syllabus content. Each topic begins with a short summary of relevant syllabus material. Each activity is introduced in that context as a method for students to experiment with the topic of the day. Each activity then states clearly its objectives. Generally, these objectives match the objectives in the Physics Teachers' Guide. The teacher should use both resources, side by side, when preparing activities.

Each activity description then lists the required materials. Instructions for the local manufacture of several items are given in the first section of this book in the section called "Manufacture of Apparatus." If an activity requires the use of materials from this section they will be marked with a star (\*) in the materials list. For example, the materials list may look like this: "Materials: beakers\*, test tubes\*, plastic spoon" If you see this, you can refer to the materials list to see a suggested method for making your own beakers.

After listing the objectives and materials, the description lists any hazards associated with the activity and precautions teachers should take to minimize these hazards. Next are procedures, both for preparing the activity and for executing the experiment. While preparation steps are generally to be performed by the teacher, the activity steps are often to be performed by the students themselves.

The description next outlines the expected results and what conclusions may be drawn from them. Then follow the instructions for cleaning up. The section closes with questions useful for guiding classroom discussion. Students should discuss these questions in groups and share their answers with the class.

Many of the activities also include a "Notes" section to provide the teacher with additional information about the activity. This information may be practical or theoretical.

## Application of the Companion Guide

This guide is written for teachers to acquire the knowledge and skills needed to lead students in hands-on science learning. While all of the experiments in this companion guide may be performed as demonstrations, the intention is for many of the activities to be performed by the students themselves, individually or in small groups, under the direction of the teacher.

To prepare for such lessons, the teacher should attempt these experiments first. Especially for teachers who are new to hands-on science experimentation, these experiments should, in themselves, provide a useful training. If there are multiple subject teachers at the school, they are encouraged to experiment together. Once the teacher has achieved comfort and proficiency with the given activity, the teacher should integrate the activity into relevant lesson plans.

The vision is not for students to be spectators of science, but players themselves.

Finally, the teacher is advised to not regard the activities in this book as the only possible activities nor even the only possible activities for these particular objectives. Every educator has ideas for effective teaching and new ideas are the substance of development. After trying an activity, the teacher is strongly encouraged to devise and attempt alternatives. When possible, teachers should collaborate with each other on such experiments, and share with each other the ideas they develop.

The vision is not for teachers to be passive implementors, but innovators themselves.

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# Chapter 1

## Laboratory Equipment

Throughout this book you will see materials that have been marked with an asterisk (\*). These are locally available materials which can be made or purchased for your laboratory. The guide for using and making these local materials are found in the following section.

### **Beakers**

Use: To hold liquids

Materials: Water bottles, juice containers, lids for bottles or jars, and a knife

Procedure: Take empty plastic bottles of different sizes. Cut them in half. The base can be used as a beaker.

### **Delivery Tube**

Use: For the movement and collection of gases, capillary tubes, hydraulic press

Materials: Straws, pen tubes, or pawpaw petioles

### **Needles**

Use: Compass needles, optical pins, making holes, flying wire

Materials: Office pins, sewing needles, needles from syringes

### **Droppers**

Use: To add small amounts of liquid to something

Materials: 2 mL syringes

Procedure: Take a syringe. Remove the needle.

**Funnel**

Use: To guide liquid or powder into a small opening

Materials: Empty water bottles

Procedure: Take an empty water bottle and remove the cap. Cut them in half. The upper part of the bottle can be used as a funnel.

**Heat Source**

Use: Heating substances

Materials: Candles, kerosene stoves, charcoal burners, or a moto poa stove

Procedure: Cut a metal can in half and add a small amount of moto poa

**Stopper**

Use: To cover the mouth of a bottle, hold a capillary tube

Materials: Rubber, cork, plastic water bottle cap

Procedure: Cut a circular piece of rubber. If the stopper is being used to hold a capillary tube, a hole can be melted in a plastic cap or rubber stopper.

**Water Bath**

Use: To heat substances without using a direct flame

Materials: Heat source, water, and a cooking pot

Procedure: Bring water to a boil in a small aluminium pot, then place the test tubes in the water to heat the substance inside the test tube.

**Circuit Components**

Use: Building simple circuits, Ohm's Law, amplifier, wave rectifiers

Materials: Broken radio, computer, stereo, other electrical devices

Procedure: Remove resistors, capacitors, transistors, diodes, motors, wires, transformers, inductors, rheostats, pulleys, gears, battery holders, switches, speakers and other components from the devices.

**Masses**

Use: Calibrating and using beam balance and spring balance, Hooke's Law

Materials: Known masses, beam balance, sand, stones, plastic bags, thread, paper, tape, pen

Procedure: Use a beam balance and known masses at a duka or nearby school to measure exact masses of sand or stones. Use a marker pen to mark the

masses on the stones. If using sand, place a small piece of plastic bag on the scale pan and fill it with sand until you have the required mass. Tie the sand in the plastic bag with thread. Use paper and tape to make a label on the outside, marking the mass with pen. These masses can be used in your school. Water can also be as a known mass. The density of water is 1.0 g/mL, so you can use a known volume of water in a bottle to create a known mass. Be sure to also account for the mass of the bottle.

### **Plane Mirror**

Use: Laws of Reflection, periscope, water prism

Materials: piece of thin glass, kibatari, Optional: small pieces of mirror glass are cheap or free at a glass cutter's shop

Procedure: Light the kibatari so that it creates a lot of smoke. Pass one side of the glass repeatedly over the kibatari until that side is totally black. The other side acts as a mirror.

### **Iron Filings**

Use: To map magnetic fields

Materials: Steel wool / Iron wool used for cleaning pots

Procedure: Rub some steel wool between your thumb and fingers. The small pieces that fall are iron filings. Collect them in a matchbox or other container to use again.

## **Checking Voltmeters and Ammeters/Galvanometers**

Needed: Meters to check, a couple of wires, some resistors and a fresh battery.

Important note: There is a wrong way to hook up the meter. The needle will try to detect down because negative and positive are swapped. If the reading is zero, make sure that you try the opposite connection to be sure.

### **Voltmeters**

Hook up the voltmeter across the battery. The battery is probably 1.5 V, but do not worry if you see 1.1, 1.2, even if using a brand new battery. Try not to use a battery that reads much below 1 V on several different meters.

### Unusable Voltmeters

- Totally dead, no detection of the needle
- Voltage reading jumps excessively. Ensure that the connections are solid and test again.
- Measured voltage is totally wrong, not close to 1.5 V

### Usable Voltmeters

- Read a voltage close to 1.5
- If the voltage is not 1.5 exactly, the voltmeter is probably working and the battery is just old a bit.

## Ammeters

Hook up the ammeter in series with a resistor. Because you do not necessarily know the condition of the ammeter before testing, be sure to have several different resistors on hand. An ammeter may appear not to work if resistance is too high or too low. Start testing different ammeters.

### Unusable Ammeters

- Totally dead, no detection of the needle
- Current reading jumps excessively (but check connections)
- Totally wrong, reads much different from other ammeters

### Usable Ammeters

Reads a current similar to other ammeters.

Hard to say exactly what current, but feel free to calculate based on your resistor using  $V=IR$ , although do not forget that there is some internal resistance  $r$  of battery, so  $V = I(R + r)$ .

The resistance of the resistor is usually coded on the resistor in a series in stripes - see the instructions under Resistors in the Sources of Equipment section.

Tip: You can hold the wires onto the battery with your fingers; the current is far too low to cause a shock.

Other: Now that you have tested to see if your voltmeters and ammeters

work, you can feel free to check all of them for accuracy, by calculating expected values and comparing between meters. Most practicals will still work alright with somewhat accurate meters.

# Chapter 2

## Physics Activities for Form I

### Measurement

#### Construction of a Metre Rule

##### Learning Objective

- To construct and use a metre rule.

##### Background Information

Length is an interval between two points. It is usually measured in metric units like the metre (m), millimetre (mm), centimetre (cm), kilometre (km).

##### Materials

Wooden board, pen/pencil, a handsaw, ruler or tape measure

##### Preparation Procedure

1. Use the saw to cut a piece of wood 100 cm x 3.5 cm x 0.5 cm.
2. Use a ruler to mark a scale in cm on the wood.

##### Activity Procedure

Use the new metre ruler to measure length of different objects.

##### Discussion Question

What other objects can be arranged in order to measure distance?



## **Notes**

Instead of a wooden block, string can be used by making knots at a definite intervals.

## **Construction of a Measuring Cylinder**

### **Learning Objective**

- To construct and use a measuring cylinder.

### **Background Information**

A measuring cylinders measures the volume of liquids in millilitres (mL).

### **Materials**

Plastic bottles of different sizes, syringes (30-50 mL), marker pen, ruler, bucket full of water

### **Preparation Procedure**

1. Using the syringe, take a known volume of water from the bucket.
2. Transfer the known volume of water in the syringe to the empty plastic bottle.
3. Using the marker pen, mark the level of water in the plastic bottle with the volume from the syringe.
4. Repeat this step for a range of volumes, marking each volume on the side of the bottle.
5. Use a ruler to complete the scale.

### **Activity Procedure**

Use the constructed measuring cylinder to measure volumes of different liquids.

### **Clean Up Procedure**

Remove waste and return materials to their proper places.

## **Discussion Question**

Explain how to use a measuring cylinder.

## **Notes**

A measuring cylinder cannot be used to measure the volume of a solid by itself, though if the solid is immersed in a liquid, the volume can be determined with a measuring cylinder. The volume of granular and porous materials can also be measured if they are immersed in a liquid in a measuring cylinder.

## **Construction of Beam Balance**

### **Learning Objective**

- To construct and use a beam balance.

### **Background Information**

Mass is a fundamental quantity and is measured by using a beam balance. In physics mass is usually measured in grams (g) or kilograms (kg).

### **Materials**

Wooden bar 30 cm x 2 cm, string/wire, ruler, pencil/pen, 2 large plastic bottles, nails, heat source\*

### **Preparation Procedure**

1. Cut a piece of wood block to 30 cm x 2 cm.
2. Find the balancing point and then mark the point using a pencil or pen.
3. Make a hole at the balance point using a hot nail.
4. Mark 5 cm spaces on each side of the hole using a ruler.
5. Cut 2 plastic bottles about 3 - 4 cm from the bottom.
6. Make 3 round holes in the bottom of a plastic bottle at equal intervals. These will be used as scale pans.
7. Tie pieces of thread/wire about 15 cm length into the holes of the bottom of a plastic bottle.

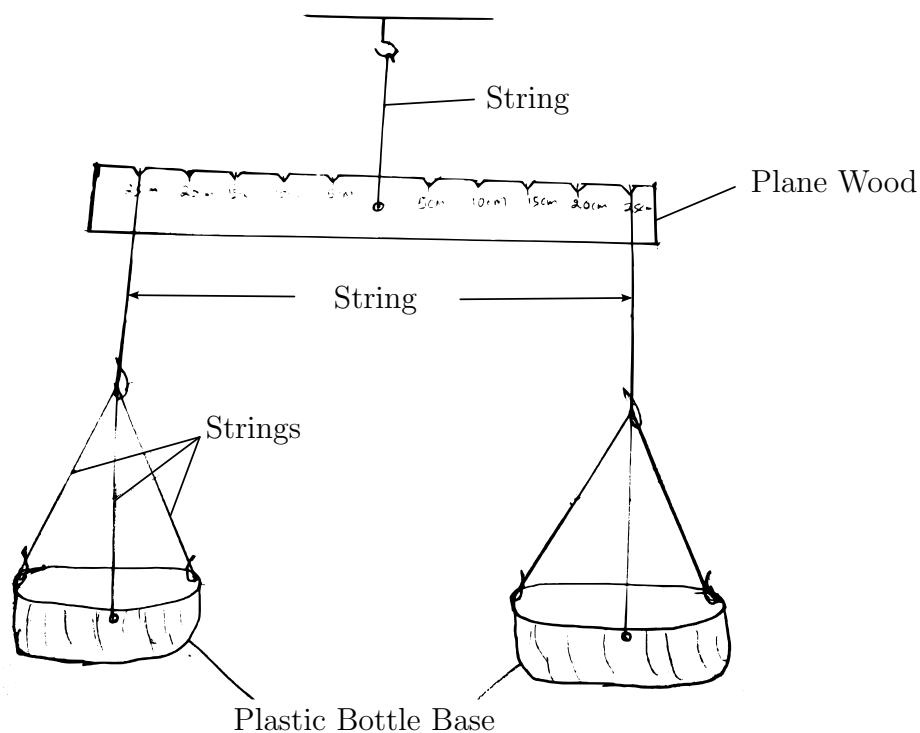


Figure 2.1: A beam balance

8. Join the upper ends of the thread/wires together.
9. Suspend the wooden block by using a piece of string/wire tied through the centre hole.

### Activity Procedure

Use the beam balance to measure the masses of different objects in the class-room.

### Clean Up Procedure

Return all materials to their proper places.

### Discussion Question

How can you improve the beam balance?

## Notes

There are different kinds of balances, such as a digital balance, double beam balance, single beam balance and triple beam balance. Each can be used to measure mass according to its sensitivity.

## Measurement Errors

### Learning Objectives

- To understand the meaning of experimental error
- To understand the importance of accurate measurement and sample size

### Background Information

Measurement is one of the most important aspects of science. However, it is impossible to make a perfect measurement because of our own errors and errors in the tools that we use. To improve our accuracy, we take many measurements and compare them to get an average result. However, it is important to understand the source of errors, how to account for them and how to reduce them. Different people measure differently, and even one person will measure differently from one moment to another.

### Materials

Metre rules, stopwatches, other measuring instruments, materials to measure

### Preparation Procedure

Collect different tools used for measuring, like metre rules or rulers, stopwatches, syringes, etc.

### Activity Procedure

1. Draw a line on the board or floor.
2. Have several students measure the line and secretly record their results.
3. Collect the results from the students and record them on the board. Observe any differences.
4. Distribute stopwatches to several students.

5. Clap twice; the students should measure the time between claps and record their results secretly.
6. Collect the results from the students and record them on the board. Observe any differences.
7. Have several students make other similar measurements, keeping their results secret until you record them on the board.
8. Have students decide what the best result is for each of the collected measurements.

## **Results and Conclusions**

The measurements will be different from person to person. Lengths, times, volumes, etc. will all vary for the same quantity. This is because each person measures slightly differently; this is fine as long as each person is trying their best to be accurate. The best result is the average of the results, combining the accuracy of all people in the final result.

## **Discussion Questions**

1. Why do the measurements differ from student to student?
2. How accurate are the tools that we use?

## **Notes**

Be sure that students understand that error is not bad. Many science students feel that they need to make their answers better, even if it means changing their data. Every measurement ever made has an error. Some tools are better at measuring than others; we simply use what we have and measure as accurately as we can. However, error needs to be understood and taken into account when doing experiments.

# **Density and Relative Density**

## **Relative Density of a Liquid**

### **Learning Objectives**

- To determine the density and relative density of a liquid.

## Background Information

Bodies of different materials have different densities. Density can be found by taking the ratio of a body's mass to its volume.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

Relative density (R.D.) can be used to compare the density of a given material to that of water. Water is the standard with a density of 1.0 g/mL, so all other densities are compared to water.

$$\text{R.D.} = \frac{\text{Density of substance}}{\text{Density of water}}$$

## Materials

“Density bottle” (small empty can or bottle), rubber stopper/dry grass/maize cob\*, plastic bag, water, honey, kerosene, cooking oil, straw/bamboo stick

## Activity Procedure

1. Weigh the can with its stopper and plastic bag in air (variable  $M_0$ ).
2. Fill the small can with water and weigh it (variable  $M_1$ ).
3. Pour out the water from the can and dry it with a piece of clean cloth or tissue.
4. Fill the can with another liquid, like honey, kerosene, or cooking oil, and weigh it again. (Variable  $M_2$ )
5. Repeat steps 3 and 4 for other liquids
6. Calculate the relative density of each liquid tested

## Results and Conclusions

Mass of density bottle =  $M_0$

Mass of density bottle with water =  $M_1$

Mass of the density bottle with liquid A =  $M_2$

$$\text{Relative density of liquid A} = \frac{\text{Mass of liquid A}}{\text{Mass of water}} = \frac{M_2 - M_0}{M_1 - M_0}$$

We use this formula to find the relative density of any liquid.

## **Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later.

## **Discussion Questions**

1. Determine the mass of the water.
2. Calculate the volume of the density bottle and the relative density of honey.

## **Notes**

A density bottle can also be used to find the density of a solid, liquid and granules. When finding relative density, units must be considered carefully. Before you find the ratio of liquid density to water density, be sure that the units are the same. g/mL or kg/L are the common units.

## **Construction and Use of a Hydrometer**

### **Learning Objectives**

- To construct a simple hydrometer.
- To explain the use of a hydrometer.
- To calibrate a hydrometer.
- To use a hydrometer to measure the density of various liquids.

### **Background Information**

Each liquid has a different density. The level at which an object will float in a liquid depends on the density of that liquid, so the different densities of liquids can be observed and measured by observing the level at which an object floats in them.

### **Materials**

Plastic straw, small piece of plastic bag, dry sand, several containers to hold liquids, marker pen, rubber band or thread, ruler, water, kerosene, honey, any other liquids

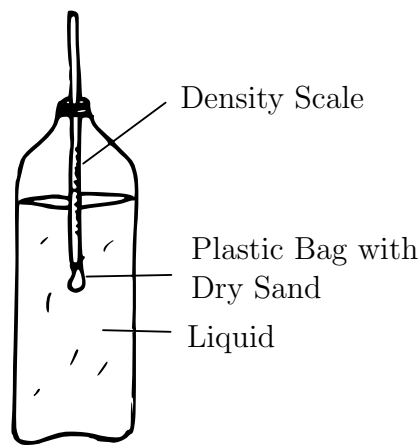


Figure 2.2: A Hydrometer

### Preparation Procedure

1. Close one end of the straw with the plastic bag and secure it with the rubber band or thread so that water cannot enter.
2. Place the straw in water with the plastic bag side down.
3. Pour sand into the straw until the bottom is heavy enough that the straw floats upright.

### Activity Procedure

1. Place the straw in water so that it floats upright without touching the bottom or leaning.
2. Use the marker pen to mark the water level on the outside of the straw. Label this mark as 1.0 (the known density of water).
3. Place the straw in a container of kerosene so that it floats upright without touching the bottom or leaning to one side.
4. Use the marker to mark the kerosene level on the outside of the straw. Label this mark as 0.8 (the known density of kerosene).
5. Remove the straw from the kerosene and clean it. Be careful not to get any liquid inside the straw.



6. Use a ruler to draw an accurate scale on the straw, using the 1.0 and 0.8 marks as starting points. Begin by making a mark directly between them as 0.9, etc.
7. When the scale is complete (both above 1.0 and below 0.8), use the designed hydrometer to measure the densities of other liquids by reading the mark at the level of the liquid.

## **Results and Conclusions**

The straw, when properly weighted, will float upright in any liquid and will therefore provide a good surface to write levels of liquids. The density of water is known as 1.0 and is relatively constant. Kerosene is also known as 0.8 and will not vary from place to place. By writing both of these points on the hydrometer and the respective floating levels, we can create a scale extending up from 1.0 and down from 0.8. This can then be used to measure the densities of other liquids.

## **Clean Up Procedure**

1. Return all liquids to their proper containers.
2. Clean the outside of the hydrometer.
3. Return all materials to their proper places.

## **Discussion Questions**

1. What liquids have high density?
2. What liquids have low density?
3. Why, when reading a hydrometer, do the small numbers appear at the top of the scale?

## **Notes**

Be careful not to get any liquid in the straw. If the sand becomes wet, the hydrometer will not work again until it dries.

## **Applications of Material Densities**

### **Learning Objectives**

- To observe the difference between densities of different liquids and solids.
- To design a density tower using a variety of liquids with different densities.

### **Background Information**

Materials can usually be distinguished from each other by their densities. Normally, less dense materials float on denser liquids. When liquids are placed in a container, the heavier (denser) liquids sink while the lighter (less dense) liquids float. A density tower can be designed using liquids of different densities, even if they are soluble.

### **Materials**

Water, honey, glycerine, cooking oil, spirit, kerosene, beakers\*, test tubes\*, syringes, small pieces of wood, small pieces of rubber, small pieces of metal, and different food colour (optional).

### **Preparation Procedure**

1. Find a test tube or syringe.
2. Place each liquid into a beaker so it can easily be obtained by students.

### **Activity Procedure**

1. Place a small amount of honey into the test tube.
2. Slowly add glycerine to the test tube.
3. Slowly pour water into the test tube.
4. Slowly add methylated spirit to the test tube.
5. Add cooking oil into the test tube.
6. Slowly add kerosene to the test tube.
7. Put a small piece of wood, rubber and iron into the test tube.

8. Observe the positions of the liquids and solids relative to each other.

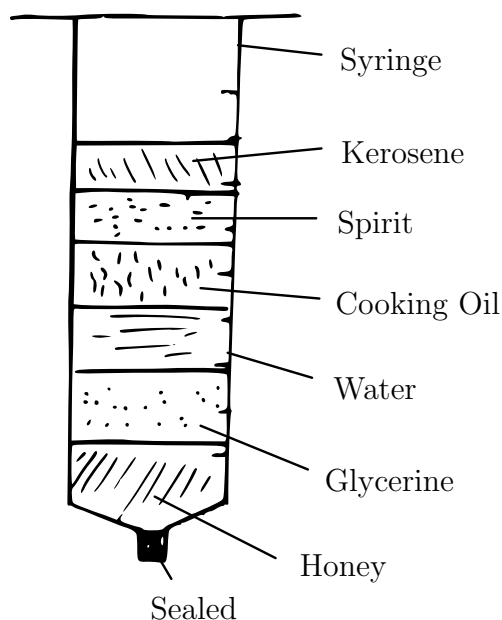


Figure 2.3: Density tower

## Results and Conclusions

The liquids with a higher density will sink, while the liquids with lower density will float. When the solid materials are dropped into the test tube, the solid material will rest in the liquid that has a relatively equal density.

## Clean Up Procedure

Collect all materials and return them to their proper place.

## Discussion Questions

1. Why should liquid be poured slowly into the test tube?
2. What happens when the wood, iron, and rubber are placed into test tubes?

## Notes

Heavier density liquid should be poured into the test tube first, followed by relatively less dense liquids. Pouring the liquids should be done slowly to avoid mixing of liquid. Food colour can also be added to colorless liquid such as water, kerosene, and glycerine.

## Archimedes' Principle

### Construction of Eureka Can

#### Learning Objectives

- To construct a eureka can and use it to measure volumes of irregular objects.

#### Materials

Plastic bottles of 500 mL or 1000 mL, straws\* or a syringe needle cap, a knife/razor blade, heat source\*, cellotape or super glue, nail, and a wire

#### Preparation Procedure

1. Cut the plastic bottle in half and use the bottom part.
2. Heat a sharp pointed end of the nail.
3. Using the heated sharp point of the nail, make a small hole about 5 cm from the top of the cut plastic bottle.
4. Cut a piece of straw about 5 cm long or use the syringe needle cap.
5. Insert the piece of straw into the hole. Make sure the piece of straw is tightly fixed with cellotape or super glue.

#### Activity Procedure

Use the constructed eureka can to overflow different liquids and to measure the volume of liquid displaced when an object floats in it.

#### Clean Up Procedure

Collect all the used materials, cleaning and storing items that will be used later.

### **Discussion Questions**

1. What is the relationship between the weight of a floating object and the weight of water it displaces?
2. What is the reason for using a Eureka Can instead of a normal bottle?

### **Notes**

A Eureka Can is typically used to move a certain volume from the can into another container. When an object floats in a liquid, it displaces its own weight in water. If the level of water in the Eureka can is at the level of the spout, the water displaced will flow through the spout into another container. This water can then be measured on a beam balance to find the weight of the object.

## **Flotation**

### **Conditions of Flotation**

#### **Learning Objectives**

- To explain the conditions for a floating body.

#### **Materials**

Water, fresh egg, salt, beaker\*

#### **Activity Procedure**

1. Fill a beaker with water.
2. Release a fresh egg on the surface of water slowly and observe its position.
3. Add some salt while stirring and observe the position of the egg.
4. Continue adding salt and observe the position of the egg.

## **Results and Conclusion**

The egg sinks to the bottom of the container because its density is greater than that of water. After adding the salt, the egg rises and finally floats on the surface of water. This is because the density of the water becomes higher than that of the egg.

## **Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later.

## **Discussion Questions**

1. Why does the egg sink initially?
2. What causes the egg to float after the addition of salt?

## **Notes**

An object immersed in water experiences upward force equal to the weight of the water it displaces. The upthrust competes with the downward pull of gravity which diminishes the weight of the object. If the upthrust is greater than the object's weight, it will float. Otherwise, the object will sink. If the water density is greater than the average density of the object, the object will also float. If the water density is less than the average density of the object, the object will sink.

# **Properties of Matter**

## **Surface Tension in Bubbles**

### **Learning Objectives**

- To observe the effect of surface tension in soapy water

### **Background**

Surface tension is the force which holds the molecules together on the surface of a liquid. It can be strong enough that insects can walk on water, or objects with high density can float on a liquid. Bubbles form under the force of surface tension. As the surface of a liquid naturally forms a shape with the smallest surface area, a thin film of liquid will form a sphere, held together

by surface tension around air. The air inside pushes out with equal force that air outside pushes in. Bubbles do not form easily in water, so a soapy solution is needed.

### **Materials**

Thin piece of wire (approximately 30cm), water, detergent, glycerin (optional)

### **Preparation Procedure**

1. Bend the wire to form a loop of 2 to 3 cm in diameter.
2. Continue to bend the wire so that it circles around the circumference of this circle several times.
3. Leave a straight piece several centimeters long to use as a handle. This is the bubble blower.
4. prepare a concentrated solution of detergent by mixing powdered soap in water with a small amount of glycerin.

### **Activity Procedure**

1. Dip the circular part of the bubble blower into the detergent.
2. When you remove the bubble blower from the solution, a thin soapy film should remain across the circle.
3. Gently blow through the center of the circle. With a little practice, you should be able to cause a spherical bubble to separate from the blower and float away.

### **Results and Conclusions**

When you blow through the bubble blower, we can see that the tension is pulling it back towards the surface. Once an independent bubble is formed, we see that it forms a nearly perfect sphere. This is because the surface is under tension. This tension forces the bubble to form the shape with the minimum surface area, a sphere.

### **Clean Up Procedure**

Return all materials to their proper places.

## Discussion Questions

1. What is inside the bubble?
2. Compare the pressure inside the bubble to the pressure outside the bubble.
3. Why do bubbles form easily in soapy water but not in fresh water?

## Notes

Try making the solution without glycerin and note any different results. It will be seen that the bubbles have colours; this is due to thin film interference, or the refraction of white light in a thin liquid medium.

## Changing Surface Tension

### Learning Objectives

- To observe the effect of surface tension
- To observe the effect of an impurity on the surface tension of water

### Background Information

Surface tension holds the molecules of a liquid together at the surface. However, the surface tension is not uniform; it depends on the composition of the liquid as well as the other forces present. In this experiment, we observe the effects of changing the surface tension.

### Materials

Cup or dish, water, ground black pepper, soap or detergent

### Preparation Procedure

Make sure that the cup or dish is clean, and has no soap or detergent residue.

### Activity Procedure

1. Fill the cup or dish with clean water.
2. Sprinkle ground black pepper over the surface of the water in a way that the pepper is distributed evenly and covers the whole surface.



3. Apply a small amount of soap or detergent to one finger.
4. Using this finger, touch the surface of the water at the center of the cup or dish.

## **Results and Conclusions**

When your finger touched the center of the surface of the water, the pepper moves quickly towards the edge of the water. This is because as your finger touches the surface, you introduce a small amount of soap or detergent, lowering the surface tension at that point. The surface of the water is now unbalanced; the surface tension near the edge is pulling the surface outwards more strongly than the surface tension at the center is pulling the surface inwards. As there is a net force on the surface outwards towards the edge, the surface moves, pulling the pepper along with it to the edges of the cup or dish.

## **Clean Up Procedure**

Dispose of the water and return all materials to their proper places.

## **Discussion Questions**

1. Why does the pepper move quickly away from the center?
2. What happens if you add other liquids instead of soap?

## **Notes**

Floating objects will tend towards the area with highest surface tension. The pepper in this case is following the higher surface tension towards the side of the container.

## **Water Dome**

### **Learning Objectives**

- To observe the strength of surface tension and cohesion

## **Background Information**

Surface tension can be surprisingly strong. Insects and objects can float on top of water because of its tension; also water itself holds together in droplets. Combining droplets allows cohesion to form more bonds, creating a larger droplet with the same surface tension.

## **Materials**

Coin, water, syringe or eyedropper

## **Activity Procedure**

1. Place a coin on the table.
2. Using the syringe or eyedropper, carefully drop individual water drops onto the coin. With some practice, you should be able to get quite a few drops onto the coin before the water spills over, creating a dome of water.

## **Results and Conclusions**

As you add more water to the coin, the water forms a larger and larger dome rather than spilling off the coin. The surface tension of the water holds it together against the force of gravity, which is trying to pull the water off the coin.

## **Clean Up Procedure**

Return all materials to their proper places.

## **Discussion Questions**

1. How many drops did you think would fit on the coin? How many actually did fit?
2. Why does the water dome eventually break?
3. Describe all the forces acting on the water.

## **Notes**

The most dramatic results can be seen on small coins, though big coins can also be used. You should be able to get at least 60 drops on a 200 shilling coin.

## **Cohesion in a Moving Liquid**

### **Learning Objectives**

- To observe the effect of cohesion on moving water

### **Background Information**

Cohesion is the force between molecules in a liquid. It holds liquids like water together if they are standing still or moving.

### **Materials**

Empty 0.5 litre bottle, water, syringe needle OR pin OR small nail

### **Preparation Procedure**

Make five small holes at the bottom of the side of the bottle. Make the holes close together (about 5 mm apart) with the syringe needle or nail.

### **Activity Procedure**

1. Pour water into the bottle and allow the water to start flowing out of the holes at the bottom.
2. Using your thumb and forefinger, pinch the streams of water together so that they form a single stream.
3. To separate the streams again, pass your hand in front of the holes and the five streams will appear again.

### **Results and Conclusions**

When you pinch the streams of water together, they form a single stream or a few streams. Water has a tendency to cling to itself due to its surface tension and cohesion. As you bring the streams together, you allow the water to stick to itself forming a single stream. Passing your hand in front again stops the flow of water at the holes and allows it to start again, which it will do in five streams.

### **Clean Up Procedure**

Return all materials to their proper places.

## Discussion Questions

- How did the behaviour of the water streams change as the level in the bottle decreased?
- What force holds the water streams together?
- Why do the streams eventually split?

## Notes

Be careful not to let the holes overlap or be too far apart. This will cause the water to form one stream from the beginning or make it impossible to pinch the streams. Practice pinching the water and make new holes if necessary.

## Elasticity

### Learning Objectives

- To explain the concept of elasticity.
- To demonstrate elasticity.
- To deduce the relationship between the applied force (tension) and the increase in length (extension) from Hooke's law.

### Background Information

The force applied to a spring is related to the extension of the spring as it stretches under the force. This is described by Hooke's Law. Provided that the elastic limit of the spring is not exceeded (meaning that the spring is not stretched too much), the extension of a spring or other material is directly proportional to the load or tension force. This is because of its elasticity.

### Materials

Rubber band, spring balance\*, and sling shot (catapult), metre rule, weights

### Hazards and Safety

- When making the small extension of the rubber/spring balance, be careful not to use too much force to avoid breaking the material.

### **Activity Procedure**

1. Take the rubber band or spiral spring and measure its original length. Record this measurement.
2. Hold the rubber band/spring balance and fix one end while slightly pulling on the other end. Check the increase in length after stretching and record the new length.

### **Results and Conclusions**

There is an increase in length when a force is applied to the rubber band/spring balance. The increase in length of the material when there is an applied tension, along with the return of the body to its original length when the tension is removed, is known as Elasticity. There is a relationship between the amount of force(tension) applied and increase in length(extension). This relationship is stated in Hooke's law.

### **Clean Up Procedure**

After finishing the demonstration, untie the rubber band/spring balance and leave it in the normal state as it was in the beginning.

### **Discussion Question**

Explain why the rope or spring breaks when very high tension (force) is used.

### **Notes**

Everything has an elastic limit where it will break or cease to be elastic. Stretching a spring to far will cause it to exceed its elastic limit and stop working.

## **Determining Adhesion and Cohesion**

### **Learning Objectives**

- To observe cohesion and adhesion forces of different liquids.
- To determine adhesive forces between water molecules.
- To determine cohesive forces between different liquids.

## Background Information

Adhesion is the force of attraction between a material and its surroundings. Cohesion is the force of the liquid molecules to stick to themselves. The concept of adhesive and cohesive forces can be used in different ways such as determination of viscosity of the liquids and explaining the transportation of liquid in plants and animals. When a drop of water is placed on a sheet of glass, the water spreads because adhesive forces between glass and water are greater than the cohesive forces between water molecules. When a drop of honey, cooking oil, or glycerine is placed on a sheet of glass, it remains almost spherical because the cohesive force is greater than the adhesive force.

## Materials

Sheet of glass, water, honey, glycerine, cooking oil, syringe, and 2 wooden blocks

## Activity Procedure

1. Place 2 wooden blocks on the top of the table.
2. Place a piece of pane glass horizontally over the two wooden blocks.
3. Using a syringe, place different drop of liquids on top glass. Record your observations.

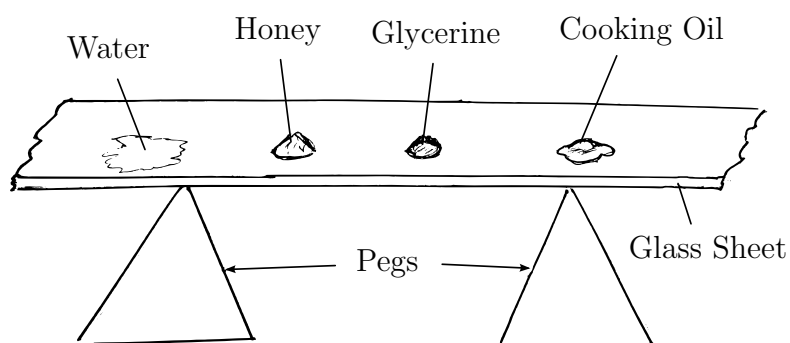


Figure 2.4: Observing adhesive and cohesive forces

## **Results and Conclusions**

When a drop of water is placed on top of glass, water spreads and wets the glass. While material like honey, glycerine, and cooking oil remain in a spherical shape. The adhesive forces between the water molecule and glass molecule is greater. While the cohesive forces between the molecule of honey, glycerine and cooking oil is larger.

## **Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later.

## **Discussion Questions**

1. Explain why water wets the glass while glycerine does not wet the glass.
2. Discuss where we apply the concept of adhesive and cohesive forces in other areas of science.
3. How are cohesion and viscosity related?

## **Notes**

The liquids which have the greatest forces of cohesion are also those with the highest viscosity.

## **Capillarity**

### **Learning Objectives**

- To observe the effect of capillarity in various liquids.
- To explain the mode of action of capillarity.

### **Background Information**

Capillarity, or capillary action, is possible because of the combined effects of cohesion and adhesion. Cohesion holds a liquid together, especially at the surface. Adhesion allows a liquid to attach itself to another material, like the vertical surface of a container.

## **Materials**

Clear thin plastic straws with different diameters, shallow container (bottom of a water bottle, jar cap), various liquids like water, spirit, cooking oil, and kerosene

## **Activity Procedure**

1. Pour some water into the container so that it is about 1 cm deep.
2. Place one end of the straw into the liquid so that the end is completely submerged but not touching the bottom of the container.
3. Observe the change in water level in the straw for about a minute.
4. Repeat these steps for the other liquids and compare.
5. Repeat these steps for straws of different diameters and compare.
6. Repeat these steps for different liquids and compare.

## **Results and Conclusions**

Liquid in a thin tube will slowly climb up the tube without any visible force present. Adhesion and cohesion are pulling the liquid up the tube. The capillary action of the liquid depends on the diameter of the tube. Different liquids have different capillary action for the same size capillary.

## **Clean Up Procedure**

1. Return all liquids to their proper containers and put them away.
2. Wash the container and straw and put them away.

## **Discussion Questions**

1. What causes the liquid to move up the straw?
2. What causes the liquid at the edge to cling to the straw while the liquid in the middle remains lower?
3. Which liquid moved up the straw fastest? Which moved slowest?
4. What would happen if the diameter of the straw was increased? What would happen if it was decreased?



## Notes

Liquids are able to climb up a thin tube due to the combined effects of adhesion and cohesion. Cohesion allows a liquid to remain connected to itself while adhesion allows a liquid to remain connected to another surface. Adhesion causes a liquid to climb slightly up the side of any container; the surface tension of the liquid (cohesion) then pulls the remainder of the liquid up as well. In a normal container, the adhesive force at the side of the container is not strong enough to pull all the other liquid up. In a thin container, a larger proportion of liquid is attached to the side of the tube and a smaller proportion is being held by surface tension, so the adhesive force is strong enough to pull all the liquid up the tube.

## Conservation of Energy

### Potential Energy of a Spring

#### Learning Objectives

- To observe the change in energy from potential to kinetic

#### Background Information

In a closed system, where no force acts on the objects, the total energy remains constant. In the case of mechanical energy, this means that potential energy and kinetic energy can change, but their total remains the same. Springs and other elastic materials also have potential energy in the form of elastic potential.

#### Materials

Clothes pin, thread, two pencils

#### Activity Procedure

1. A clothes pin has two ends: one for gripping clothes and one for pushing with fingers. Press the finger ends together so the gripping end is open as far as possible. Use a thread to tie the finger ends together so that the gripping ends stay wide open.
2. Place the clothes pin side-down on a table and place two pencils touching the clothes pins as shown in the figure below.

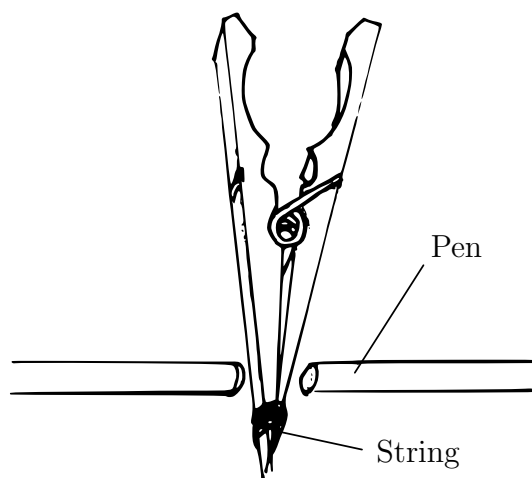


Figure 2.5: Arrangement of Materials

3. Cut the thread holding the clothes pin open, the clothes pin should open quickly and push the pencils away.

### Cleanup Procedure

Return all materials to their proper places.

### Discussion Questions

1. What two types of energy are being used here?
2. Describe the change in energy occurring here.

### Notes

The spring inside the clip holds energy when it is forced to contract. When the clip is allowed to close, the potential energy of the spring is converted into mechanical energy as the clip moves, forcing the pencils away quickly.

The interconversion of potential and kinetic energy may also be shown with a simple pendulum. Another option is to hold a heavy book above the table and then to drop it on the table.

# Forces

## Presence of Gravity

### Learning Objectives

- To identify the force of gravity as it acts on falling bodies
- To identify the effect of air resistance on falling bodies

### Background Information

All objects on the earth experience a force of attraction exerted by the earth. This is a natural force called Gravity and it acts on all bodies at all times. The force of gravity varies from one point to another; some areas experience stronger gravity than others, but this effect is not noticeable. All objects are pulled by gravity with equal force, regardless of their weights or masses.

### Materials

Various objects, a piece of paper, and a book (the book should be the same size or bigger than the paper)

### Activity Procedure

1. Hold the various objects at shoulder height.
2. Drop the objects to the ground one at a time. Repeat this step, but releasing the objects at the same time.
3. Observe if there is any difference in speed as the objects fall to the ground.
4. Hold a piece of paper at shoulder height and then release it.
5. Place a piece of paper on top of a book and hold the book flat at shoulder height.
6. Release the two items together and observe any differences between the motion of the paper by itself and of the paper and book together.
7. Bunch the paper into a tight ball and drop it again.

## **Results and Conclusions**

It will be seen that all objects, with the exception of paper and other light, wide objects, fall at exactly the same rate. This is because the acceleration due to gravity for all objects on earth is the same. The paper, however, falls very slowly. This is not because gravity pulls less on paper; it is because the paper is more affected by air resistance. All objects are affected by air resistance, but it is most obvious with objects that have a small weight but a large surface area. The effects of air resistance can be greatly reduced by placing a book under the paper. The book moves easily through air and blocks all of the air which would normally push against the paper. This is why the paper and book fall at the same rate. When the paper is bunched into a ball, the mass stays the same but the air resistance is greatly reduced so it should fall at the same rate as the book.

## **Clean Up Procedure**

Collect all materials and return them to their proper place.

## **Discussion Questions**

1. Did the objects fall at the same rate or at different rates?
2. Why did the paper fall slowly the first time?
3. Why did the paper fall quickly when it was placed on top of the book?
4. Why did the paper fall quickly when it was bunched into a tight ball?
5. What force is pulling all objects down? Does this force ever change?

## **Notes**

When performing this experiment, it is important to remember the effect of air resistance. Gravity pulls equally on all bodies, but air resistance opposes the motion of light-weight objects more effectively than heavy-weight objects.

## **Making a Spring and a Spring Balance**

### **Learning Objectives**

- To make springs for various uses.
- To create and calibrate a spring balance.

## **Background Information**

Springs typically have a constant value which determines how much they can stretch or compress. Because the value is constant, we can use it to accurately measure mass or weight, as it will always extend to the same length with the same force.

## **Materials**

Strong metal wire of swg 24 or 26 of various types like copper, nichrome or constantine; a rod of diameter 14 to 18 mm of any material, piece of wood, ruler, plane paper, known masses, glue.

## **Preparation Procedure**

Cut the metal wire into different lengths of at least 50 cm.

## **Activity Procedure**

1. Take a piece of wire and hold one end to the rod.
2. Coil the wire tightly along the rod, keeping the coils close together.
3. When the entire wire is coiled along the rod, remove the rod.
4. Bend both ends of the wire into hooks.
5. Repeat these steps for all of the wires of different types and lengths.
6. Try stretching and compressing the springs to test the different strengths.
7. Attach the end of one spring to the top of a piece of wood with a nail or screw.
8. Glue or tape some white paper to the wood behind the spring.
9. Use a pen to make a mark at the bottom of the spring.
10. Hang a known mass on the spring so that it is stretched downward a short distance.
11. Make a mark at the bottom of the spring in its new position. Label this with the mass of the object hung from the spring.
12. Repeat this process for other masses, marking each mass on the paper.

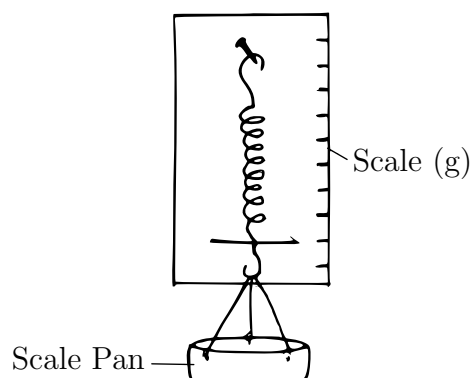


Figure 2.6: A Spring Balance

13. Use a ruler to finish the scale by filling in masses above, below and between the marks you have made.

## Results and Conclusions

When a load is placed on the spring, it increases the length of the spring. When the load is removed, the spring returns to its original length. Different materials of the same swg have different spring constants (strengths), or force per extension length.

## Clean Up Procedure

Return all materials to their proper places.

## Discussion Questions

1. What are some uses of springs?
2. What are the qualities of a good spring?
3. What is the relationship between the wire's diameter and the strength of the spring?
4. Which metal makes the strongest spring? Which metal makes the weakest spring?

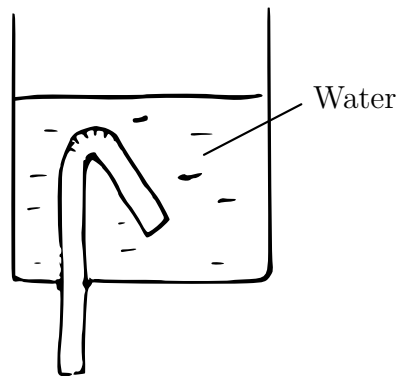


Figure 2.7: The Automatic Flushing Tank

### Notes

A good spring must obey Hooke's Law. Springs can be used to make a spring balance or can be used in physics practicals to find the relationship between force and the resulting extension.

## Pressure

### Automatic Flushing Tank

#### Learning Objectives

- To identify the application of pressure differences

#### Background Information

The effect of pressure in a liquid can be observed in different ways. Automatic flushing tanks operate under the influence of pressure in a liquid. When the level of water in a container reaches the highest point in the exit pipe, water will drain from the tank until the level of the water in the tank is below the level of the outlet. The tank can then be refilled to repeat the cycle. This type of system is useful for flushing or when you need a certain amount of water for a given amount of time.

#### Materials

Empty drinking water bottle, straw, water, bucket, chewing gum OR super-glue

## **Preparation Procedure**

Cut off the top of an empty water bottle, make a hole at the bottom so as to fit the straw through it. Bend the straw inside the bottle so that it makes an upside down 'U' shape. Use the chewing gum or superglue to seal the hole.

## **Activity Procedure**

1. Hold the bottle and place the bucket below the bottle.
2. Pour some water into the bottle up to and above the bend in the straw and observe what happens.

## **Results and Conclusions**

The water will flow into the bucket through the bent straw.

## **Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later.

## **Discussion Question**

What causes the water to flow from the bottle to the bucket? How does this work?

## **Notes**

The siphon principle states that liquid is able to flow without pumping because the combined pressure of the water and the atmosphere pushing down on the water is greater than the air pushing up on the straw. The automatic flushing tank does not require a handle to trigger the flush. Once the water flows into the tank up to the level of the siphon, the tank will flush automatically.

## **Cartesian Diver**

### **Learning Objectives**

- To observe characteristics of a submerging body
- To describe and apply the concept of Cartesian diver in daily life



## **Background Information**

When the body is immersed in a liquid it may sink or float. The body will float in water when its density is less than density of water. A submerging body is designed in such a way that it will sink a little but also float in water.

## **Materials**

Large Bottle (1.5 litres) or transparent long container with a cover or cap, water, syringe, and small stones

## **Preparation Procedure**

Remove the needle from the syringe.

## **Activity Procedure**

1. Fill a bottle with some water.
2. Remove the plunger from the syringe and insert a few stones into the syringe.
3. Replace the plunger so that the syringe is full of air but sealed at the top.
4. Hold the syringe upright and immerse it in the bottle making sure that the syringe and its contents float upright in the water.
5. Close the bottle with the cap.
6. Gently squeeze the bottle near the bottom.
7. Observe what happens.

## **Results and Conclusions**

When the bottle is gently squeezed the syringe sinks down to the bottom. When the bottle is released the syringe rises back up.

## **Discussion Question**

Why does the syringe move down when the bottle is squeezed?

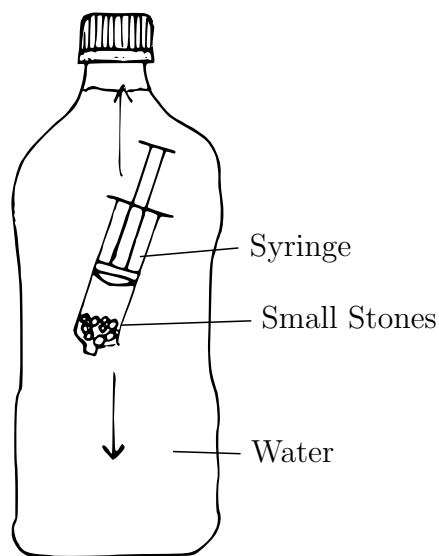


Figure 2.8: The Cartesian Diver

### Notes

The syringe sinks down because the pressure in the bottle increases when you squeeze it. Added pressure will cause water from the bottle to enter into the syringe through the needle hole. This increases the weight of the syringe and thus it sinks. When the pressure is released, the water in the syringe leaves and so the syringe will float again. A Cartesian diver and a submarine use the same principle to sink and float in deep water.

## A Siphon

### Learning Objectives

- To demonstrate how to shift water from one bucket to another bucket using suction
- To identify the applications of atmospheric pressure

### Materials

Two buckets, water, thick rubber tube about 1 m long

### **Activity Procedure**

1. Pour some water into a bucket and place it on the table. Place the other bucket below the table.
2. Put the rubber tube in the bucket and fill it with water.
3. Bend one end of the tube so that air cannot enter and remove it from the bucket. Make sure the other end of the tube remains underwater.
4. Lower the bent end of the tube into the lower bucket.
5. Open the bent end. Observe what happens.

### **Results and Conclusions**

Water will flow from the bucket on the table to the other bucket below the table. This is because of the combined force of atmospheric pressure pushing in the top bucket and gravity pulling the water to the bottom bucket.

### **Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later.

### **Discussion Question**

If the two buckets were switched, would the water flow from the lower bucket to a bucket on the table? Explain your answer.

### **Notes**

The flow of water is driven by the net difference in elevation of the two ends of the tube. The force of gravity pulls the water through a siphon. As long as the inlet is above the outlet, water will flow even if it has to go up before it goes down. This is because as water is pulled down the of the tube by gravity the pressure decreases at the top of the siphon and air pressure in the bucket pushes the water into the tube. This will continue until the water level in the top bucket is below the inlet of the tube.

## **Liquid Pressure and Depth**

### **Learning Objectives**

- To verify the variation of pressure with depth in water

## **Background Information**

The wall of a dam is made much thicker at the bottom than at the top. Also, water storage tanks are placed at the top of a building. This is because the pressure in a liquid is related to its depth.

## **Materials**

Plastic bottle, nail or metal pin/needle, matches, water

## **Preparation Procedure**

1. Light a match and heat the sharp point of the nail or pin.
2. Use the heated nail to put three holes into a bottle. Put one hole near the bottom, one near the middle, and the last hole between them.

## **Activity Procedure**

1. Fill the bottle with water up to the rim.
2. Hold the bottle in air using your hand or place the bottle at the top of a tall object like a stool on a table.
3. Allow water to flow out of the bottle and observe the trajectory of water from each hole. Note the horizontal distance reached of water from each hole.

## **Results and Conclusions**

The water flows faster from the hole with the greater depth because there is greater pressure, showing that the water pressure increases with the depth of the water. This is because the weight of the water on top acts downward causing pressure. The greater the depth, the greater the weight, resulting in greater pressure.

## **Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later.

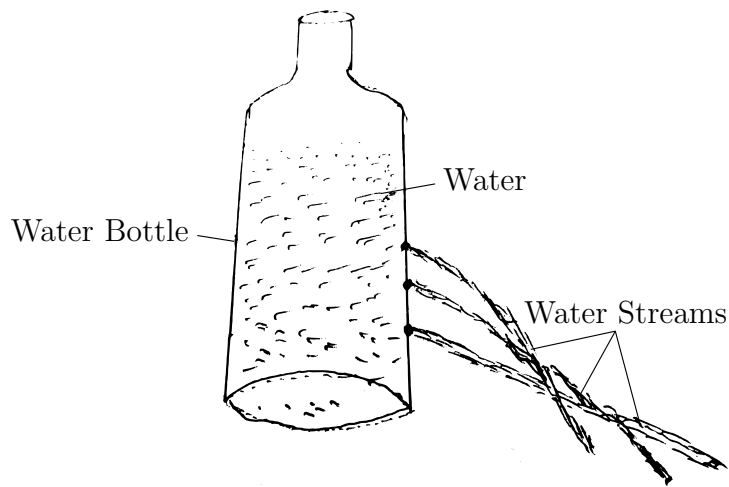


Figure 2.9: Demonstration of the effect of depth on liquid pressure

### Discussion Questions

1. What have you observed in the trajectory of water from each hole?
2. How does the pressure change with the depth of water? Why?

### Notes

There is a difference between depth and height. Height is measured from the reference point upward while depth is measured from the reference point downward. The reference point in this case is at the surface of water.

## Making a Magdeburg Hemisphere

### Learning Objectives

- To demonstrate the effect of atmospheric pressure

### Materials

Two small cooking pots of equal size, oil, matches, small pieces of paper

### Preparation Procedure

Spread oil or grease around the edge of one of the cooking pots.

### **Activity Procedure**

1. Place some pieces of paper into the cooking pot which does not have any oil.
2. Light the pieces of paper on fire.
3. Allow the paper to burn until about half of it has burned.
4. Place the greased cooking pot upside-down on top of the ungreaed cooking pot so that they create a sort of ball and no air can escape.
5. Allow the pots to cool.
6. Try to separate the pots.

### **Results and Conclusions**

After the pots have cooled it is very difficult to separate them. This is because when you burn the paper, the air in the pot expands and escapes. When you cover the pots, no more air can enter and the air inside cools, reducing the pressure inside the pots while the pressure outside the pots remains the same. The atmospheric pressure therefore presses the pots together so as to equalize the pressure on either side of the pot.

### **Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later.

### **Discussion Questions**

1. What is the reason for burning the paper and then covering the pot?
2. What happens when the pots cool?

### **Notes**

The principle behind the Magdeburg hemisphere is used to create suction. When air is heated, it expands and escapes. If the hot container is sealed and allowed to cool, the reduced number of particles causes a lower pressure than atmospheric pressure. Thus, the force pushing the two pots together from the outside is greater than the force pushing out from the inside and thus the two pots are very difficult to separate.

## **Air Pressure**

### **Learning Objectives**

- To observe the effects of air pressure on a flexible material

### **Background Information**

Air in a container pushes out with equal force on all sides of the container. If the pressure in the container is low, the force is small; if the pressure is high, the force is large. If the pressure is high, it is difficult to bend or crush the container as the air pressure inside resists being pushed. If the pressure is high enough, it can cause a flexible container to be rigid.

### **Materials**

Plastic straw, potato

### **Activity Procedure**

1. Hold a straw and push it hard into the potato.
2. Observe what happens to the straw.
3. Place your thumb firmly over one end of a straw and push the other end into the potato.
4. Observe what happens to the straw and potato.

### **Cleanup Procedure**

Dispose of the potato and return the straw to its proper place.

### **Discussion Questions**

1. Why does the straw not pierce the potato when your thumb is not blocking the back of the straw?
2. Why does the straw pierce the potato when your thumb is blocking the potato?

## Results and Conclusions

When the straw is pushed into the potato, it bends. The skin of the potato is strong enough that the straw cannot pass through it. However, when your thumb covers the back of the straw, the straw breaks the skin of the potato and passes through. This is because the air in the straw pushes out against the sides of the straw. Without your thumb, the air can simply escape out the back of the straw without applying a force. When your thumb covers the hole, the air cannot go anywhere so it applies a force outward. This causes the side of the straw to become rigid, allowing it to break the skin of the potato.

## Notes

Be sure that, in the first step, you are not holding your thumb over the back of the straw. This should only be done later.

## The Effect of Surface Area on Pressure

### Learning Objectives

- To observe the factors affecting pressure
- To demonstrate the effects of surface area on pressure

### Background Information

When a force acts on an object, the results are greatly affected by the area over which it acts. Consider the pain in your hand when you carry a bucket of water with a thin wire handle. Wrapping a piece of fabric around the handle greatly reduces the pain. This can be explained using pressure and summarized in the equation:

$$\text{Pressure} = \text{Force} \times \text{Area}$$

$$P = F \times A$$

### Materials

Bar of soap, thin thread, thick string, 4 heavy stones of approximately equal weight, two stools, and a small wooden board.



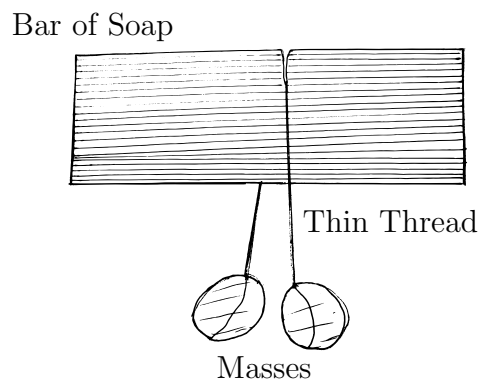


Figure 2.10: Thin Thread

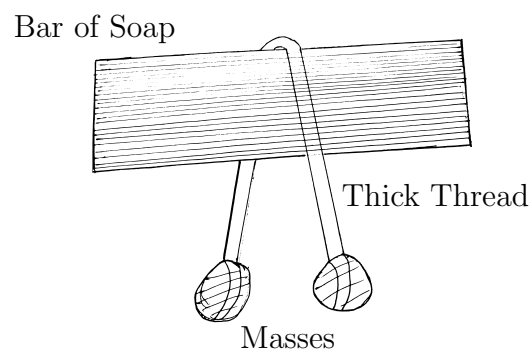


Figure 2.11: Thick String

### Activity Procedure

1. Place the wooden board between the two stools.
2. Place the piece of soap on top of the wooden board.
3. Tie stones to the ends of the thick string. Then tie stones to the end of the thin thread.
4. Hang each type of thread across the bar of soap so that the stones hang freely.
5. Observe the effect of each thread on the bar of soap.

## **Results and Conclusions**

It will be seen that the bar of soap was cut easily by using a thin thread but not by using a thick string. This because the thin thread has a small surface area and the same force and therefore a large pressure, while the thick thread has a larger area for the same force and therefore smaller pressure.

## **Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later.

## **Discussion Question**

Why does a thin thread cut easily through a bar of soap while a thick thread does not?

# **Light**

## **Light in a Straight Line**

### **Learning Objectives**

- To explain the concept of light rays and beam of light
- To demonstrate that light travels in straight line

### **Materials**

Torch/kerosene lamp/light source, cardboard, 6 large books, iron nail

### **Preparation Procedure**

Cut 3 rectangular pieces of cardboard. Make a hole at the center of each piece of cardboard using a nail. The holes should all be the same distance from the bottom of the cardboard so they can be easily aligned.

### **Activity Procedure**

1. Arrange the cardboard pieces in between two books so they stand upright and arrange them in a straight line. The cardboard pieces should be at least 45 cm apart so that the holes are aligned.

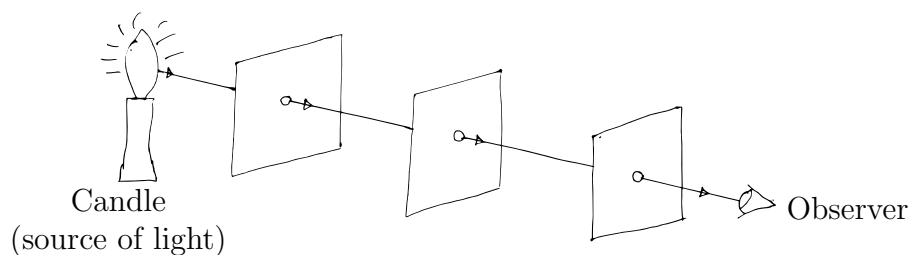


Figure 2.12: Experiment to show that light travels in straight lines

2. Place a light source 30 cm from the first piece of cardboard. Have an observer stand at the other end of the table.
3. Look through the series of holes to see the light source.
4. Slightly displace one of the pieces of cardboard and again look through the holes.

### Clean Up Procedure

Collect all the used materials, cleaning and storing items that will be used later.

### Discussion Questions

1. What does this experiment show about the way that light travels?
2. Draw a ray diagram to show the two alignments of the cardboard pieces.

### Notes

This activity is best done at night or in a dark room so that the light can be seen clearly through the holes.

## Pin Hole Camera

### Learning Objectives

- To construct a pinhole camera.
- To use a pinhole camera to demonstrate that light travels in a straight line.

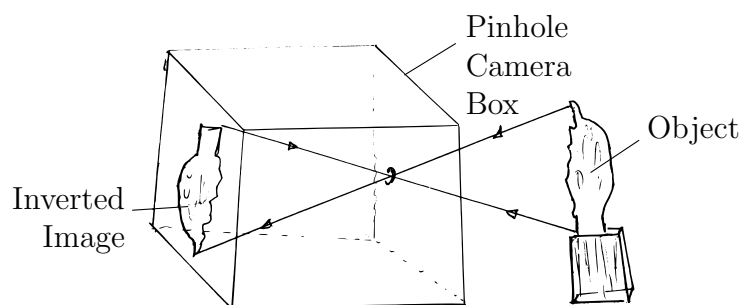


Figure 2.13: Construction of a pinhole camera

### Background Information

Light rays travel in a straight line. When the rays of light from a source pass through a small hole, the image of the source (any object producing or reflecting light) can be seen inverted on the other side of the hole. A simple, closed box can be used to demonstrate this property of light. This instrument is called a pinhole camera and it demonstrates the basis of photography.

### Materials

Cardboard box, plain paper, candle, kerosene, pin, glue, matches

### Preparation Procedure

1. Remove one side of an empty box and on the opposite side make a small hole using a pin.
2. Soak a piece of plain paper in kerosene to make it translucent.
3. Using glue, cover the open side of the box with the translucent paper to act as a screen.
4. Light the candle.

### Activity Procedure

1. Place the candle in front of the box on the side with the small hole.
2. Observe and record the image of the candle on the plain paper.

## Results and Conclusions

Rays of light travel in a straight line. The observed image is inverted as the result of the path of light rays from the object to the paper – the rays cross at the pin hole.

## Clean Up Procedure

The pinhole camera can be stored for later use.

## Discussion Questions

1. What properties of light allow the image to appear?
2. Why is the image of the candle inverted?
3. Draw a ray diagram to represent how a pinhole camera works.

## Notes

The hole must be very small, clean for the pin hole camera to work properly. A large or jagged hole will create a blurred image. If it is difficult to see the image go to a darker room or try the experiment in the evening or night.

## Laws of Reflection

### Learning Objectives

- To verify the laws of reflection in a plane mirror

### Materials

Plane mirror, pins, thick cardboard, protractors and rulers, white paper, pen, pencil

### Activity Procedure

1. Place a plane mirror vertically on a sheet of white paper on top of the cardboard.
2. Draw a line along the back of the mirror.
3. Construct a perpendicular line to the line on which the mirror stands.
4. Draw a line making an angle of incidence  $i$  from the normal.

5. Insert two pins on the line drawn which makes an angle  $i$  with the normal.
6. Look into the mirror such that the images of the pins look as if they are in straight line.
7. Insert two more pins so that they are in line with the images of the first two pins. These two more pins mark the path of the reflected ray.
8. Remove the pins and draw lines joining the marks of the pins.
9. Using a protractor measure and record the angle between the reflected ray and the normal.

### **Results and Conclusions**

This practical is used to verify the Laws of Reflection and to observe and describe images formed in a plane mirror. It will be seen that the angles of reflection are equal to the angles of incidence in each case.

# Chapter 3

## Physics Activities for Form II

### Static Electricity

#### Concept of Static Electricity

##### Learning Objectives

- To demonstrate the charging of an object
- To explain the concept of static electricity

##### Background Information

All objects carry charges which attract or repel other charges. Normally, the total charge on an object is zero, meaning an equal number of positive and negative charges. Sometimes, however, charges can be added to or removed from an object, causing the object to become charged. This can be seen when two objects attract or repel each other.

##### Materials

Sweater wool, dry plastic sheets

##### Activity Procedure

1. Place two transparent plastic sheets together on top of a book.
2. Rub the two plastic sheets with the sweater wool several times.
3. Separate the two plastic sheets slowly and listen to what happens.
4. Bring the plastic sheets closer and observe what happens.

5. Separate the two plastic sheets and rub them individually with the sweater wool several times.
6. Bring the sheets close to one another and observe what happens.

## **Results and Conclusions**

When the two plastic sheets are separated a cracking sound is heard. When they are brought together they are attracted to each other. This is because the upper sheet acquires a different charge from the lower sheet. When the two plastic sheets are rubbed separately and brought closer, they tend to repel. This is because they acquire the same charge. Charging by rubbing removes electrons or adds electrons. When rubbing the plastic sheets with a sweater, electrons will move from the sweater to the upper plastic and the protons from the lower plastic will attract the electrons from the upper one. That is why the sheets attract when they are rubbed together. When rubbing the sheets separately, you give them both a negative charge (electrons) from the sweater. That is why they repel each other.

## **Clean Up Procedure**

Collect all the used materials, storing items that will be used later.

## **Discussion Questions**

1. Why do we hear a crackling sound when we pull a sweater over our head?
2. Why do the sheets attract each other in one case but repel each other in another case?

## **Notes**

The crackling sound heard when the two sheets separate is caused by the movement of charges. The concept is the same as that of lightning, which involves moving charges. As the charges move, they displace air and leave a trail of low pressure. Air then rushes in to fill the empty space or low pressure, causing a crack sound.

## **Construction of an Electroscope**

### **Learning Objectives**

- To construct a leaf electroscope



- To understand the mode of action of an electroscope

### Background Information

A gold-leaf electroscope is used to detect the presence of electric charge on an object. It consists of a conductor attached to a very thin leaf of gold. When a charged object is brought to the electroscope, the charge moves along the conductor and leaf, causing them to repel each other. If the leaf deflects it means that there is a charge on the electroscope and therefore on the object being measured. If the leaf does not deflect, it means that there is no charge present.

### Materials

Clear jar with a plastic cap, iron nail, small piece of aluminium foil, glue

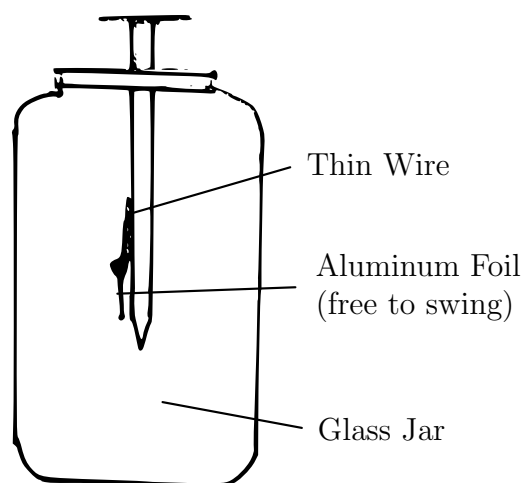


Figure 3.1: Aluminium foil electroscope

### Preparation Procedure

1. Use the iron nail to make a hole in the plastic cap.
2. Insert the nail down into the hole so that only about 1 cm is sticking up above the cap.
3. Use glue to secure the nail in the cap.
4. Cut a piece of aluminium foil 0.5 cm by 2 cm.

5. Attach one end of the foil (only the tip) to the iron nail with glue about 2 cm from the bottom of the nail.
6. Bend the foil at its pivot (where the glue is) so make sure that it can swing easily. If it cannot, wrap the end of the foil around a piece of thin wire and glue the wire to the nail so that the foil is free to swing close to the nail.
7. Close the cap with the nail and foil on the jar.

### **Activity Procedure**

1. Bring a charged object near the top of the nail.
2. Observe any deflection on the foil leaf.

### **Results and Conclusions**

When a charged object is brought close to the nail, the foil leaf deflects from the nail. This is because the charged object repels one type of charge in the nail and attracts the opposite charge. This causes one type of charge to move down the nail into the bottom of the nail and into the leaf. The charges in the leaf and nail repel each other, so the leaf deflects away from the nail.

### **Clean Up Procedure**

Return all materials to their proper places. Store the electroscope for later use.

### **Discussion Questions**

1. Why is it necessary to use a metal nail instead of plastic or wood?
2. Why do we close the leaf in the jar?
3. What does the foil leaf do when a charged object is brought near the nail head?

### **Notes**

A gold-leaf electroscope works as described above. Gold is used because it can be made very thin, so it has a very small weight and can deflect easily. Aluminium is not as thin so it cannot deflect as much, but it still shows the presence of charge.

## Detection of Charges

### Learning Objectives

- To determine the presence of charges
- To demonstrate the charging of the leaf electroscope

### Background Information

Charges form the basis of our understanding of static and current electricity. They are simply electrons; the presence of electrons increases the negative charge on an object, the absence of electrons decreases the negative charge on an object, and it is electrons which move through a conductor to create electric current. However, electrons are too small to see, even with a microscope. Therefore, we can only detect the presence of charges, not the charges themselves.

### Materials

Glass and silk or plastic pen and hair, leaf electroscope (see above activity to construct this)

### Preparation Procedure

Collect the necessary materials.

### Activity Procedure

1. Take glass and rub it with the silk or take the plastic pen and rub it in your hair, then quickly bring it close to the nail of the electroscope.
2. While the glass is still touching the metal cap observe the deflection of the foil in the electroscope (is there attraction or repulsion with the metal nail?).
3. Record the results from your observation and determine if charge is present.
4. Repeat these steps using notebook paper or any other objects you can find.
5. Compare results from different materials.

## **Results and Conclusions**

By touching the charged body to the top of the metal cap, charges are transferred to the leaf of the electroscope. Because both are equally charged the leaf and conductor will repel each other showing the presence of charge whether negative or positive. The amount of deflection is dependent on the amount of charge on the electroscope. An object with greater charge will cause the leaf to deflect more than an object with less charge.

## **Clean Up Procedure**

Store items for later use.

## **Discussion Question**

From your experimental results, how can you know if there is charge on the object touching the electroscope?

# **Current Electricity**

## **Conductors and Insulators**

### **Learning Objectives**

- To distinguish between conductors and insulators

### **Materials**

A nail, small piece of a bucket lid, aluminium foil from an empty cigarette packet, cotton thread, connecting wires, two dry cell, light bulb

### **Activity Procedure**

1. Connect a bulb, dry cell, and a nail in a series using the connecting wire. Observe the effects.
2. Replace the nail with aluminium foil, a cotton thread, and a small piece of a bucket cap, one after the other. Observe the effects.

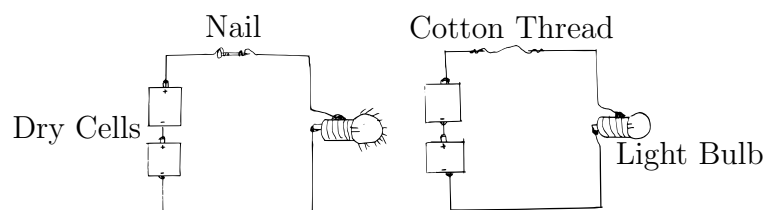


Figure 3.2: Testing the Conductivity of Different Materials

## Results and Conclusions

The bulb lights when it is connected with a nail and aluminium foil, indicating that there is a flow of current. The bulb does not light when it is connected with a cotton thread and a small piece of a bucket lid, indicating that a current does not flow. A nail and aluminium foil are conductors of electricity while a piece of a cotton thread and a piece of bucket cap are insulators — they do not conduct electricity.

## Clean Up Procedure

Collect all the used materials, cleaning and storing items that will be used later.

## Discussion Questions

1. What is a conductor?
2. Give four examples of (a) conductors (b) insulators.

## Notes

Metals like copper, aluminium, iron are used for connecting electric current. When electrons flow through the metal they reach the bulb and so it lights up. Such metals are called Conductors. On the other hand, plastics, wood, cotton threads are not used because electrons are not free flow through them so the bulb will not light. Such materials are called insulators.

## Finding Electric Circuit Components

### Learning Objectives

- To identify various components used in electric circuits

- To find circuit components locally

## **Background Information**

All of the electrical components studied in secondary school are common devices. These include resistors, capacitors, wires, motors, rheostats, switches, diodes, transistors, transformers, speakers, inductors, bulbs, etc. These components are common enough that they can be found in varying numbers and combinations in any electrical device.

## **Materials**

Broken radio, broken car stereo, broken computer, broken phone charger, broken disc drive, etc., pliers, screw driver, soldering iron (*optional*)

## **Hazards and Safety**

- If you are using a soldering iron, be careful not to touch it or touch someone else with it. It can very quickly cause second degree burns.
- After breaking and removing components, dispose of any sharp pieces.
- NEVER open a component which is connected to an electrical source!

## **Preparation Procedure**

1. Ask people to bring any broken electrical devices.
2. Go to a radio repair shop in town to find any broken or old components.

## **Activity Procedure**

1. Open any electrical device.
2. Identify all of the components visible inside the device.
3. Remove as many components as possible from the devices and place them in a container. Pliers can be used to retrieve most things, but sometimes a soldering iron will be necessary to melt the flux holding some components into their boards.

## **Results and Conclusions**

Circuit components can be found almost anywhere and can be used to perform many activities.

## **Clean Up Procedure**

1. Collect all useful components in a container and store for later use.
2. Dispose of any unused pieces.

## **Discussion Questions**

1. What components were you able to retrieve, and from what devices?
2. What components were you not able to retrieve, and where might you find them?

## **Notes**

This should be an ongoing activity for any school. Circuit components are always needed as they are easily destroyed in the laboratory. Keep looking for more things to take apart.

## **Measuring Emf of a Cell**

### **Learning Objectives**

- To identify the terminals of a cell
- To use a voltmeter or multimeter in parallel
- To measure the electromotive force of a single cell or battery

### **Background Information**

Electromotive force (Emf) — also called voltage or potential difference — is the force from a cell or battery to move electric current through a circuit. A voltmeter reads the difference in voltage between two points in a circuit. If the difference in voltage is measured across a cell, the amount of voltage used in the entire circuit, from the positive terminal of the cell to the negative terminal, is being measured. This is the same as measuring the amount of voltage supplied by a cell, or the Emf.

### **Materials**

Working dry cells, speaker wire / connecting wire, multimeter or voltmeter

### **Activity Procedure**

1. Set the multimeter to the DCV (direct current voltage) setting.
2. Connect the terminals of the multimeter to the terminals of the battery so that the multimeter displays a voltage level.
3. Adjust the voltage magnitude on the multimeter until the voltage displayed is a clear, readable value.
4. Connect two batteries in series and measure the total Emf.
5. Connect two batteries in parallel and measure the total Emf.

### **Results and Conclusions**

If a new battery is being used, the voltmeter should display the full Emf of a cell, which is 1.5 V. If an older battery is being used, the Emf may show a slightly lower value. Students will see that the voltage (Emf) measured across a single cell shows all of the force of the cell without losing any through resistors. Also, the Emf of batteries in series is more than that of batteries in parallel.

### **Clean Up Procedure**

1. Turn off the multimeter.
2. Collect all the used materials, storing items that will be used later.

### **Discussion Questions**

1. What causes the force of the cell?
2. What is moving through the circuit?
3. Why is a voltmeter connected in parallel across a cell in order to measure Emf?
4. What is the difference between the Emf of batteries in series and parallel?
5. How would you calculate the Emf of batteries in series? In parallel?



## Notes

Electromotive force (Emf) is a kind of voltage. The other kind of voltage is Potential Difference and is used to measure the voltage difference across a resistor. Emf is always the same for a battery; it does not depend on the circuit it is connected to. Connecting batteries in series simply adds the forces of all the batteries together. Connecting batteries in parallel provides the same voltage as the battery with the largest voltage.

## Magnetism

### Magnetic and Non-magnetic Materials

#### Learning Objectives

- To identify magnetic and non-magnetic materials
- To observe the effect of a magnet on magnetic and non-magnetic materials

#### Background Information

The only naturally occurring magnet is Lodestone, which is a kind of mineral. However, we tend to use iron to make magnets as it is easily magnetized and very strong. Magnets can have a very strong attractive or repulsive force, but the force only acts on some materials.

#### Materials

Magnet\*, various objects in the classroom or home like iron nails, plastic, wood, cloth, metal, etc.

#### Activity Procedure

1. Bring the magnet close to an object.
2. Observe if the object moves or if it is difficult to remove the magnet.
3. Repeat this for any object you or the students can find in the classroom.
4. Keep a list of what is attracted by the magnet and what is not.

## Results and Conclusions

Many metals are attracted to magnets. Most other materials are not attracted to magnets.

## Discussion Questions

1. What objects were attracted to the magnet?
2. In general, what materials are attracted to magnets?
3. What objects were not attracted to the magnet?
4. In general, what materials are not attracted to magnets?

## Notes

Note that some common metals (e.g. copper and aluminium) are not attracted to magnets. Also note that some rare non-metals (e.g. liquid oxygen) are attracted to magnets. Of the elements students learn about in ordinary level, iron makes the strongest magnets.

## Magnetic Fields

### Learning Objectives

- To map magnetic field lines of a given magnet using iron filings
- To explain the shape and direction of magnetic fields on a magnet or between magnets

### Background Information

Magnetic fields are invisible lines of force that run between the poles of a magnet (from North to South) or between the poles of multiple magnets. We cannot see these lines, but we can feel them when we bring magnets close to each other.

### Materials

Steel wool, magnets\*

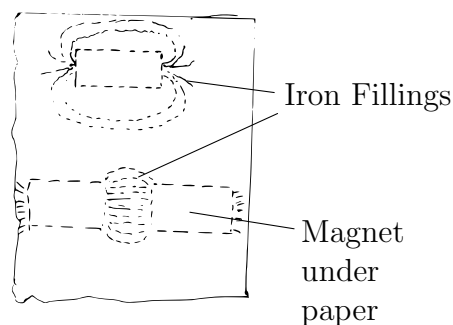


Figure 3.3: Observing Magnetic Field Lines

### Preparation Procedure

1. Place a sheet of paper on the table
2. Take the steel wool and rub it over the sheet of paper. Small pieces (filings) of the steel wool will fall to the paper.

### Activity Procedure

1. Place a magnet on the table.
2. Place a piece of paper over the magnet so that the paper is flat
3. Slowly and gently drop the iron filings on the paper. Spread them evenly.
4. Observe the positions of the filings and the shape they create.
5. If another magnet is present, place it near the other magnet under the paper.
6. Drop more filings on the paper to observe the shape of the field between the two magnets.
7. Repeat this process for the two magnets in various positions: repelling, attracting, etc.

### Results and Conclusions

The iron filings are magnetic and light-weight, so they will move to follow the magnetic lines of force on a magnet. The filings will clearly show the curved

lines around the magnet from one pole to the other. If the magnet is strong enough, the filings will show the three-dimensional field. Between magnets, the filings will show a strong concentration of force between opposite poles and a neutral point between like poles.

### **Clean Up Procedure**

1. Store iron filings inside a *dry* bottle after using them
2. Return the magnets to a safe storage place.

### **Discussion Questions**

1. Describe the shape of the magnetic field lines
2. Where is the magnetic force strongest? Where is it weakest?

### **Notes**

You can visit any garage in town where there is a welder or metal saw and collect iron dust and use them as iron filings.

## **Earth's Magnetic Field**

### **Creating a Simple Compass**

#### **Learning Objectives**

- To construct a compass and understand its mode of action
- To observe the presence of Earth's magnetic field

#### **Background Information**

The earth is a magnet. Its magnetic field lines extend from its North pole (near the geographic South pole) to its South pole (near the geographic North pole). However, we cannot see these lines as they are simply lines of force. Any magnet feels the force of the earth's magnetic field and tries to turn to face North. If a light-weight magnet is allowed to rotate freely, it will turn, thus showing the direction of North and South.

## **Materials**

Needle or pin, magnet, small plastic lid, water, small piece of paper, and a small plastic lid.

## **Preparation Procedure**

1. Collect the needle or pin. If it has a heavy end, break it so that it is uniform.
2. If needed get the bar magnet from a broken radio or speaker from the radio repair shop.

## **Activity Procedure**

1. Rub one side of the needle or pin on a bar magnet in one direction several times, do not scratch it.
2. Pour some water into the can cap.
3. Stitch the magnetized pin or needle into the piece of paper and place them on the surface of the water, let it rest. Observe it.
4. Give a slight push to the piece of paper so that it rotates slowly. Observe it.

## **Results and Conclusions**

A magnetized pin or needle always comes to rest in the North-South direction. This implies that the needle is pointing in the direction of earth's magnetic field towards the geographical north pole.

## **Clean Up Procedure**

Return all materials to their proper places and put the magnet in a safe place.

## **Discussion Question**

Which direction does the magnetized pin always point? Why?

## **Notes**

When magnetizing the pin or needle make sure you rub it only in one direction. Do not rub back and forth.

## Magnetic Dip Gauge

### Learning Objectives

- To observe the presence of magnetic dip
- To measure magnetic dip

### Background

The earth's magnetic field extends from near the geographic south pole to the near geographic north pole. However, its lines of force pass through the surface of the earth because the lines are not perfect circles around the earth. Where the field passes through the surface of the earth, it has a certain angle which we call the magnetic dip, or the angle of the field lines relative to the earth's surface.

### Materials

magnet, sewing needle, cork or foam, two pins, paper, pen, cardboard or metal strip

### Preparation Procedure

1. Push the two pins into the ends of the cork to create an axle.
2. Push the sewing needle through the cork perpendicular to the axle pins so that the needle rolls end-over-end when you roll the cork/pins between your fingers.
3. Adjust the needle so that it rests horizontally when the cork is free to pivot (equilibrium).
4. Use the magnet to magnetize the needle without changing its position in the cork. You can do this by stroking the needle in one direction on the magnet.
5. Bend the metal or cardboard strip into a U-shape to create a stand for the cork and pins.
6. Rest the pins on each vertical side of the U-stand so that the needle is free to rotate vertically.
7. Cut out a semicircular piece of paper and label the angles 0 to 90 degrees on it; tape or glue this to the stand.

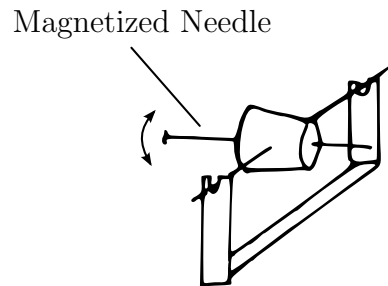


Figure 3.4: Magnetic Dip Gauge

### Activity Procedure

1. Set up the magnetic dip gauge so that the needle is free to rotate vertically.
2. Measure the angle of the needle relative to the ground.

### Results and Conclusions

Before magnetizing the needle, it will be able to balance horizontally in equilibrium. However, when the needle is magnetized, it will dip down to show the direction of the earth's field. Like a compass, the needle naturally moves to show the direction of the earth's magnetic field.

### Cleanup Procedure

Return all materials to their proper places and put the magnet in a safe place.

### Discussion Questions

1. What is the direction of the needle?
2. Why does the needle not point horizontally, as it did before it was magnetized?
3. What is the angle between the needle and the ground?

### Notes

The magnetic dip gauge works only when it is facing North and South. If it is facing East/West, the magnetic field will be moving perpendicular to the

poles of the gauge, so it will not be able to show the correct direction. Also, you may need to turn the gauge around if it is not showing the dip; if the needle is magnetized opposite to the direction of the earth's field, it will fail to show the correct direction.

## **Newton's Laws and Forces**

### **Inertia and Newton's First Law of Motion**

#### **Learning Objectives**

- To understand the concept of inertia
- To demonstrate Newton's First Law (the Law of Inertia)

#### **Background Information**

Newton's first law, also called the Law of Inertia, states that "an object in motion will continue in that motion, and an object at rest will remain at rest unless acted upon by an external force". This simply means that an object will continue doing what it is doing and will resist any changes. The inside of a fresh egg is liquid while the inside of a boiled egg is solid. Therefore, if you change the motion of the shell of a fresh egg, the liquid inside will resist the change and continue with whatever motion it had. If you change the motion of a boiled egg shell, the inside of the egg will follow the same motion as the shell.

#### **Materials**

1 fresh egg and 1 boiled egg

#### **Activity Procedure**

1. Place both eggs on the table and note that it is impossible to tell which egg is fresh and which egg is boiled.
2. Spin the first egg.
3. While the egg is spinning, stop it briefly with your hand and then release the egg. Record any observations.
4. Spin the second egg.



5. While the egg is spinning, stop it briefly with your hand and then release the egg. Record any observations.

## Results and Conclusions

The fresh egg, which is liquid inside, will continue spinning even after its rotation is stopped briefly by your hand. The boiled egg, which is solid inside, will stop spinning after its rotation is stopped briefly by your hand. The fresh egg continues spinning because the liquid inside continues to spin and causes the shell to move with it. However, the boiled egg stops spinning because the solid inside has stopped moving and thus will remain stationary.

## Discussion Questions

1. Which egg is fresh and which egg is boiled?
2. Why does the boiled egg stop completely when your hand releases it while the fresh egg continues spinning?
3. Explain the motion of the eggs in terms of inertia.

## Conservation of Linear Momentum

### Learning Objectives

- To demonstrate the principle of conservation of linear momentum

### Background Information

Everything has momentum which depends on its mass and velocity.

$$\text{momentum} = \text{mass} \times \text{velocity}$$

The momentum of an individual body can change as its velocity or mass changes. However, if two objects collide, the total momentum of the objects is conserved. This means that the total momentum of the objects before the collision is equal to their total momentum after the collision.

### Materials

Toy car with motor, plane surface or smooth table, metre rule or tape measure, beam balance\*, different sized stones, and stop watch

### **Preparation Procedure**

1. Measure the masses of different stones on the beam balance.
2. Measure the mass of the toy car.
3. Measure a distance of 2 m on the plane surface or table.
4. Make a mark at 0 m and place an obstacle at 2 m.

### **Activity Procedure**

1. Place the toy car at the 0 m mark on the table.
2. Release the car and start your stop watch.
3. Record the time it takes for the car to move from the 0 m mark to the obstacle at the 2 m mark.
4. Use this time and distance to calculate the average velocity of the car.
5. Place a stone on top of the toy car (use tape or string if necessary in order to secure it).
6. Measure the new mass of the car with the stone on top.
7. Start the car and release it on the table at the 0 m mark.
8. Again, measure the time it takes for the car to reach the obstacle at the 2 m mark.
9. Calculate the average velocity of the car and stone.
10. Repeat these steps for various stones, measuring the masses and average velocities for each case.
11. For each case, calculate the momentum of the car and stone.
12. Record your results in a table. Fill in values for mass, time, velocity and momentum.
13. Compare the values for momentum.

## Results and Conclusions

The momentum for each experiment is almost the same. As the mass increases, the velocity decreases. However, the product of the two remains the same. However, the momentum decreases slightly more than expected with increased mass because friction on the axles of the car is also increased. When two bodies, one heavy and one light, are acted upon by the same force for the same amount of time, the lighter object's velocity increases more than that of the heavy object. However, the momentum that each gains is the same.

## Clean Up Procedure

Return all materials to their proper places.

## Discussion Questions

1. What factors affect the momentum of the car?
2. When the mass of the car is increased by adding stones, what happens to the average velocity?
3. What do you observe when comparing the values for momentum?

## Notes

Conservation of momentum is only true in a frictionless environment. However, the effects can be seen clearly even if friction is present. The toy car has friction between its wheels and axles, so adding mass to the car will increase the effect of friction. However, it will still be seen that the momentum is relatively equal for each mass.

## Bottle Rocket

### Learning Objectives

- To observe the effect of Newton's Third Law of Motion

### Background Information

Newton's Third Law tells us that, for every action, there is an equal and opposite reaction. This means that if you apply a force to something, it applies an equal force back on you. Rockets make use of this principle by

ejecting gas at high speeds out of one end so that they are forced in the opposite direction.

### **Materials**

Empty 500 mL water bottle, nail, rubber stopper, straight pin, bicycle pump, needle attachment for pump (the type used to fill a football), tape, old pen, rigid straight wire (approx 1 meter), water

### **Preparation Procedure**

1. Make a small round hole (between 0.5 and 1.0 cm in diameter) in the lid of the water bottle by heating a nail and using it to put a hole in the lid.
2. Cut a round piece of the rubber stopper so that it can be used to stop this hole.
3. Pierce the stopper with a straight pin so that you can pass the needle attachment for a bicycle pump through the stopper.
4. Insert the stopper into the hold in the bottle top. The stopper should form a good seal in this hole, and it should be possible to push the stopper through the hole by exerting force on it.
5. Insert the needle attachment through the stopper so that you can increase the pressure inside of the bottle.
6. Disassemble a pen and take the plastic case.
7. Cut the case in half so that you have two hollow cylindrical pieces approximately 3 cm long each.
8. Attach them to the side of the bottle using adhesive tape. They should be in a straight line with each other.

### **Activity Procedure**

1. Insert the rigid straight wire into the ground outside.
2. Fill approximately half the bottle with water.
3. Push the stopper into the inside of the lid.
4. Put the needle attachment through the stopper.

5. Put the lid on the water bottle and tighten it so that air cannot escape.
6. Pass the rigid wire through the pen cylinders and lower the bottle to the ground.
7. Pump the bicycle pump until the stopper is pushed out completely.

### **Hazards and Safety**

- This is a rocket and will take off quickly and travel far. Be sure that no one is standing in the way of the rocket, and launch it in a large, open space where no one and nothing can be hit by it.

### **Results and Conclusions**

Once the pressure in the bottle becomes great enough, the stopper will be forced out of the bottle, and the rocket will fly into the air. It should be possible to reach a height of 10 meters or more. When the stopper leaves the bottle, pressurized air forces water out of the bottom of the bottle at a high speed. Just as with the matchstick rocket, this results in a reaction force forwards on the rocket. We can also consider this from the perspective of conservation of momentum.

### **Discussion Questions**

1. What causes the rocket to launch?
2. Explain the two opposing forces present in this experiment.

### **Notes**

All rockets use this principle; that rapidly expanding gases in one direction causes motion in the opposite direction. This combines Newton's third law and conservation of momentum. This activity takes practice. Test this several times before doing it with students.

## **Matchstick Rocket**

### **Learning Objectives**

- To explain the mode of action of a rocket
- To apply Newton's Third Law to the motion of a rocket
- To understand the application of Newton's Third Law to propulsion

## **Background Information**

The motion of a rocket is due to the simple principle of reaction. Newton's third law explains that a force in one direction will be opposed by a force in the opposite direction. In other words, if an object pushes backwards against an obstacle, the obstacle will push forward on the object. When a match burns, the gases that are produced are very hot and expand rapidly. In order for the match to continue burning, the match pushes the gases backwards, and the gases need to escape.

## **Materials**

Matches, aluminium foil, pin or syringe needle

## **Hazards and Safety**

- When the rocket ignites, some foil and hot air may be expelled, so no one should be very close. When igniting it yourself, keep your face away from the rocket.

## **Preparation Procedure**

If you are using a syringe needle instead of a pin, break the needle near the plastic base so that your needle is only the metal part.

## **Activity Procedure**

1. Cut or rip a small piece of foil, about 2 cm x 3 cm. Make sure it is flat and does not contain any holes.
2. Hold the pin next to a match so that the tip of the pin touches the head of the match.
3. Hold the pin and match tightly together and wrap the foil around the head of the match (with the pin) so that about 1 cm of foil covers the match and pin, and about 1 cm extends beyond the tip of the match and pin. Wrap the foil tightly so that no openings can be seen around the shaft of the match and pin.
4. Fold the extra foil down over the match head tightly so that there are no openings.
5. Remove the pin by sliding it out of the bottom of the foil, leaving a thin tunnel.

6. Support the match rocket at a 45-degree angle on a stone or other object. Make sure that no one is standing in front of the rocket.
7. Light another match and hold it under the foil of the rocket to ignite the first match. It may take a few seconds to work.
8. Repeat all steps until you have a good rocket.

### **Results and Conclusions**

The matchstick rocket moves forward quickly when the match-head ignites inside the foil. The match moves forward because the gases are moving backward; a force in one direction must be balanced by an equal force in the opposite direction.

### **Clean Up Procedure**

Return the supplies to their proper places.

### **Discussion Questions**

1. What causes the rocket to move forward?
2. Where do the gases from combustion of the match go when the rocket ignites?
3. What would happen if the exhaust hole left by the pin was facing another direction?
4. What would happen if you increase the amount of gas escaping from the match?
5. What would happen if you increase the weight of the match?

### **Notes**

As a match ignites, the gases quickly expand. By removing the pin from the foil over the match head, you leave a small path for the gases to expand: they cannot go any other direction but backward. Newton's Third Law tells us that "For every action (or force) there is an equal and opposite reaction." The action in this case is the rapid movement of gases backward. The reaction produced is the movement of the matchstick forward.

## **Verification of Newton's First Law of Motion**

### **Learning Objectives**

- To explain the concept of inertia
- To Verify Newton's first law of motion

### **Background Information**

An object will tend to resist changes to its motion. This is called inertia and is explained by Newton's first law of motion. This law states that "an object at rest will tend to stay at rest unless acted upon by an external force. An object in motion will continue in that motion unless acted upon by an external force." In short, this means that an object will continue doing what it is doing. The concept of inertia explains the reason why passengers move forward when the driver applies breaks, or fall back when the car starts moving suddenly.

### **Materials**

Empty soda bottle, small manila sheet OR card, knife, coin

### **Preparation Procedure**

Cut a small piece of card from the manila sheet.

### **Activity Procedure**

1. Place the bottle on top of the table.
2. Cover the mouth of the bottle with the card.
3. Put a coin on top of the card on the rim of the bottle.
4. Flick or quickly pull the piece of manila sheet horizontally off of the bottle.

### **Results and Conclusions**

As you flick the piece of card quickly the card flies away and the coin remains in the same position (on top of the bottle rim). The coin remains at the same point due to its tendency to maintain its position. This property of resisting change to motion is called inertia.



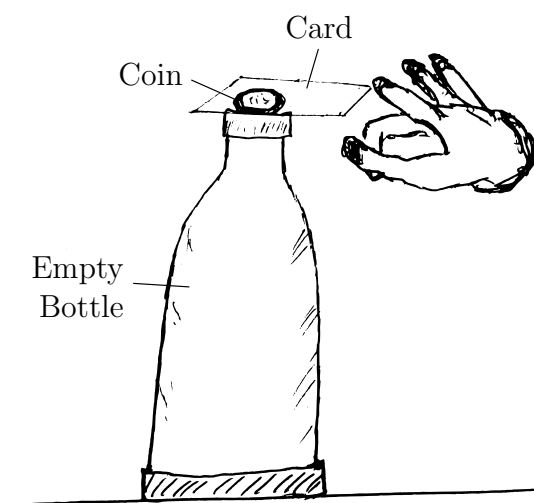


Figure 3.5: Demonstration of Newton's First Law

### Clean Up Procedure

Return the materials to their proper places.

### Discussion Questions

1. Discuss your daily experience with the concept of inertia.
2. Design another way to demonstrate the concept of inertia.
3. Explain why Newton's first law is known as the "Law of Inertia."

## Rotation and Equilibrium

### Centre of Gravity

#### Learning Objectives

- To determine the centre of gravity of uniform wooden rod

#### Background Information

The weight of object is concentrate at single point. This point is called the centre of gravity. For a uniform rod, the centre of gravity is normally at the centre of the rod. Finding the center of gravity is something used often in daily life – especially when balancing a bucket or large stick on the head.

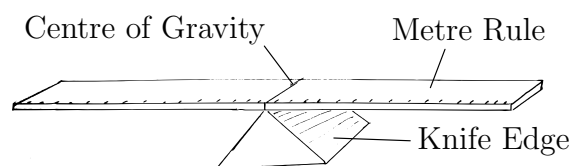


Figure 3.6: Finding the Centre of Gravity

### Materials

Uniform wooden rod about 1 m long, triangular blocks, ruler, wooden block

### Activity Procedure

1. Place the wooden block on the table.
2. Place the triangular block on the table so that the sharp edge is pointing upward.
3. Slowly place the wooden rod on top of sharp edge of the triangle block and move it until it balances horizontally.
4. Mark this balancing point on the wooden rod and measure its distance from both ends.

### Results and Conclusions

The wooden bar balances near the middle. The balance point is known as the centre of gravity.

### Clean Up Procedure

Collect all materials and return them to their proper places.

### Discussion Questions

1. Was the centre of gravity at the centre of the wooden rod? How do you know?
2. Discuss another method to locate the centre of gravity of a uniform rod.

## Verification of the Principle of Moments

### Learning Objectives

- To determine the moment of forces of a uniform wooden bar

### Background Information

The body will be in equilibrium when the clockwise moments equal the anti-clockwise moments. The turning forces depend on the product of the distance from the pivot to the point of application of the force and the magnitude of the perpendicular forces acting on the mass.

### Materials

Metre rule, three dry cells or any two objects of equal weight, thread, triangular wooden block or any object that will create a pivot point.

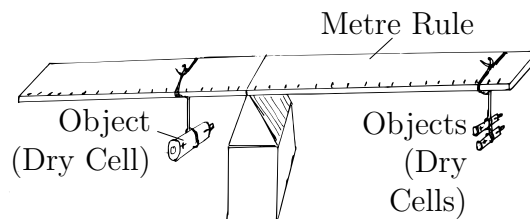


Figure 3.7: Equilibrium of Moments

### Activity Procedure

1. Balance the metre rule on the pivot point so that it remains horizontal.
2. Place two equal weights 20 cm from the pivot on the right and left sides of the pivot so that the ruler remains balanced.
3. Now move the right weight 5 cm further away from the pivot point and observe what happens.
4. Return that weight to the 20 cm mark and the system back to equilibrium. Now move the same weight 5 cm closer to the pivot point and observe what happens.
5. Now balance the metre rule itself on the pivot and place one weight at the 20 cm on the left side of the pivot and the two other weights at the

10 cm mark on the opposite side of the pivot. The metre rule should remain balanced.

### **Results and Conclusions**

When the system is in equilibrium the product of the distance to the pivot point and the weight on opposite sides of the pivot are equal.

### **Clean Up Procedure**

Put the instruments back in their respective places.

### **Discussion Question**

Explain the relation between the masses and distance from the pivot when the metre rule is at equilibrium.

### **Notes**

The wooden bar or metre rule should be uniform in order to simplify this experiment. Many objects and tools operate by the principle of moments. For a turning force to be more effective, the distance of the force from the pivot should be large. A force close to the pivot will have a smaller effect. This explains why the handle of a door is far from the hinge, or why a bottle opener has a long handle.

## **Simple Machines**

### **Pulley**

#### **Learning Objectives**

- To determine the mechanical advantage, velocity ratio and efficiency of a pulley system

#### **Background Information**

A pulley is a wheel which can be turned by a rope or string. You can have many pulleys in different configurations in order to reduce the effort needed to do work. The mechanical advantage of a pulley is calculated by dividing the load by the effort needed to lift the load.

$$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

The velocity ratio of a pulley is calculated by dividing the distance moved by the effort by the distance moved by the load. This is also equal to the number of pulleys in the system. The efficiency of the pulley and all other simple machines is equal to the mechanical advantage divided by the velocity ratio.

## **Materials**

Piece of cardboard from a box, thread, stones, spring balance (see the “Spring Balance” activity in order to make one), two empty water bottles, retort stand or piece of wood

## **Preparation Procedure**

1. Cut off the tops of the water bottles just below the lip where the cap rests.
2. Cut the piece of cardboard into two equal size pieces. They should be at least 5 cm squares.
3. In the middle of each piece of cardboard, cut a hole just big enough for the water bottle tops to fit through.
4. Thread the water bottle tops into the holes so that they are secure.
5. Make a small hole near the edge of each piece of cardboard.
6. Fix one of the cardboard pieces vertically on a retort stand or up high on a piece of wood.
7. Tie a piece of thread to the hole in the cardboard on the retort stand.
8. Fix a stone or other weight to the other cardboard piece and measure its weight, or measure its mass and convert this to weight.
9. Use the thread to suspend one of the cardboard pieces from the piece on the retort stand. Pass the thread over the rails of the water bottle tops so that it can roll over the thread like a pulley. Extend the thread back up to the top of the retort stand and wrap it over the top of the water bottle top.
10. Place a metre rule on the retort stand.

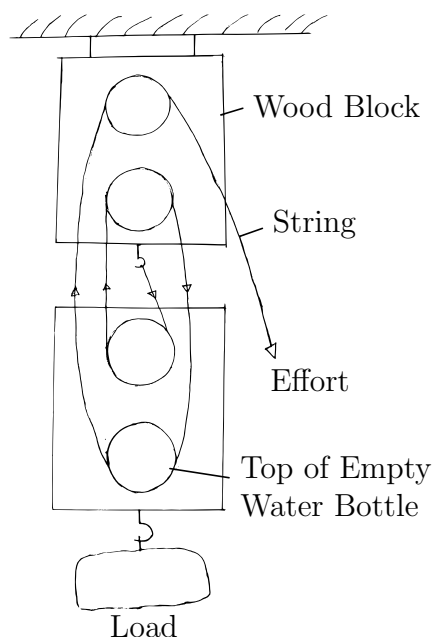


Figure 3.8: Simple Machines: The Pulley

11. Attach the free end of the thread to a spring balance which can be pulled down to lift the load on the pulley at the bottom. You now have a pulley system consisting of one fixed pulley and one move-able pulley.

### Activity Procedure

1. Pull the spring balance down a certain distance and record the distance moved by the load (the lower pulley with the stone) and the effort (the spring balance).
2. Use these distances to calculate the velocity ratio of the pulley system.
3. Record the force used on the spring balance to lift the load.
4. Use this force and the weight of the load to calculate the mechanical advantage of the pulley system.
5. Use your calculated values of velocity ratio and mechanical advantage to calculate the efficiency of the pulley system.

## Results and Conclusions

The velocity ratio calculated by measuring the lengths is equal to the number of pulleys in the system, in this case two. When this number is divided from the mechanical advantage, the efficiency of the system should be close to 100% (the ratio is 1). It will not be exactly 100% because there is friction in the system which reduces the mechanical advantage.

## Discussion Questions

1. What is the relationship between the distance moved by the load and the distance moved by the effort for this pulley system?
2. Compare the velocity ratio of this system to the number of pulleys present.
3. What would be the velocity ratio of a pulley system with 5 pulleys?
4. What was the mechanical advantage of this system?
5. What was the efficiency for this system?
6. Why is the efficiency not exactly 100%?

## Notes

The efficiency of this pulley will not be 100% because of friction. Try to use other resources to make a better pulley in order to reduce the effect of friction.

# Chapter 4

## Physics Activities for Form III

### Friction

#### Concept of Friction

##### Learning Objectives

- To describe the methods of reducing friction

##### Background Information

Friction is the force which opposes motion. When two bodies in contact are moving against each other, there is opposition to the motion. Friction between two surfaces depends on the nature of the surfaces in contact.

##### Materials

Lubricants\*, rollers\*, ball bearings, 50 cm wood board

##### Activity Procedure

1. Place the block of wood on the rollers.
2. Slide the block and observe how easily it moves.
3. Place the block of wood on the table without rollers and push it slightly.
4. Smear a lubricant on the table top, then place the block of wood on the table and push it slightly.



## Results and Conclusions

The block of wood will be easier to push on the rollers and lubricated table because these things reduce friction.

## Clean Up Procedure

Clean up the smeared surface with oil/grease.

## Discussion Questions

1. Why does a car slide on the road during a heavy rainstorm?
2. Which surface do you think has more friction, a tile floor or a dirt floor? Why?

## Notes

Friction causes noticeable effects; these effects can be reduced in class by using rollers, wheels and lubricants like oil and air.

## Limiting Friction and the Coefficient of Static Friction

### Learning Objectives

- To make use of an inclined plane to determine the limiting friction
- To observe the effect of static friction on a body
- To calculate the coefficient of static friction of a body on an inclined plane

### Background Information

Friction opposes the motion of all bodies. As a body slides along a surface, the surface itself opposes the motion of the body, causing a force in the opposite direction of the body's motion. This type of friction is called Dynamic Friction and depends on the nature of the surfaces in contact.

Static friction, however, opposes the force on an object that is not moving. If you push an object gently, it will not move. In order to cause the object to move, you need to increase your force. The force which is opposing you is the static friction between the object and the surface it is resting on. Static friction is present until the object starts moving. At that point, the force of

friction is called Limiting Friction: the minimum force needed to cause an object to move.

### Materials

Two smooth wooden boards about 60 cm by 10 cm by 2 cm, wood block about 10 cm by 5 cm by 2 cm with one rough side and one smooth side, nails, hinge from a door or window, objects of different masses, thread, pulley, beam balance or spring balance (see the balance construction activities to make one yourself), protractor, plastic water bottle

### Preparation Procedure

1. Connect the boards together at one end with a hinge and nails.
2. Find a pulley from a broken tape deck or other source.
3. Fix the pulley to the end of one of the boards (the end that is not attached to the hinge).
4. Prop up the board with the pulley to create an inclined plane.
5. Cut the bottom 5 cm off of the water bottle to create a scale pan.

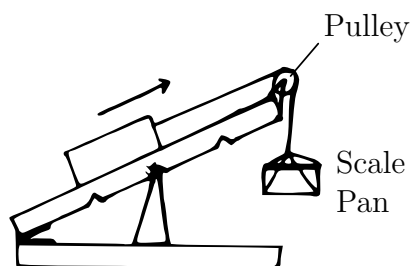


Figure 4.1: Determining the Limiting Friction

### Activity Procedure

1. Use a balance to measure the mass of the wooden block. Record this value.
2. Use a protractor to measure the inclination of the inclined plane. Do this by measuring the angle between the two boards at the hinge.

3. Place the wood block on the inclined plane and attach one end of the thread to it.
4. Pass the thread over the pulley fixed to the top of the inclined plane so that it hangs vertically.
5. Attach the hanging thread to the plastic water bottle bottom (scale pan).
6. Add objects to the scale pan until the block begins to slide up the inclined plane.
7. Measure the mass in the scale pan and record this value.
8. Increase the angle of the inclined plane and repeat these steps, measuring the mass needed to move the block in each case.
9. Convert the masses from the scale pan to weight. These weights are equal to the limiting friction.
10. Use these values and the weight of the block to calculate the coefficient of static friction between the block and the inclined plane.

## Results and Conclusions

The mass, and therefore weight, needed to move the block increases when the angle increases. The weight is the force on the block, or the Limiting Friction. The limiting friction is the minimum force necessary to move the block; this is measured using the weights in the scale pan.

The values for limiting friction can be used to calculate the coefficient of static friction. First we need the normal reaction on the block, which is the force perpendicular to the inclined plane. The normal reaction will be equal to the weight of the block times the cosine of the angle of the inclined plane.

We find the coefficient of static friction by dividing the limiting friction by the normal reaction.

$$\text{coefficient of static friction} = \frac{\text{limiting friction}}{\text{normal friction}}$$

## Clean Up Procedure

Remove the masses and return all materials to their proper places.

## Discussion Questions

1. What is the limiting friction in each case?
2. Does the limiting friction increase or decrease as the angle increases?

## Notes

Limiting friction is used to find the coefficient of static friction. It is possible in this activity to calculate the coefficient of static friction if you first calculate the normal reaction, which will be equal to the weight of the wood block times the cosine of the angle of inclination of the inclined plane.

# Reflection of light

## Total Internal Reflection in Water

### Learning Objectives

- To observe the effect of Total Internal Reflection of light inside water

### Background Information

When light passes from a high-density medium to a low-density medium, it can undergo total internal reflection if the angle of incidence is great enough. If light is passing through water, some of it will pass into air but some will be reflected at the surface back into the water. This is the mechanism behind fibre-optic cables, which use total internal reflection in a clear wire to move light over great distances..

### Materials

Opaque container like a Nido can, nail, torch, water, bucket

### Preparation Procedure

1. Use the nail to poke a hole at the bottom of one side of the opaque container.

### Activity Procedure

1. Pour water into the opaque container so that it can flow out of the hole near the bottom into the other container.

2. In a dark room, shine a torch down into the water.
3. Observe the light in the water falling from the hole.

## **Results and Conclusions**

The light is reflected at the surface of water (total internal reflection), so when it travels through the stream of pouring water, it continues to be reflected inside the stream until it reaches the container below. The light that only escapes farther down in the pouring water is what we see as the glowing effect.

## **Cleanup Procedure**

Clean up the water and return materials to their proper places.

## **Discussion Questions**

1. What causes the water to glow?
2. What is the light doing inside the water stream?

## **Notes**

While the light is being reflected inside the water stream, what we are seeing with our eyes is the light that escapes. A certain percentage of light will escape each time it hits the surface of the water and air. Light that enters the air at a small angle will escape and reach our eyes; light that hits at a large angle will be reflected again inside the water.

# **Refraction and Colour**

## **Dispersion of White Light: Part 1**

### **Learning Objectives**

- To demonstrate the dispersion of white light

### **Background Information**

White light is light which contains all colours. The light from the sun and some bulbs is white light, so we can divide it into its component colours. When light travels from air to a denser material, each wavelength of light

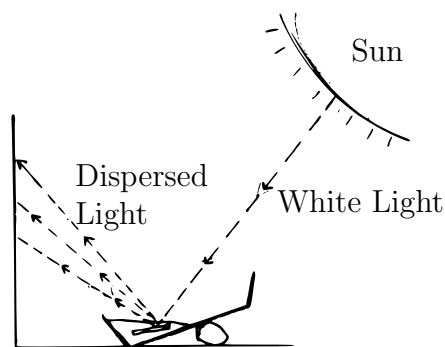


Figure 4.2: Dispersion of White Light by a Mirror in Water

(colour) bends at a different angle so the white light splits into all the colours of the visible spectrum, of which the most visible are red, orange, yellow, green, blue, indigo and violet (ROYGBIV). This may be easily shown by placing a mirror in a basin of water, as shown below:

The dispersion of light may also be shown with soap bubbles, as discussed in the followin activity.

### Materials

Water, soap, beaker\*, light, and straw

### Preparation Procedure

Make a soap solution by mixing water and soap.

### Activity Procedure

1. Place the beaker with the soap solution near a source of white light or in open sunlight.
2. Immerse the straw into the soap solution and blow into it to form bubbles.
3. Describe and record any observations.

### Results and Conclusions

Different colours are observed as the sunlight hits the soapy bubbles and undergoes refraction into its component colours. This is because the light is

refracted when passing into the soap and then again when passing back into air.

### **Clean Up Procedure**

Collect all materials and return them to their proper place.

### **Discussion Question**

What colours did you see in the soap bubbles? Why?

### **Notes**

The dividing of white light into its colours is called dispersion. Dispersion of sunlight can be observed in a rainbow, a thin layer of oil or soap, etc. This can be demonstrated most easily with soap bubbles or a triangular prism.

## **Newton Colour Wheel**

### **Learning Objectives**

- To identify the colours of visible light in the electromagnetic spectrum
- To observe the mixing of colours to form white light

### **Background Information**

The colours of light are somehow different from the colours of pigment. The primary colours are red, green and blue, and the secondary colours are cyan, magenta and yellow. These are different from pigment. Also, when the colours of light are mixed, the product is white. White is the presence of all colours while black is the absence of all colours. By mixing the colours of light, we can see that they form white. The easiest way to mix colours is to use the spectrum of visible light, namely ROYGBIV, or Red, Orange, Yellow, Green, Blue, Indigo and Violet.

### **Materials**

coloured pencils in red, orange, yellow, green, blue, indigo and violet; white paper, scissors, plastic lid to a Nido can or other container; 1-inch screw, tape or glue, optional compass from a mathematical set

### **Preparation Procedure**

1. Place the plastic lid flat on the white paper.
2. Use a pencil to trace the outline of the lid on the paper.
3. Cut the circle of paper out.
4. Use a pencil to divide the circle into seven equal slices meeting at the center of the circle. If you have a compass it can be used to divide the circle more evenly into seven slices.
5. Find the center of mass of the plastic lid by balancing it on a pencil.
6. Thread the screw through the center of the lid so that it sticks out the bottom of the lid and is flat on top.
7. Tape or glue the coloured paper to the top of the lid.

### **Activity Procedure**

1. Hold the colour wheel on a table so that the wheel balances on the tip of the screw and the colours face upward.
2. Spin the wheel between your fingers so that it spins on its own on the table.
3. Observe the change in colour.

### **Results and Conclusions**

When the colour wheel is stationary, all seven colours can be seen clearly. When the wheel spins quickly, the colours blend together to form white. This is because when all the colours of light are mixed, white is produced.

### **Clean Up Procedure**

Return all materials to their proper places.

### **Discussion Questions**

1. What are the colours on the colour wheel?
2. Why is it better to use all the colours rather than just a few?
3. What colour is seen on the wheel when it is spinning quickly.



## Notes

The colour wheel works best if the screw is placed in the exact center of the plastic lid. If it is off center, the wheel will not spin well. Also, you can get a clearer white colour if you divide the wheel into more sections of colour. 14 is better than 7, though 7 will work well.

## Measuring Refractive Index of Glass

### Learning Objectives

- To explain the refraction of a light ray from one medium to another
- To show the refraction of a ray of light at different angles
- To apply Snell's Law to find the refractive index of a medium by measuring incident and refracted angles
- To see the effect of refraction on an image

### Background Information

Light bends as it moves from one medium to another. When moving from a medium of low density to one of high density, a ray of light will bend inward towards the normal; when moving out again from the medium of high density to the medium of low density, the light ray will bend outward away from the normal.

Refracted light obeys Snell's Law, which states that  $n_1 \times \sin i = n_2 \times \sin r$  where  $n_1$  is the refractive index of the first medium,  $i$  is the incident angle of the light,  $n_2$  is the refractive index of the second medium and  $r$  is the refracted angle of the light in the second medium. Because we know the refractive index of air, and we can measure the angles of incidence and refraction with a protractor, we can calculate the refractive index of any material.

### Materials

Protractor from a mathematical set, pen, 30 cm square piece of thick cardboard from a box, piece of white paper, four-figure or calculator, tape or glue, 4 pins or syringe needles, rectangular glass block at least 6 mm thick from a glass shop (the glass block does not need to be large: 8 cm  $\times$  10 cm is easily enough). Often the glass block can be found for free, just make sure that the edges are even and that you can see through the block by looking through the edges.

## **Hazards and Safety**

- Be careful when using the glass. If you are using a local glass block from a glass cutter, the edges may be sharp enough to cut skin.
- If using syringe needles, use pliers or a hammer to bend the end of the needles so that they may not be used for any other purpose.

## **Preparation Procedure**

1. Collect all of the materials on a table.
2. Tape or glue the white paper to the cardboard and cut the paper so that it is the same size as the cardboard.

## **Activity Procedure**

1. Place the cardboard flat on the table with the paper-side up.
2. Place the glass block in the center of the paper and trace it with a pen.
3. Remove the block from the paper; you should see its outline clearly from the pen.
4. Use a protractor to draw a line perpendicular ( $90^\circ$ ) near the center of one of the long sides of the glass block outline.
5. Extend this line through both sides of the glass block so that on the paper you should have a picture of a rectangle with a line through its center.
6. Where the line intersects one of the long sides of the rectangle, make a mark and label it  $O$ .
7. From the point  $O$ , draw a line outward at an angle of 10 degrees to the normal. Use a protractor to do this.
8. Repeat this step to draw lines at angles of  $20^\circ$ ,  $30^\circ$ ,  $40^\circ$  and  $50^\circ$  to the normal, all converging on the point  $O$ .
9. Replace the glass block in its outline on the paper.
10. Place two pins or needles on the line for the incident light at  $10^\circ$ . Place one of the pins close to the glass block and the other as far away as possible on the 10 degree line. The pins should stick upright easily in the cardboard

11. From the opposite side of the glass block, look through the block so that you can see the two pins on the other side through the block (do not look over the block).
12. Close one eye and move left or right until the two pins you see through the block are perfectly aligned so that they look like one pin.
13. On this side of the glass block, place another pin close to the block so that all three pins are aligned.
14. Repeat this step with a fourth pin closer to your eye.
15. Make sure that, as you look through the glass block, all four pins are aligned perfectly.
16. Remove the pins on this side of the block and mark their positions (the holes in the paper) with a pen.
17. Use the straight edge of the protractor to trace a line through the two points to the edge of the glass block.
18. Mark this line as 10 degrees.
19. Repeat steps 10 through 18 for the incident rays of 20, 30, 40 and 50 degrees. At the end you should have five lines coming from your side of the glass block at different points, each labeled with a different angle. These lines should be diverging from one another.
20. Remove the glass block from the paper.
21. Using the straight edge of the protractor, trace a line from  $O$  to the point on the edge where the ray labeled “10 degrees” emerges.
22. Repeat this step for each line so that you have five lines inside the glass block outline, each connecting point  $O$  with one of the lines emerging from the block. These lines inside the block are the refracted rays corresponding to each of the incident rays (10, 20, 30, 40 and 50 degrees).
23. Use the protractor to measure the angle between the normal inside the block and the first refracted ray.
24. On a separate piece of paper, record the incident angle ( $10^\circ$ ) and the corresponding refracted angle (which should be around  $7^\circ$ , though this will change depending on the material you are using).

25. Repeat these steps for the incident angles of 20, 30, 40 and 50 degrees and their respective refracted angles.
26. Record these results in a table showing each incident angle and its respective refracted angle.
27. Use a four-figure or calculator to find the Sine of each of these angles and record these in your table as well.
28. Use a ruler to make a graph of  $\sin r$  against  $\sin i$ . The x-axis (horizontal axis) should contain the values for the Sine of the incident angles, and the y-axis (vertical axis) should contain the values for the Sine of the refracted angles.
29. Mark each of the five data points on the graph using your table of values for  $\sin i$  and  $\sin r$ .
30. Use a ruler or other straight edge to draw a straight line through the five points. Extend this line back through the y-axis (the axis containing values of  $\sin r$ ).
31. Calculate the slope of this line by using:

$$\text{slope} = \frac{\text{change in } y}{\text{change in } x}$$

32. Calculate the refractive index of glass by using:

$$\text{refractive index} = \frac{1}{\text{slope}}$$

## Results and Conclusions

It will be observed that the angle of a ray of light changes when moving from one medium to another. An object seen through two or more media appears to be in a different place than where it actually is. We can measure the angles of incidence and refraction, then use Snell's Law to find refractive index.

## Clean Up Procedure

Return all supplies to their proper places making sure that the glass block is in a safe place where it will not break.

## Discussion Questions

1. Why does light bend when moving from one medium to another?
2. In what direction does light bend when moving from a low-density medium to a high-density medium?
3. In what direction does light bend when moving from a high-density medium to a low-density medium?
4. What other materials could you use to measure refractive index instead of the glass block?
5. Why is it better to repeat the experiment for many angles of incidence instead of just one angle?
6. On the graph, what is the y-intercept? Why?

## Notes

This activity is very simple to perform but requires some practice, especially when trying to align all of the pins. Make sure that you can do the entire activity easily before you do it with students. Any material may be used; the glass block is only one option. Stained glass, water and plastic also work well. This activity appears often as a practical on the exams, so you can repeat it many times with students so that they know it very well.

## Refraction of Light in Glass

### Learning Objectives

- To demonstrate refraction of light

### Background Information

Buckets and basins appear shallow due to refraction. When light passes from one medium to another it changes its direction. This is because the light moves slower in a medium of high density than in a medium of low density. Because the light is moving slower, distances seem shorter.

### Materials

Glass block, pen/pencil

## **Hazards and Safety**

- Hold the glass carefully if it is sharp.

## **Preparation Procedure**

Collect a glass block from the laboratory equipment dealers.

## **Activity Procedure**

1. Take a glass block and place it in-front of your eyes. One student should hold a pencil in front of the glass block about 25 - 30 cm away.
2. From above, move your hand straight and touch the pointer of the pencil.

## **Results and Conclusions**

It is not easy to locate exactly the pointer of the pencil due to change of wavelength as light passes from one medium to another. Light slows down in the glass, so the distance to the pencil seems shorter than it actually is.

## **Clean Up Procedure**

Return the glass block to its proper place.

## **Discussion Questions**

1. Why it is difficult to locate exactly the position of the pencil when looking through the block?
2. What is happening to the speed of light as it enters the glass?

## **Notes**

When light passes from one medium to another medium it undergoes refraction because its wavelength is changing.

# Heat Transfer

## Designing a Calorimeter

### Learning Objectives

- To create a calorimeter
- To measure specific heat capacity of different materials

### Background Information

Materials can be distinguished by their specific heat capacity. Using the relation:  $\text{Heat} = \text{mass} \times \text{specific heat capacity} \times \text{change temperature}$ . You can calculate specific heat capacity for liquid objects or solid objects.

### Materials

Box made from wood, ceiling board or a piece of wood, aluminum cup, aluminum wire, pieces of blanket or sweater, and a thermometer.

### Preparation Procedure

1. Use wood to make a box with 10 cm x 10 cm x 12 cm width.
2. Prepare a top cover with wood or ceiling materials.
3. Use aluminium wire to make a stirrer.
4. Prepare a stirrer-holder with an insulator material like rubber.
5. Remove the aluminum cup handle.

### Activity Procedure

1. Place the piece of blanket in the box.
2. Put the aluminum cup in the box.
3. Put stirrer in the aluminium cup.
4. Place the top cover on the box.
5. Place the stirrer holder.
6. Insert the thermometer in the middle hole.

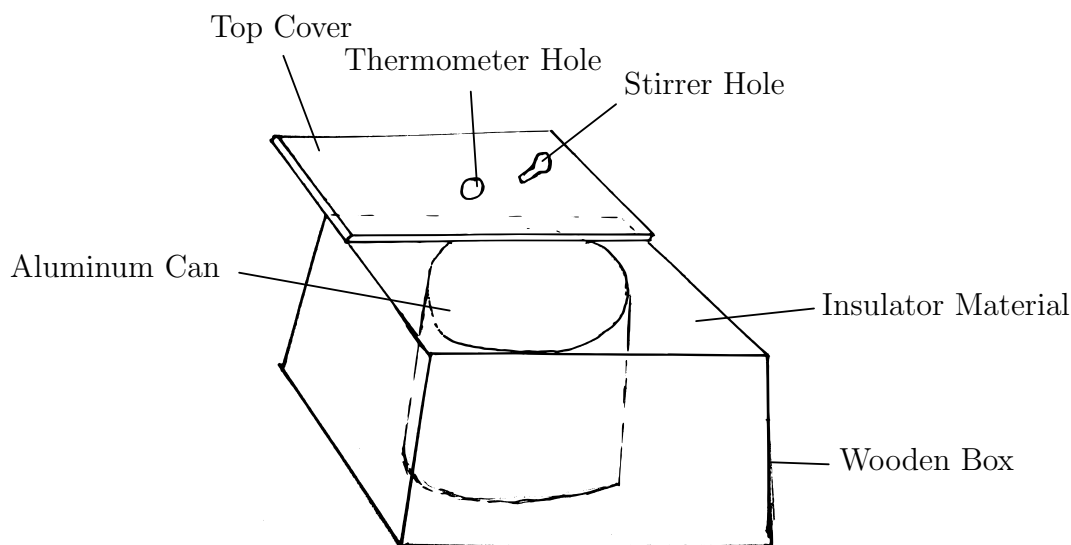


Figure 4.3: Construction of a calorimeter

## Results and Conclusions

Calorimeter can be used to determine the specific capacity of liquid and solid objects.

## Discussion Questions

1. Why is it important for the calorimeter and stirrer to be made of the same material.
2. Discuss an experiment that requires a calorimeter?

## Notes

Heat energy transfer depends on the material. Different materials transfer heat differently. The specific heat capacity can be obtained by finding heat transfer from one material to another. By using a calorimeter you can find the specific heat capacity of the material. The specific heat capacity tells the ability of material to lose or gain heat energy.

## Heat Conduction

### Learning Objectives

- To observe the progression of heat through a solid



- To differentiate between good and bad heat conductors
- To explain the progression of heat through solids in terms of the motion of molecules

### **Background Information**

Heat moves through solid bodies by conduction. Some solids are very good conductors of heat while others are not. Heat energy always moves from a hot body to a cold body, which it can do easily in a good conductor but not in a bad conductor. In this way, heat moves through an object from the hot end to the cold end.

### **Materials**

iron nail, piece of glass, wooden stick, candle with a holder, matches, chair, books or other supports

### **Hazards and Safety**

- The nail will become quite hot after being in the candle flame. It is best to wait a minute after removing the candle before you pick it up to clean it off.

### **Preparation Procedure**

1. Collect all materials.
2. Light the candle.
3. Use the lit candle to drip wax at even intervals along the glass, iron and wood (about 1 cm apart).
4. Set the iron nail, glass and stick on the edge of a chair so that one end of each sticks out at least 4 cm beyond the edge of the chair and converge at the same point. They should not be touching at any point.

### **Activity Procedure**

1. Make sure that the glass, nail and stick are secure on the chair and meet at one point beyond the edge of the chair.

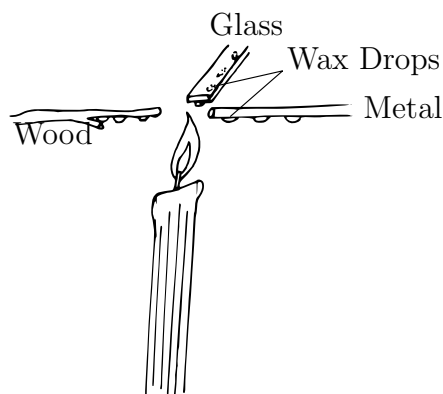


Figure 4.4: Heat Conduction in Different Materials

2. Place the candle under the three objects so that the flame just touches the end of each. Use books if necessary to prop up the candle.
3. Wait and observe the rate at which the wax melts on each of the three objects.
4. Have students find other objects which they want to test for heat conduction.

### Results and Conclusions

It will be seen that the wax on the iron nail melts quickly, near the candle at first and then moving back along the nail. The wax on the glass, however, melts very slowly and does not progress very far while the wax on the stick does not melt at all. This shows that heat moves quickly through metal and slowly through wood and glass, or that metal is a good conductor and glass and wood are bad conductors.

### Clean Up Procedure

1. Blow out the candle.
2. Clean the wax off of the three objects and return all materials to their proper places.

### Discussion Questions

1. On which object did the wax melt the fastest?

2. On which object did the wax melt the slowest?
3. Which object is a good conductor?
4. Which objects are bad conductors?
5. What causes the wax to melt?
6. How does heat move through the objects?

## Notes

Metal, a good conductor of electricity, is also a good conductor of heat. This is why we use metal cooking pots but we pick them up with fabric. Metal has many free electrons which carry energy easily through the metal, whether the energy is heat or electricity. Wood and glass, however, cannot transmit heat easily and so will burn or melt before heat is transmitted through the whole body. This is why we can hold firewood from one end while it burns at the other end. If you use plastic, be careful as it will melt quickly before the wax does. This shows it to be a very bad conductor and is a good demonstration, but it is also dangerous if it melts on your skin.

## Convection

### Learning Objectives

- To observe convection currents in water
- To explain the transfer of heat in fluids

### Background Information

While solids transfer heat by conduction, liquids and gases transfer heat by convection. In convection, energy is carried by molecules as they move through a liquid or gas, thereby transferring the heat from one place to another.

When a fluid is heated, the molecules with the most energy, namely the hot fluid, rises as its density decreases with temperature. The cooler fluid, or molecules with less energy, move down to replace the warmer liquid. By moving down, the cooler fluid then gains heat. The warmer fluid which moved up loses its heat and moves down again. This cycle repeats forever. It is called a convection current.

We normally cannot see the convection currents in a fluid because the fluid is invisible or uniform. However, if we put particles in the fluid so that they float in the middle, they will follow the convection currents.

### **Materials**

Water, clear water bottle, sawdust, source of heat

### **Hazards and Safety**

- Do not hold the bottle too close to the heat source as it will melt. The convection will work even if the heat is not strong.

### **Preparation Procedure**

1. Collect all materials. Sawdust can be found at a carpenter's shop or can be made at home. You want small pieces.
2. Fill the water bottle about 10 cm with water.
3. Pour some sawdust into the bottle so that it is visible in the water but does not absorb the water.

### **Activity Procedure**

1. Turn on or light the heat source.
2. Hold the bottle with the water and sawdust above the heat so that the bottle receives heat but does not melt.
3. After a few minutes, observe the motion of the sawdust in the water.

### **Results and Conclusions**

As the water in the bottle becomes warmer, the sawdust will be seen to move up. After that it will begin to sink again. This is because it is following the water in which it rests. As the water at the bottom becomes warmer, it moves up. At the top, there is less heat so the water cools again. Then it sinks again to replace the new warm water rising again. This cycle continues and causes the sawdust to continue circling from top to bottom and back.

### **Clean Up Procedure**

Dispose of the water and return all materials to their proper places.

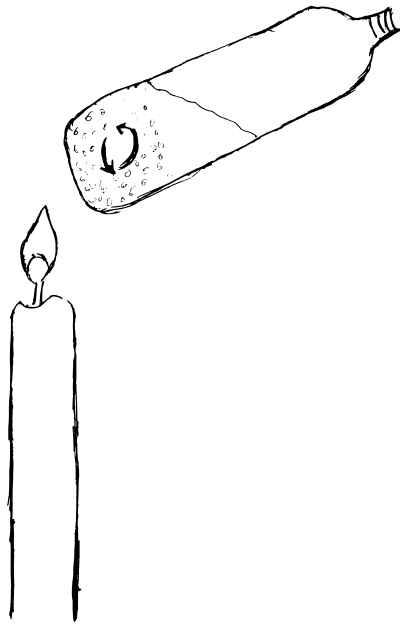


Figure 4.5: Thermal Convection

### Discussion Questions

1. Describe the motion of the sawdust.
2. Why does the sawdust move like this?
3. How is this type of heat transfer different from that in solids?

### Notes

Convection occurs in all gases and liquids. The currents can be seen in many forms, like the movement and formation of clouds or the movement of smoke.

## Radiation

### Learning Objectives

- To explain the concept of radiation
- To observe the heating effect of radiation
- To explain the difference between reflection and absorption of heat

## **Background Information**

Radiation is the transfer of heat through a vacuum. It also occurs in air but it is difficult to detect because of the effect of convection. However, the effects of radiation can be seen by observing the relative absorption and reflection of light and heat by various bodies. A dark, rough surface will absorb heat while a shiny, smooth surface will reflect heat. This is why many cars in hot places are painted white and why solar cookers are black.

## **Materials**

Two small pieces of flat wood, two metal plates, short candle, matches, small nails or glue, small kerosene burner or kibatari, steel wool

## **Hazards and Safety**

- This activity should be done indoors to avoid any wind.

## **Preparation Procedure**

1. Cut the pieces of wood into equal sizes about 4 cm by 6 cm. The exact size and shape is not important.
2. Cut two metal plates of equal size. The metal around the outside of a D-cell battery is best.
3. Use the steel wool to rub the metal plates until they are clean and shiny.
4. Fix the metal plates to the pieces of wood so that the plates stand upright and the wood lies flat. You can use glue or nails for this.
5. Light the kibatari.
6. Hold one of the metal plates above the kibatari until the plate's face is entirely coated in soot. You should now have two upright metal plates: one black and one silver.

## **Activity Procedure**

1. Light the candle.
2. On the back top of each of the metal plates, drip some wax from the candle.

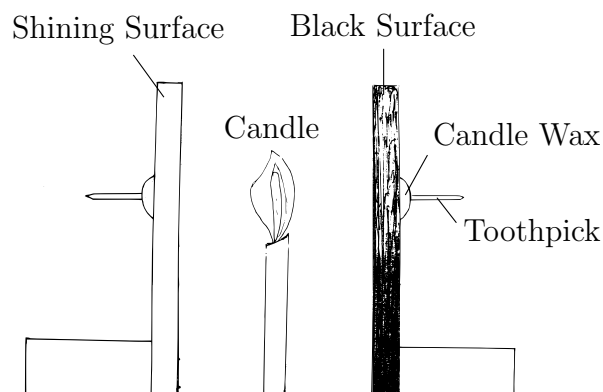


Figure 4.6: Demonstration of the effect of surface colour on radiative heat transfer

3. Fix the used matches into the the wax so that they stick out horizontally from the back of the metal plate when the wax dries.
4. Place the candle on the table so that the flame is at the same height as the middle of each plate.
5. Place the metal plates a few inches to either side of the candle flame, facing in.
6. Wait and observe any changes.

## Results and Conclusions

The wax on the back of the black plate melts quickly and slides down the plate, bringing the match with it. The wax on the silver plate takes a long time to melt. This is because the black plate tends to absorb radiation while the silver plate tends to reflect radiation. This causes the black plate's temperature to increase quickly, melting the wax.

## Clean Up Procedure

1. Blow out the candle.
2. Return all materials to their proper places.

## Discussion Questions

1. What happened to the wax on the back of the black plate?

2. What happened to the wax on the back of the silver plate?
3. Explain why the wax behaves differently on the black plate than on the silver plate.

### **Notes**

Two forms of heat transfer are present here: convection in the air and radiation. However, the convection in the air carries heat equally to the black plate and silver plate. The difference in heating rate is caused by the absorption rates. Black materials absorb light and therefore heat, while shiny materials reflect light and therefore stay cool.

## **Thermal Expansion**

### **Bimetallic Strip**

#### **Learning Objectives**

- To identify components of a bimetallic strip
- To observe and explain the function of a bimetallic strip
- To understand the mode of action of a bimetallic strip

#### **Background Information**

Solids expand when heated, but every solid has a different expansivity which depends on what material it is. For example, copper expands noticeably when heated, but wood barely expands at all.

#### **Materials**

Aluminium foil, paper, glue, candle, matches

#### **Preparation Procedure**

1. Cut one piece of aluminium foil and one piece of paper of equal size. About 3 cm by 10 cm works well.
2. Lay the foil flat on the paper so that they are aligned.
3. Glue the pieces together and leave them to dry.



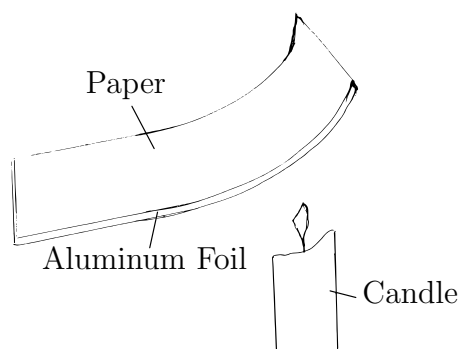


Figure 4.7: A Bimetallic Strip

### Activity Procedure

1. Light the candle.
2. Hold the strip above the candle far enough away that it won't burn or blacken, but close enough that it can feel the heat of the flame.
3. Observe any changes in the shape of the strip.

### Results and Conclusions

The strip bends towards the side of the paper because the aluminium foil expands more than the paper, forcing the paper to bend in to accommodate the expanding foil.

### Clean Up Procedure

Snuff the candle and return all materials to their proper places.

### Discussion Questions

1. What happens when the strip is held above the flame with the paper on the bottom and foil on top?
2. What happens when the strip is held above the flame with the foil on the bottom and paper on top?
3. Why does this occur?

## Notes

A real bimetallic strip contains two metals: usually copper and iron or two other strong metals. The metals, as with the paper and foil, have different expansivities. When they are heated, the metal with the larger expansivity expands more than the other. But as they are attached along their lengths, the more expansive metal pulls the other metal and therefore bends inward toward the metal with lower expansivity. In this activity, the paper acts as the metal with lower expansivity, bending inward to accommodate the expanding foil while not expanding much itself. It helps in this activity to hold just a piece of foil or piece of paper over the flame first to show that, alone, neither one will bend. They only bend when they are glued together.

## Thermal Expansion of Gases

### Learning Objectives

- To observe the expansion of a gas when heated
- To explain why gases expand when heated

### Background Information

Unlike solids, gases expand quickly when heated. Because the molecules of a gas are spread out and moving, the volume increases quickly when more energy is added.

### Materials

Source of heat, small cooking pot, water, clear thin plastic straw or tubing

### Hazards and Safety

- The water will boil and the steam will hurt your hand, so use a long straw and keep your hand out of the way of the steam. Use tongs to help you hold the straw if necessary.

### Preparation Procedure

Collect all materials.

### **Activity Procedure**

1. Light the heat source.
2. Fill the small pot half-way with water and place it over the heat.
3. Place one end of the straw or tubing just below the surface of the water.
4. Place your thumb over the other end of the straw and remove it from the water so that a single drop remains in the bottom of the straw.
5. Turn the straw over and remove your thumb so that the water drop moves down to the center of the straw.
6. Place one end of the straw back in the water, leaving the other end open.
7. Observe the motion of the water drop in the straw as the water in the pot is heated.
8. Hold your thumb over the open end of the straw.
9. Remove the straw from the water and insert it into cold water.
10. Remove your thumb and observe again the motion of the water drop in the straw.

### **Results and Conclusions**

As the gas in the straw is heated, the water drop rises. This is due to the expansion of the gas below the drop, as the gas can only expand up. It will be seen that as the gas in the straw is cooled, the drop falls. This is due to the contraction of the gas below the drop, as the gas decreases in volume when its temperature decreases.

### **Clean Up Procedure**

Turn off the heat source and return all materials to their proper places.

### **Discussion Questions**

1. Describe the behavior of the drop when the straw is heated.
2. Describe the behavior of the drop when the straw is cooled.
3. What causes the drop to move up the straw?

4. What causes the drop to move down the straw?
5. What is expanding in this experiment? What is expanding the fastest?

### **Notes**

The behavior of gases is actually more complicated; gases will expand as much as the pressure will allow.

## **Thermal Expansion of Solids - Breaking Glass**

### **Learning Objectives**

- To observe the effects of thermal expansion of solids
- To break glass containers evenly

### **Background Information**

Solids expand when heated, though not always noticeably. However, it is enough that if an object is heated on one side but not on another, the side that is heated expands and the other side does not. If the object is rigid, like glass, it will break instead of bending. In this way, glass containers like soda bottles and beakers can be broken evenly.

### **Materials**

Soda bottle or other open glass container (bottles with uniform sides are best), water, heat source

### **Hazards and Safety**

- The glass will break and may leave sharp edges. It is important that the glass is properly disposed of.
- Be sure that the bottle is not covered. If you cover the bottle it could explode rather than just break evenly.

### **Preparation Procedure**

1. Collect all materials.

### **Activity Procedure**

1. Place some water in the soda bottle so that it is about half full. It is best if the water level is at a point where the bottle's side is uniform.
2. Place the bottle over a heat source and wait.
3. If the bottle does not break before the water boils, remove the bottle from the heat until the water stops boiling, then place it in a container of cold water.

### **Results and Conclusions**

The glass bottle will break evenly at the level of the water inside. This is because the water is gaining more heat than the air above it, so the glass bottle touching the water gains more heat than the glass touching the air. Therefore the glass below the water level expands more than the glass above the water level, so the glass breaks evenly.

### **Clean Up Procedure**

1. Dispose of broken glass.
2. Return all materials to their proper places.

### **Discussion Questions**

1. Why does the bottle break at the level of the water?
2. Which part of the glass bottle is expanding most?

### **Notes**

Glass is one of the few materials which does this. Metal bends when heated, hence the bimetallic strip. However, a similar technique is used in many places to break large stones, especially in villages where other equipment is not available.

## **Thermal Expansion of Liquids**

### **Learning Objectives**

- To observe the expansion of liquids when heated
- To observe that different liquids expand at different rates

## **Background Information**

All substances expand when heated. While solids expand with specific dimensions, liquids and gases expand in volume only.

## **Materials**

500 mL plastic water bottle with cap, nail, source of heat, small cooking pot, water, food colouring (optional), clear plastic straw or tubing, super glue, various liquids (cooking oil, kerosene, milk, etc. )

## **Hazards and Safety**

- The water in the small pot will boil after a short time, so be careful not to touch it.

## **Preparation Procedure**

1. Collect all materials.
2. Heat the nail.
3. Use the hot nail to put a hole through the center of the bottle cap.
4. Insert the straw through the hole half way so that half of the straw is below the cap and half is above.
5. Use the hot nail and super glue to seal the hole so that no air can pass through the bottle cap. Be careful not to seal the straw itself.

## **Activity Procedure**

1. Fill the bottle three quarters with water and add a pinch of food colouring.
2. Close the cap on the bottle so that the bottom of the straw is in the water.
3. Fill the small pot half way with water.
4. Place the pot over the heat source and place the water bottle in the pot (water bath).
5. Allow the water to heat and observe the water level in the straw.

6. Remove the water bottle from the pot and place it in cold water.
7. Observe again the water level in the straw.
8. Repeat all of these steps for various other liquids.
9. If possible, prepare one water bottle for each liquid and observe their levels at the same time in the water bath.

## **Results and Conclusions**

Liquids expand when heated and contract when cooled. This is because their atoms are moving with more energy and so must increase in volume. Because the water is sealed in the bottle and is expanding, it can only move up the straw.

## **Clean Up Procedure**

1. Turn off the heat source.
2. Empty all the water and return all materials to their proper places.

## **Discussion Questions**

1. What happens to the water level in the straw when the water is heated?
2. What happens to the water level in the straw when the water is cooled?
3. What causes the water level to rise and fall?
4. Which liquid expands the fastest?
5. Which liquid expands the slowest?

## **Notes**

Liquids expand noticeably when heated so it is simple to see the effect. By using a capillary tube, we can see the effect much more easily as the liquid level will rise in the tube only. By sealing the cap on the bottle, we allow the liquid to expand in only one direction: up through the capillary tube.

## **Thermal Switch**

### **Learning Objectives**

- To observe the thermal expansion and contraction of solids
- To explain the mode of action of a thermal switch
- To explain the effect of heating on solids

### **Background Information**

All substances expand when heated. Solids expand only a small amount, but metals expand noticeably.

### **Materials**

flat piece of wood, 2 thick sticks about 5 cm tall, several small nails, short piece of thick wire (about 8 cm), connecting wires, 2 dry cells, bulb or galvanometer, candle, matches

### **Hazards and Safety**

- The thick wire will become very hot in the candle, so be sure not to touch it.

### **Preparation Procedure**

1. Collect all materials.
2. Nail the two sticks upright on the piece of wood, about 6 cm apart.
3. Fix one nail into the side of one stick near the top so that it sticks out horizontally towards the other stick.
4. Bend the end (about half a cm) of the wire at a right angle.
5. Place the wire on the top of the other stick so that the bent end just touches the nail fixed to the other stick.
6. Move the wire back slightly so that there is a gap of about 1 mm between the bent end of the wire and the nail.
7. Fix the wire where it is by putting a nail in the top of the stick to hold the wire in place.



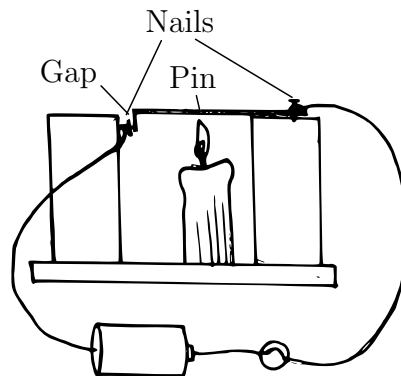


Figure 4.8: A Thermal Switching Circuit

8. Attach one connecting wire to the back of the thick wire and the other connecting wire to the nail fixed to the top of the other stick.
9. Attach the connecting wires to the bulb and batteries in series.
10. You should now have a circuit in series which is disconnected by the small gap between the thick wire and the nail.

### Activity Procedure

1. Set up the switch circuit on the table.
2. Check to make sure that the batteries and bulb are working and that there is a small gap between the thick wire and the nail.
3. Light the candle.
4. Hold the candle under the thick wire until the wire expands to touch the nail. The bulb should light.
5. Take the candle away to let the wire cool. The bulb should turn off.
6. Repeat these steps until it is clear what is causing the bulb to turn on and off.

### Results and Conclusions

The wire's length increases when it is in the candle flame and decreases when the candle is removed and the wire is allowed to cool. This is because the wire

(a solid) expands when it is heated. This application of thermal expansion is used in thermostats.

### **Clean Up Procedure**

Disconnect all wires and return all materials to their proper places.

### **Discussion Questions**

1. What happens to the wire when it is heated? What happens when it is cooled?
2. What causes the circuit to be completed and the bulb to turn on?
3. What causes the bulb to turn off?

### **Notes**

Solids typically expand very little so that it is difficult to see with the naked eye. Metals expand enough that they can be used to demonstrate thermal expansion. The wire in this activity expands in the candle flame to complete the circuit, thereby lighting the bulb. When the source of heat is removed, the metal cools quickly and contracts, breaking the circuit and turning off the bulb.

## **Change of State**

### **Boiling at Room Temperature**

#### **Learning Objectives**

- To observe the effect of pressure on the boiling point of water
- To explain why the boiling point of water decreases with pressure

#### **Background Information**

Boiling and melting points are usually assumed to be constant. For example, the melting point of ice is 0-degrees C and the boiling point is 100-degrees C. However, this is only true at STP, or Standard Temperature and Pressure. Standard pressure is 760 mm Hg, which is only true at sea level. Pressure decreases with elevation, therefore the boiling point of water also decreases. The boiling point of water at sea level will be measurably different from the boiling point on a mountain.

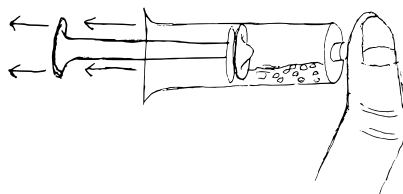


Figure 4.9: Boiling Water at Room Temperature

### Materials

10 mL or 20 mL syringe without needle, water

### Preparation Procedure

Collect the syringe and remove the needle.

### Activity Procedure

1. Fill the syringe with a small amount of water.
2. Place your thumb over the opening of the syringe.
3. Pull the plunger out as far as you can.
4. Observe the behavior of the water in the syringe.

### Results and Conclusions

When the plunger is pulled out as far as it will go (without removing it from the syringe), the water will begin to bubble, meaning that it is boiling. This is because the pressure inside the syringe is decreasing, and the boiling point of the water is decreasing with the pressure. When the boiling point is reduced to room temperature, the water begins to boil.

### Clean Up Procedure

Dispose of the water and return all materials to their proper places.

### **Discussion Questions**

1. Why is it difficult to pull the plunger out when your thumb is covering the syringe opening?
2. By pulling out the plunger, are you increasing or decreasing the pressure in the syringe?
3. What happens to the water when you pull the plunger as far as you can?

### **Notes**

When pulling water into the syringe, you only need to take a small amount. If you take too much water, you will not be able to reduce the pressure in the syringe before the plunger comes out. Before doing this activity, be sure that the students understand that the presence of bubbles means that a liquid is boiling.

## **Heat Capacity and Latent Heat**

### **Latent Heat of Fusion**

#### **Learning Objectives**

- To observe the process of fusion
- To explain the difference between heat capacity and latent heat
- To observe the constant temperature of latent heat

#### **Background Information**

As a substance is heated, there are two types of heat involved. Heat capacity is the heat needed to raise the temperature of the substance; latent heat is the heat needed to change the substance from one state to another. Heat capacity is the heat that we normally see: you can measure it with a thermometer as it raises the temperature of a body. Latent heat, however, is "hidden." This means that latent heat does not raise the temperature of a body, so it cannot be measured with a thermometer. When a substance is heated, its temperature increases as it gains heat as per its heat capacity. However, when it changes state from solid to liquid or liquid to gas, its temperature remains constant as it is absorbing latent heat.

## **Materials**

Heat source, water, small cooking pot, thermometer.

## **Preparation Procedure**

The thermometer may be a real thermometer if you want to measure the temperature at which latent heat is absorbed. However, you can use any liquid in a capillary tube to see the expansion of the liquid. When the latent heat is used and the water is changing state, the liquid in the tube will stop expanding.

## **Activity Procedure**

1. Fill the pot about half-way with water.
2. Place the thermometer in the water.
3. Turn on the heat and place the pot over the heat.
4. Observe the rise in temperature as the water is heated. Record the temperature every 10 seconds.
5. Continue recording the temperature every 10 seconds after the water begins to boil.
6. Plot a graph of temperature (vertical axis) against time (horizontal axis).

## **Results and Conclusions**

The temperature will be seen to increase steadily as the water is heated. When the water begins to boil, the temperature stops increasing and remains constant while the water vapourizes. The graph will show a steadily increasing temperature until it reaches the boiling point on the vertical axis. This value should be about 100 degrees C. At this point, the temperature will level off as time continues to increase.

## **Clean Up Procedure**

1. Remove the thermometer from the water and pour it out.
2. Turn off the heat and return all materials to their proper places when they are cooled.

## Discussion Questions

1. What happens to the temperature when the water begins to boil?
2. What happens to the temperature as the water is heated but before it boils?
3. What heat is involved in heating the water?
4. What heat is involved in changing the water from a liquid to vapour?

## Notes

It is important to periodically measure the temperature and time as the water heats. This will allow you to see clearly the boiling point when the latent heat of water becomes a factor.

# Vapour

## Measuring Humidity with a Hygrometer

### Learning Objectives

- To measure relative humidity
- To explain relative humidity

### Background Information

Humidity is the concentration of water vapour present in the air. We measure humidity by using a hygrometer, which measures the difference in humidity between two thermometers, one of which is in open air and one of which is being cooled by evaporation. If air contains a lot of vapour, wet objects do not evaporate much. However, if the air is dry, wet objects evaporate a lot. By using the evaporation of water from a thermometer, we can measure the amount of vapour in the air.

### Materials

Two mercury or alcohol thermometers, container of water, piece of cotton cloth, thread

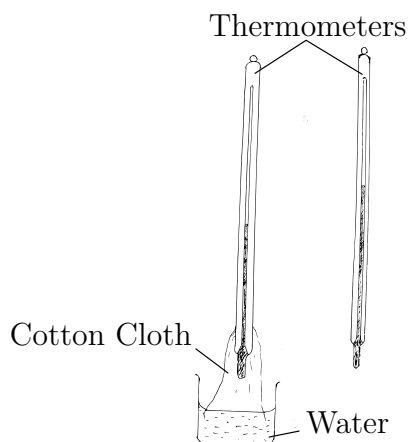


Figure 4.10: A hygrometer for measuring humidity

### Hazards and Safety

- Be careful when spinning the thermometers over your head. The thread needs to be strong so that the thermometers do not fly off. Also, be sure that the area around you is clear so that the thermometers don't hit anything.

### Preparation Procedure

1. Collect two thermometers. These are necessary and can be found in any laboratory or hospital supply shop.
2. Find a small piece of cotton cloth and a small container of any kind.

### Activity Procedure

1. Pour some water into the container.
2. Wrap the bulb of one of the thermometers with the cotton cloth.
3. Tie the cloth with thread so that it stays on the thermometer.
4. Dip the cloth into the water.
5. Remove the thermometer from the water and tie the tops of both thermometers with thread.

6. Holding the thread tightly, quickly spin the thermometers together over your head for at least 30 seconds.
7. Read the temperature on the thermometers and record both values.

## **Results and Conclusion**

s When both thermometers are rotated at a high speed, the reading of the thermometer attached to the cotton cloth drops. This is because, when it is rotated, the cloth loses water and is therefore cooled (cooling by evaporation). The amount of water that the cloth loses depends on the humidity of the air. By observing the difference between the temperature of the wet cloth and the air, we can tell the relative humidity.

## **Clean Up Procedure**

Remove the cloth from the thermometer and return all materials to their proper places.

## **Discussion Questions**

1. Why do the thermometers show two different temperatures?
2. Explain the formation of dew in terms of humidity.

## **Notes**

A hygrometer is used for measuring the relative humidity of the atmosphere. Its use depends on the fact that evaporation causes cooling. If the air is saturated with vapour, no water evaporates from the cloth and the two thermometers show the same reading. However, if the air is dry, a lot of water can evaporate from the cloth, cooling the thermometer significantly. A table is used to find the relative humidity.

# **Gas Laws**

## **Boyle's Law**

### **Learning Objectives**

- To observe the relationship between volume and pressure when temperature is kept constant



- To explain the relationship between pressure and volume
- To explain Boyle's Law

### **Background Information**

Gases can be measured by three quantities: pressure, volume and temperature. For this reason, we have laws to relate them to each other. When one quantity is held constant, the other two prove to be either directly proportional or inversely proportional.

### **Materials**

Syringes without the needle for each student

### **Preparation Procedure**

Collect the syringes and remove the needles.

### **Activity Procedure**

1. Pull the syringe plunger back as far as it will go without removing it.
2. Place your thumb over the open end of the syringe.
3. Push the plunger in as hard and as far as you can.
4. Observe any effects.
5. Remove your thumb from the syringe and push the plunger in as far as it will go.
6. Replace your thumb over the opening of the syringe.
7. Pull the plunger out as hard and as far as you can.
8. Observe any effects.
9. Have students try this themselves.

## Results and Conclusions

It will be seen that as you push the plunger in, there is a strong force pushing both the plunger and their thumb out. This is the increased pressure of the air inside the syringe. As you pull the plunger out, there is a strong force pulling both the plunger and your thumb into the syringe. This is the decreased pressure of the air inside the syringe. As volume is decreased, pressure is increased; as volume is increased, pressure is decreased. From this we can say that pressure and volume are inversely proportional.

## Clean Up Procedure

1. Collect all syringes and return them to their proper place.

## Discussion Questions

1. What quantity is being held constant in this experiment?
2. What quantities are changing in this experiment?
3. What do you feel on your thumb when you are trying to pull the plunger out? What do you feel when you are trying to push it in?
4. Describe the relationship between pressure and volume in this experiment.
5. Based on this experiment, state Boyle's Law.

## Notes

Pressure varies inversely with volume. As you push the plunger in, you are decreasing the volume and therefore increasing the pressure, which you feel as an outward force. As you pull the plunger out, you are increasing the volume and therefore decreasing the pressure, which you feel as an inward force.

## Charles's Law

### Learning Objectives

- To observe the relationship between volume and temperature when pressure is constant
- To explain the meaning of Charles' Law in terms of pressure, volume and temperature

## Background Information

Gases can be measured by three quantities: pressure, volume and temperature. For this reason, we have laws to relate them to each other. When one quantity is held constant, the other two prove to be either directly proportional or inversely proportional.

## Materials

A 5 Litre water bottle with cap, heat source, small cooking pot, water

## Hazards and Safety

- Be careful when pouring the water from the pot to the bottle. Use a funnel if necessary.

## Preparation Procedure

Collect all materials.

## Activity Procedure

1. Light the heat source.
2. Fill the small pot with water and place it over the heat source.
3. Allow the water to boil.
4. When the water is boiling, pour it into the water bottle.
5. Close the cap on the bottle and shake the water.
6. Pour the water out of the bottle and close the cap again.
7. Observe any changes to the bottle.

## Results and Conclusions

After pouring the boiled water into the bottle and closing the cap, the volume of air in the bottle increases. This is because the air is gaining heat, and therefore kinetic energy, from the water and therefore increasing in volume. Pouring the water out removes the air's source of heat. When you replace the cap on the bottle, you return the bottle to a state of constant pressure. As the air in the bottle cools, the temperature goes down. Temperature and volume are directly related, so the volume of the bottle decreases. We see this as the bottle being crushed.

### **Clean Up Procedure**

1. Turn off the heat source.
2. Dispose of the water and return all materials to their proper places.

### **Discussion Questions**

1. What quantity of a gas is constant during this experiment?
2. Which two quantities are changing?
3. What causes the bottle to be crushed?
4. Based on this experiment, what is Charles's Law?

### **Notes**

Charles's Law states that, when pressure is constant, temperature varies directly with volume. This means that, in an air-tight system, the volume will increase when something is heated or decrease when something is cooled. This is the principle behind thermal expansion and can be seen easily in the thermal expansion demonstrations. In this demonstration boiling water is used initially to increase the temperature of the air in the bottle. It is removed and the bottle is sealed, forcing the pressure to remain constant. As the air inside the bottle cools, it decreases the volume, causing the bottle to be crushed from the inside.  $T \propto V$  when  $P$  is constant.

# Chapter 5

## Physics Activities for Form IV

### Electricity

#### Creating a Leclanche Cell.

##### Learning Objectives

- To describe the production of electric current by an electrochemical cell
- To construct a simple electrochemical cell

##### Background Information

A cell converts chemical energy to electrical energy. We know cells as batteries or accumulators.

##### Materials

Many lemons, zinc plate and carbon rod from a dead dry cell battery, connecting wires, galvanometer, bulb

##### Hazards and Safety

- The black powder found in the dry cell is poisonous. The black powder will also corrode metal – wash all tools well that touch the powder.
- The outer case of the dry cell battery can be quite sharp – take care when opening.

## Preparation Procedure

Open a dry cell battery and extract the inner shell of zinc metal and the central carbon rod.

## Activity Procedure

1. Make two holes in each lemon then insert the carbon rod and zinc plate in the holes.
2. Connect one lemon with the galvanometer and then add more in series. Note changes in the galvanometer.
3. Arrange the lemons in series with the switch and bulb using connecting wire.

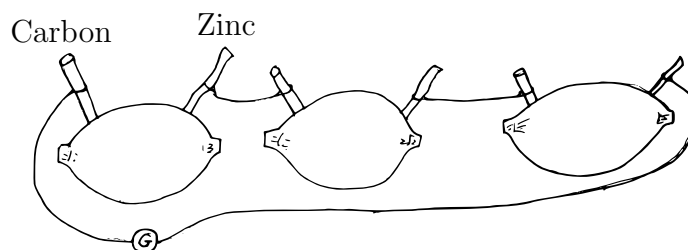


Figure 5.1: Building a Leclanche Cell

## Results and Conclusions

With one lemon connected to the galvanometer a deflection will occur. The deflection will increase with the number of lemons arranged in series. After completing the circuit with enough lemons, the bulb will light up. This shows that a lemon can be used to produce a wet cell known as Leclanche cell.

## Clean Up Procedure

1. Collect lemons and throw them in the dust bin. Make sure that people and animals do not eat the used lemons – they will contain poisonous residual manganese (IV) oxide from the battery and an unhealthy amount of zinc.
2. Put other materials in their respective places

## Discussion Questions

1. Explain your observations of the completed circuit.
2. In the absence of lemons what other materials can be used to create the Leclanche cells?

## Notes

Electric current can be produced from different sources (cells). There are dry and wet sources of electric cells. Wet cells can be made from natural fruits and foods such as lemon, Irish potatoes and salts which produce electric current based on the principle of Leclanche cells.

## Construction of a Metre bridge and Potentiometer

### Learning Objectives

- To construct and use a metre bridge and potentiometer

### Background Information

A metre bridge can be used to determine the resistance of various conductors and also to compare the Emf of batteries. It consists of a piece of resistance wire 1 m long attached in series to either a rheostat or other conductors and resistors. By using a galvanometer we can find the length of resistance wire needed to equal the resistance of the other conductors. Or we can use a voltmeter to find the potential difference along a length of the resistance wire. There are several activities that can be done with a metre bridge and each requires different materials. The construction of the metre bridge itself, however, is the same, and follows below.

### Materials

Piece of wood 110 cm by 4 cm, shoe tacks or small nails or screws, connecting wire, Constantine or nichrome wire, dry cells, resistors of known and unknown resistance, galvanometer. Alternative: Voltmeter, rheostat, micrometer screw gauge

### Hazards and Safety

- Make sure all nails are removed.

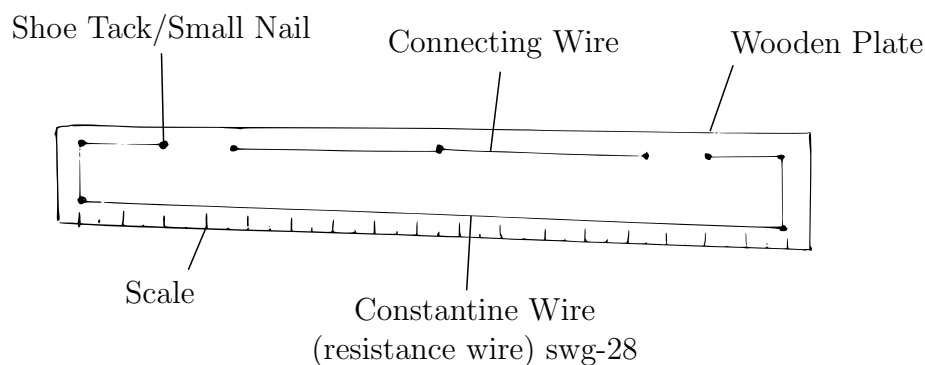


Figure 5.2: A Metre Bridge

### Preparation Procedure

1. From one side of the piece of wood, measure 5 cm and fix 2 shoe tacks or nails side by side about 2.5 cm apart, as shown in 5.2. From one of the nails measure 10 cm and fix another nail. Leave a space of about 6-8 cm and fix another nail. From the first nail again measure 50 cm and fix another nail.
2. Again from the first nail measure 100 cm and fix two nails apart as with the first end. From this end on the side of one of the nails measure 10 cm and fix another nail, leave a gap and fix another nail.
3. On the other long side place a meter ruler from first nail to the last nail, mark each cm and write the scale interval of 10 cm.
4. Fix Constantine wire from the first nail to last nail along the side with the cm markings and make sure the wire is tight.

### Activity Procedure

1. Use connecting wire to join one of the nails holding the resistance wire to the second nail along the side without the cm markings. Then leave a gap and connect another wire to the central nail and then to next nail. Leave another gap and connect a wire from following nail to nail holding the other end of the resistance wire.
2. Connect a metre bridge circuit by connecting one known and one unknown resistor into each of the gaps.



3. Connect one terminal of a galvanometer to the center nail of the metre bridge. Connect the other terminal to a connecting wire which can be moved easily along the resistance wire.
4. Move the galvanometer wire along the resistance wire until the galvanometer reads zero; that is no current is flowing.
5. Measure the length of resistance wire on both sides of the galvanometer wire. Call the left side of the metre bridge “one” and the right side “two” so these lengths are  $L_1$  and  $L_2$ .
6. Write these two lengths as a ratio, for example the length on the left side divided by the length on the right side,  $\frac{L_1}{L_2}$ .
7. Set this ratio equal to the ratio of resistances of the resistors, in this case the resistor on the left divided by the resistor on the right (one of these resistances is known, one is not).

$$\frac{L_1}{L_2} = \frac{R_1}{R_2}$$

8. Solve this equation to find the resistance of the unknown resistor, that is

$$R_1 = R_2 \frac{L_1}{L_2}$$

OR

$$R_2 = R_1 \frac{L_2}{L_1}$$

### Alternative Activity: Potentiometer

1. In the gaps of the metre bridge, place a rheostat, dry cells and a switch.
2. Connect one terminal of a voltmeter to the nail holding the resistance wire at the 0 cm mark.
3. Connect the other terminal of the voltmeter to a connecting wire which can easily move along the resistance wire.
4. Close the switch so that current is moving through the circuit.
5. Move the voltmeter wire to the 10 cm mark and read the voltage. This is the potential difference across 10 cm of the resistance wire.

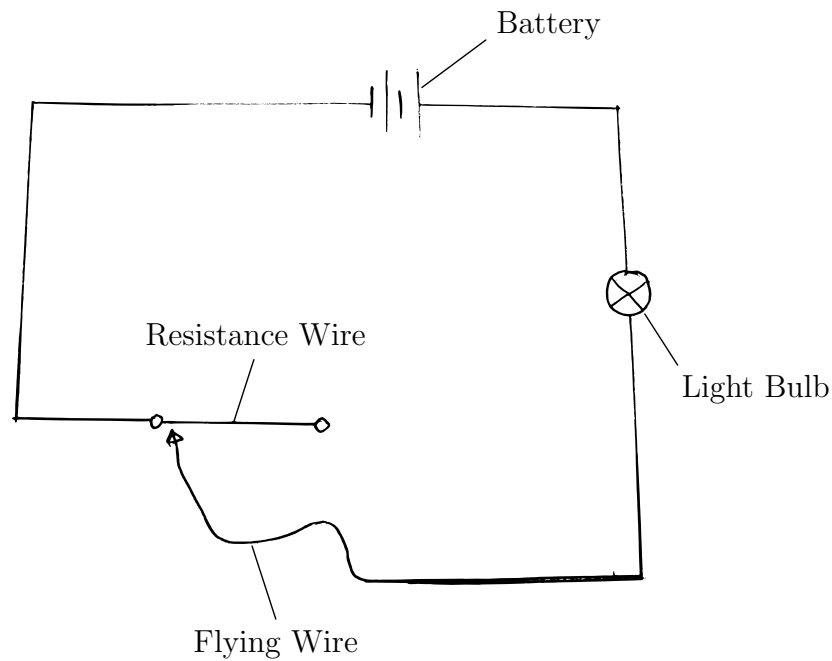


Figure 5.3: Metre bridge circuit

6. Move the voltmeter wire to the 20 cm mark and read the voltage. Repeat this process for 30, 40, 50, etc. cm and record all of the values.
7. Use the callipers to measure the diameter of the wire.
8. Make a graph of resistance and length. Use this graph to find the resistivity of the resistance wire.

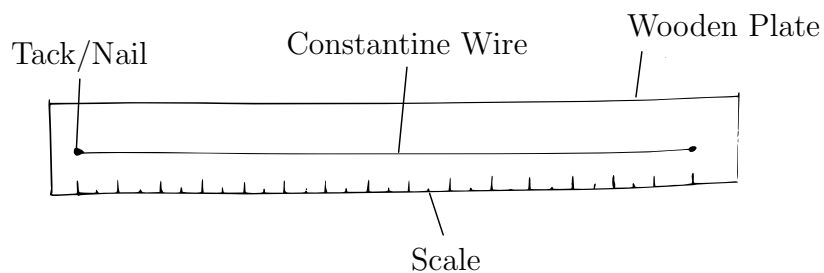


Figure 5.4: Layout of a Potentiometer

## Results and Conclusions

A constructed metre bridge functions using the relationship between a wire's length and its resistance. This principle can be used to find the resistivity of the wire or to find the resistance of any other conductors.

## Clean Up Procedure

Remove any remaining nails, pieces of wood and other equipment.

## Discussion Question

How can you manufacture a potentiometer?

## Notes

Metre bridges are used to determine unknown resistance and to compare electromotive force. When you are using a metre bridge to find the resistance of an unknown resistor, be sure to use two resistors that are similar in resistance. If the resistances are too different, it will be difficult to find with precision the point on the wire where the galvanometer reads zero.

This setup can also be used as a potential meter (potentiometer) in order to find the resistivity of the resistance wire.

## Creating a Light Bulb

### Learning Objectives

- To observe the luminosity effect of current in a thin wire
- To understand the mode of action of a light bulb

### Background Information

When electricity pass through a wire, resistance converts electrical energy into heat energy. This heat energy causes an increase in the temperature of the wire. If the wire gets hot enough, it will release energy as radiation visible light, red at lower temperatures to yellow to white at very hot temperatures. The effect, however, causes the wire to degrade and eventually the wire is not strong enough to pass current. When a lot of electrical energy is converted into light energy, the effect is that of a light bulb, which consists of a single, thin wire in a glass bulb.

## **Materials**

Glass jar with lid, glue, wires, power source, small length of thin iron wire, nail

## **Preparation Procedure**

1. Use the nail to poke two holes in the jar lid.
2. Pass a wire through each hole about half way into the jar.
3. Connect the wires inside the jar with the length of iron wire.
4. Seal the wires into the lid with glue.
5. Close the lid on the jar.

## **Activity Procedure**

1. Connect the wires outside the jar to the power source.
2. Observe the effect inside the jar.

## **Results and Conclusions**

If enough current is passing, the iron wire will light up, creating a light bulb for a short time until the wire burns out.

## **Cleanup Procedure**

Disconnect all wires and return all materials to their proper places.

## **Discussion Questions**

1. Why does the wire produce light?
2. Why do bulbs eventually stop working?
3. Mention some other materials which produce light when heated.

## **Notes**

You may need to try different types of wire for the bulb. If iron wire is not available or does not work, try other types. It should be very thin and have high resistance in order to work.

## **Fuse**

### **Learning Objectives**

- To understand the effect of a strong electric current on a wire of high resistance
- To understand the use of a fuse in electrical devices and installations

### **Background Information**

When a strong current is passed through a wire of high resistance (depending on the material, area and length), some of the electrical energy is converted into heat energy. If enough heat is produced, the wire burns and stops conducting electricity, breaking the circuit. This device can be used to protect electrical devices like radios or computers from electrical surges. If placed before all the components in a circuit, this thin wire, called a fuse, will break if too much current is passed through the circuit.

### **Materials**

Power source, wires, two small nails, small piece of wood, metal foil (from Blueband container, wrapper, etc.)

### **Preparation Procedure**

1. Hammer the nails into the wood about 5 cm apart.
2. Connect wires to each of the nails.
3. Place a thin strip of foil between the nails, bending it around the nails to secure it.

### **Activity Procedure**

1. Connect the wires to a power source to complete the circuit.
2. Observe the effect of the current on the foil when a large current is passing.

## **Results and Conclusions**

If the source is powerful enough, it will cause the foil to heat and eventually burn, breaking the circuit. It will be seen that the circuit will work at first, but then the foil will burn. Foil has a very small cross-sectional area compared to that of a wire, so it has a low tolerance for current. If too much current passes through the foil, it will burn away. This is essentially how a fuse works in a radio or other electrical device.

## **Cleanup Procedure**

1. Disconnect the wires from the battery.
2. Dispose of the burnt fuse and return all materials to their proper places.

## **Discussion Questions**

1. What causes the fuse to burn?
2. Why would a fuse be useful in an electrical device?

## **Notes**

It is best to use a rheostat in this circuit. Begin with a high resistance on the rheostat; slowly decrease it so that the foil is taking more of the voltage. As the voltage is increased, the foil will eventually burn as its resistance reaches a maximum. You can find fuses in most electrical devices; show these in class after performing this activity.

## **Making an Electric Heater**

### **Learning Objectives**

- To prepare and demonstrate an electric heater

### **Background Information**

Electricity and heat are both forms of energy, so it is possible to change energy from one form to another.

## **Materials**

1 m of resistance wire (nichrome) of swg 30 or 32, small piece of wood or paper, connecting wires, two to four dry cells (batteries), container of water, optional thermometer

## **Hazards and Safety**

- If the heater is connected to the cells while not in the water, the wire can melt or burn other objects.

## **Preparation Procedure**

1. Collect all materials.
2. Cut a small piece of wood about 4 to 6 cm long, or roll a piece of paper.

## **Activity Procedure**

1. Coil the resistance wire onto the piece of wood or rolled paper so that the coils are close but not touching. Use the entire wire.
2. Use connecting wires to connect the ends of the resistance wire to the terminals of the batteries.
3. Place the coil of resistance wire into the container of water.
4. Observe any effects on the water when current is flowing through the coil. Use your hand on the outside of the container to test the temperature.

## **Results and Conclusions**

When the heater (coil) is left in the container of water for a few minutes, the temperature of the water rises enough that it can be felt by your hand on the outside of the container. If the heater is left for a long time, the water may boil.

## **Clean Up Procedure**

1. Remove the waste products and dry the water on the table.
2. Return all materials to their proper places.

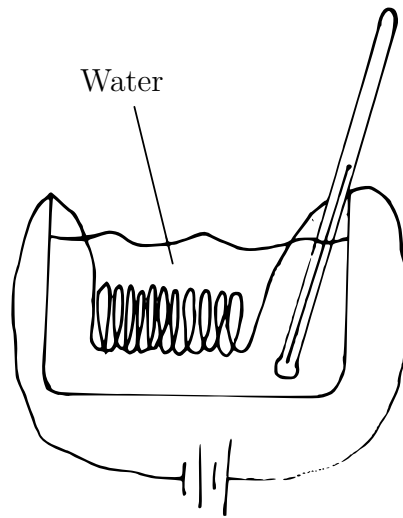


Figure 5.5: An Electric Water Heater

### Discussion Questions

1. What kind of energy is being produced?
2. What kind of energy is being converted?

### Notes

The electric heater converts electrical energy into heat energy. It can be used to boil water or other liquids, or to heat houses. The larger the coils are, the more efficient the heater will be.

## Inverter: Converting DC to AC

### Learning Objectives

- To explain the difference between Alternating Current and Direct Current
- To understand how to convert Direct Current to Alternating Current by changing the directing of current through a bulb or galvanometer
- To observe the effect of alternating current on a bulb or galvanometer



## **Background Information**

Direct Current is the current produced by any battery, cell or generator. It is current which moves in one direction only through a circuit. Alternating current is the current used in a house, school, etc. to power appliances, charge batteries, etc. It is current which changes direction many times per second; in Tanzania that current changes direction 80 times per second, so we say that the Tanzanian electrical system runs on 80 Hz, or 80 cycles per second. Rectifiers are used to convert AC to DC, but to convert the other way we need an inverter which can change the direction of electric current many times per second. The easiest way to do this is to switch the terminals of the battery repeatedly.

## **Materials**

Four (4) dry cells in the plastic wrapping, Aluminium outer coating of a dead dry cell, thin cardboard, super glue, soldering iron and flux, several small nails or screws, connecting wires, board at least 1 ft long, bulb or galvanometer, scissors, knife, retort stand with clip or alternative, small motor, horizontal pulley, rubber band, pliers, multimeter

## **Preparation Procedure**

1. Collect all of the necessary supplies.
2. Attach the horizontal pulley near one end of the board so that it is free to rotate horizontally.
3. Attach the small motor to the board so that it is also free to rotate horizontally.
4. Attach the rubber band to the motor and pulley so that when the motor turns, the pulley also turns.
5. Connect two connecting wires to the terminals of the motor and make sure it works by connecting two dry cells.
6. On one of the dry cell packs, cut away the plastic around each of the terminals on both batteries so that the batteries can be used without removing them from the plastic.
7. Solder or glue a connecting wire from the positive terminal of one of the batteries in the plastic to the negative terminal of the other battery. If

needed, glue the wire down to the plastic in the middle so that it does not stick up.

8. Glue the center battery pack on its side to the center of the horizontal pulley so that when the pulley turns, the battery pack turns on its side also.
9. Cut a small piece of thin cardboard to fit over the battery pack (about 5 cm square).
10. Glue the thin cardboard to the top of the battery pack.
11. Find the exact center of rotation of the battery pack and pulley by rotating the pulley and marking the center of rotation on the cardboard with a pen.
12. Remove the aluminium from the outside of a dead dry cell.
13. Break the aluminium into 2 equal pieces (about 5 cm x 3 cm) by bending it with straight pliers.
14. Glue the aluminium pieces to the cardboard so that there is a small space between them (so electricity cannot pass) and the hole marking the center of rotation can be seen between them.
15. Rotate the pulley again to make sure that, as it rotates, the metal plates are rotating about the axis.
16. Solder or glue a connecting wire from the free end of one of the batteries in the battery pack to one of the aluminium plates. Be sure that the wire is short enough that it does not stick up or out too much.
17. Repeat this step for the other free battery terminal and the other aluminium plate.
18. Use a multimeter to make sure that all of the wire connections are complete and that the circuit can conduct from one plate through the battery pack to the other plate. Note that the circuit is not complete because of the thin gap between the metal plates (otherwise you will have a short).
19. Cut a piece of thin cardboard about 10 cm long and 4 cm wide.
20. Fold the cardboard in half the long way.

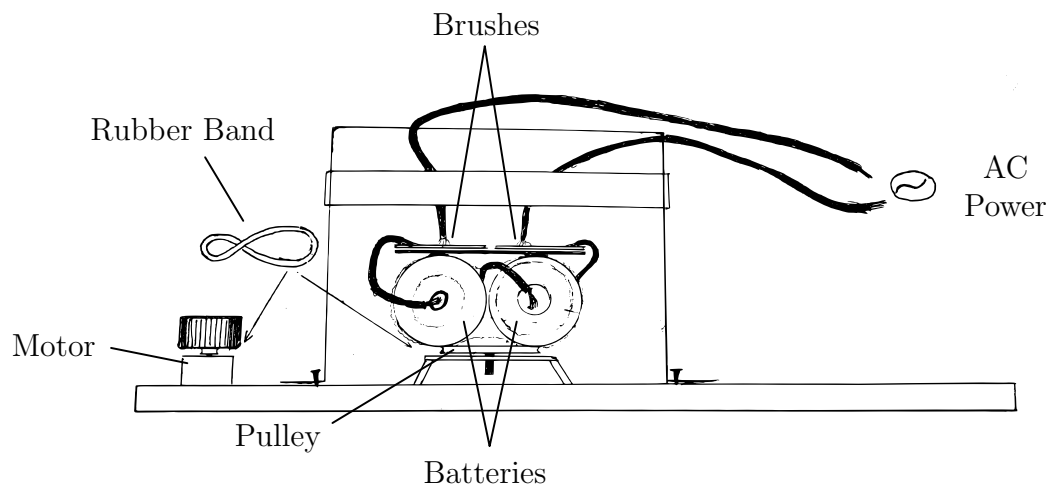


Figure 5.6: An Inverter

21. Cut two very small holes in the center of the folded edge about 2 cm apart.
22. Insert connecting wires into each of these holes so that each sticks out of the folded end by about 2 cm.
23. Remove the insulating from these connecting wires so that the copper ends form brush shapes and are free to bend slightly.
24. Extend the connecting wires back to a bulb or galvanometer and solder or glue the ends to the terminals.
25. Check that this circuit works with a multimeter or by connecting 2 dry cells across the brush ends.
26. If possible, connect a switch to the bulb or galvanometer.
27. Suspend the bulb/brush circuit about the rotating metal plates so that the wire brushes just touch the metal plates. If each brush is touching a different plate, the bulb or galvanometer should indicate a current.

### Activity Procedure

1. Check the circuits in the inverter by turning on the motor or touching the wire brushes to the metal plates.

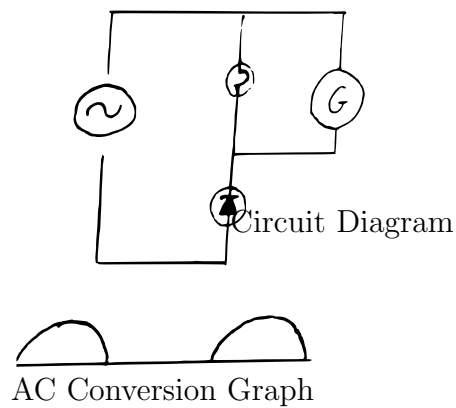


Figure 5.7: A Half Wave Rectifier

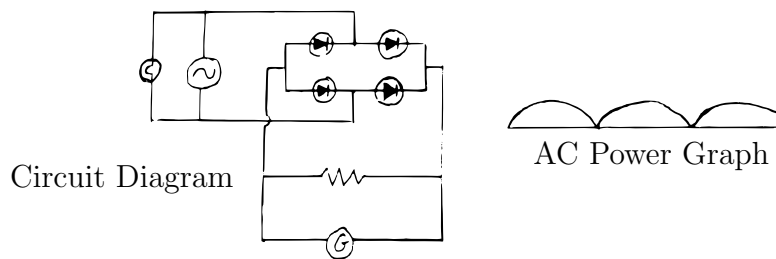


Figure 5.8: A Full Wave Rectifier

2. Align the wire brushes so that they rest in the thin gap between the metal plates. This will allow you to continue working or discussing without using up the battery or bulb.
3. Touch the wire brushes to opposite plates to show that a direct current is flowing and the bulb produces a steady light or the galvanometer shows a single direction of current.
4. Switch the plates that the brushes are touching to show that, again, a direct current is flowing and the bulb produces a steady light or the galvanometer shows a single direction of current opposite to the one previously seen.
5. Connect the motor to the batteries so that the system rotates under the brushes.

## Results and Conclusions

Students will see that when the metal plates are rotating under the brushes, the bulb flickers on and off quickly or the galvanometer changes direction quickly. Students will see that the behaviour of the bulb or galvanometer is different depending on if the plates are rotating. Students will understand that the bulb flickers or the galvanometer changes direction because the direction of current is changing every time the plates switch brushes. Students will understand that the system is converting the direct current (DC) of the battery pack to alternating current (AC) in the bulb or galvanometer.

## Clean Up Procedure

1. Disconnect the motor from the batteries and remove the bulb/brush circuit from the metal plates.
2. Return all pieces to their proper places.

## Discussion Questions

1. What is the difference between direct and alternating current?
2. What is powering the bulb or galvanometer?
3. What is the purpose of rotating the metal plates under the wire brushes?
4. Why does the bulb flicker or the galvanometer repeatedly change direction when the metal plates are rotating under the wire brushes?
5. What type of current is powering the bulb or galvanometer when the metal plates are not rotating?
6. What type of current is powering the bulb or galvanometer when the plates are rotating under the brushes?

## Notes

Normally, alternating current changes direction 80 times per second, which we cannot see with our eyes. Therefore, the difference between AC and DC is not visible in a normal household or school electrical system. In order to see the effect of AC, we need to slow down the frequency to the point where we can see the direction changing in the galvanometer or bulb.

# Semiconductors and Semiconductor Devices

## Forward and Reverse Biased Diodes

### Learning Objectives

- To explain the mode of action of a P-N junction

### Background Information

An extrinsic semiconductor has a net positive or negative charge. For example, silicon doped with phosphorus has a negative charge and is called an N-Type semiconductor. Silicon doped with boron has a positive charge and is called a P-Type semiconductor. When these two types of semiconductors are connected in series, they form a P-N Junction. We know that electric current flows from positive to negative in a circuit.

### Materials

Diode, dry cell, bulb, connecting wires, nail, heat source or soldering iron

### Preparation Procedure

1. Heat the soldering iron or nail.
2. Remove a diode from broken radio using a soldering iron or a hot nail.

### Activity Procedure

1. Join the bulb in series with the P-N junction.
2. Connect the P-terminal of the junction to the positive pole dry cell and the N-terminal of the junction to the negative pole of the dry cell.
3. Record what you observe in the circuit.
4. Reverse the terminal of the cell and observe the change in the circuit.

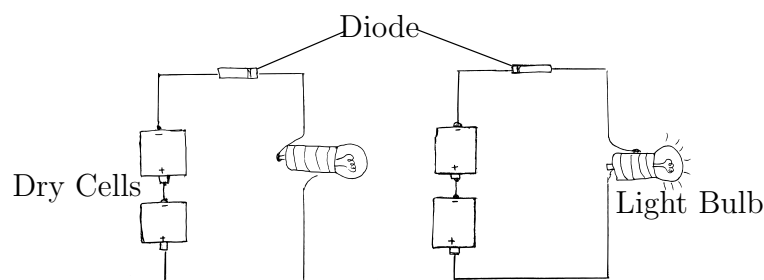


Figure 5.9: Testing the Action of a Diode

## Results and Conclusions

When the P-terminal of the junction (diode) is connected to the positive terminal of the battery and the N-terminal of the junction is connected to the negative terminal of the battery, the bulb will light, indicating that current is flowing. If the terminals are reversed so that the P-terminal is connected to the negative battery terminal and the N-terminal is connected to the positive battery terminal, the bulb will not light, indicating that current is not flowing. The P-N junction, allows current to flow only in one direction; current can flow from the P-terminal to the N-terminal, but not the other way. Current always flows from a positive terminal to a negative terminal.

## Clean Up Procedure

Disconnect the apparatus and return materials to their proper place.

## Discussion Questions

1. What is a diode?
2. What will happen when the P-terminal of the junction is connected to the negative pole of the cell?
3. Why does a diode allow current to flow in only one direction?

## Notes

A diode, which can be found in a radio, phone charger, etc. , has two colours: white and black. The black side is the P-terminal and the white band is the N-terminal. Current will only flow from the black side to the white side.

## Full-Wave Rectifier

### Learning Objectives

- To observe the effects of full-wave rectification on a galvanometer and bulb
- To explain the mode of action of a full-wave rectifier
- To explain the use of diodes in a full-wave rectifier
- To explain the relationship between AC current, full-wave rectification and half-wave rectification

### Background Information

AC is current which changes direction many times per second. When we want to change AC to DC, which moves in only one direction, we must use a wave-rectifier. A half-wave rectifier is simple to make and use, but it only converts half of the AC current to DC. In order to convert more AC current to DC, we need to use a full-wave rectifier. A full-wave rectifier allows current in one direction to pass. It then takes current in the opposite direction and changes its direction so that it can pass again. For example, all forward-moving current will pass a wave rectifier. Then all current which is moving backward will have its direction changed so that it can pass the rectifier. In this way, all of the AC current is used and changed to DC.

### Materials

Low voltage AC power source (see the activity "Inverter"), connecting wires, 4 diodes, bulb, resistor, galvanometer, optional super glue

### Hazards and Safety

- Do not use the power from outlets in a house or school. These outlets put out a high voltage (220 V) which can kill you. Instead use a laboratory power supply or use D-cell batteries with an inverter as described above.

### Preparation Procedure

1. Collect all materials.



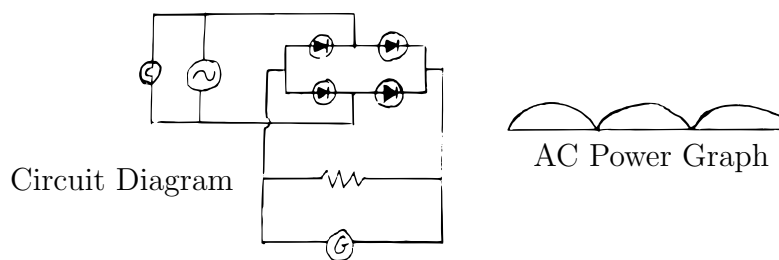


Figure 5.10: Full Wave Rectifier

2. Connect the AC power supply to the galvanometer to make sure that it is working. If you don't have an AC power supply in your school, you can create an inverter which converts the DC output of a battery into AC. This process is described in the "Inverter" activity.
3. Connect two diodes together in series with connecting wire. Use super glue to help secure them if you do not have a breadboard.
4. Repeat this step so that you have two pairs of diodes in series.
5. Connect these pairs in parallel to each other so that current can flow through either pair but only in one direction.
6. Also connect a resistor and a galvanometer in parallel across the pairs of diodes. Now you should have four things in parallel: two pairs of diodes with the same direction, a galvanometer and a resistor.
7. Attach connecting wires between the diodes in each pair.
8. Extend these connecting wires to the AC power source. Now the AC power source should be attached to the middle of each diode pair.
9. Attach a bulb in parallel across the AC source.

### Activity Procedure

1. Test the AC power source to see that the bulb flickers.
2. Connect the AC source directly to the galvanometer and observe the behavior of the galvanometer.
3. Connect the AC source to the full-wave rectifier and observe the behavior of the galvanometer in relation to the bulb.

## Results and Conclusions

When the AC source is connected directly to the galvanometer, the galvanometer needle will jump one direction and then the other, showing the changing direction of current through the circuit. However, when the galvanometer is powered through the full-wave rectifier, it can be seen that the galvanometer only indicates one direction (positive or negative) and jumps quickly between zero and its maximum value.

If observed closely with an AC source of low frequency, it can be seen that the bulb and galvanometer flicker at exactly the same rate. This is because the full-wave rectifier creates DC current which increases and decreases (but only in one direction) at the same frequency that the AC current is changing direction. As the bulb is following the AC current at a certain frequency, the galvanometer is being driven by the DC current at the same frequency of increasing and decreasing.

## Clean Up Procedure

1. Turn off the power supply and disconnect the wires.
2. Return all materials to their proper places.

## Discussion Questions

1. What is the behavior of the galvanometer when connected directly to the AC source?
2. What is the behavior of the galvanometer when connected to the full-wave rectifier?
3. Compare the behavior of the galvanometer and the bulb when the galvanometer is connected to the full-wave rectifier and the bulb is connected to the AC source.

## Notes

This activity is normally done with an oscilloscope, which clearly shows the waveform of the AC current and rectified current. However, the effect of the full-wave rectifier can be seen clearly if you are using the correct components.

First, the full-wave rectification can be compared to the half-wave rectification. If you connect the AC source to both a half-wave rectifier and a full-wave rectifier, each with a galvanometer, it can be seen that the full-wave

rectifier causes the galvanometer to move at twice the speed of the half-wave rectifier.

Also, when a bulb is attached in parallel across the AC source while the galvanometer reads the current through the full-wave rectifier, it can be seen that the bulb and galvanometer flicker at the same rate, proving that the entire AC wave is being converted directly to DC rather than only half of the wave.

## **Half-Wave Rectifier**

### **Learning Objectives**

- To observe the effects of half-wave rectification on alternating current
- To construct a half-wave rectifier
- To explain the mode of action of a half-wave rectifier
- To explain the use of a diode

### **Background Information**

Alternating current is current which changes direction many times per second. It is useful for transporting electric current over great distances but it is not always useful in appliances in the home or school. For this reason, we often need to convert alternating current into direct current, which moves only in one direction.

One way to do this is to make a one-way gate through which electric current can pass in one direction but not in another. A device which does this easily is a diode, or P-N Junction, which allows current to pass from the P-type to the N-type semiconductor of the diode. By passing AC through a diode, we produce direct current whenever the AC is moving forward, and no current whenever the AC is moving backward. The result is a half-wave of electric current, where we recover (or rectify) half of the AC current and convert it into DC.

### **Materials**

Low power AC power source (see the activity "Inverter"), diode, bulb, galvanometer, connecting wires.

## **Hazards and Safety**

- Do not use the AC power of an outlet in your home or school. These outlets carry very high voltage (220 V) which can kill you if you are not careful. Instead, use a low-power AC power supply.

## **Preparation Procedure**

1. Collect all materials.
2. If you don't have an AC power supply, you can construct an inverter which converts the DC of batteries into AC.
3. Set up the power source or inverter to produce AC current and check that it is AC by watching its effect on a galvanometer.
4. Connect the P-side of a diode (the black colour indicates P-type) to one of the connecting wires from the power source.
5. Connect one of the terminals of the bulb to the N-side of the diode (a white band indicates N-type).
6. Connect the other terminal of the bulb to the remaining connecting wire of the power source. You should now have a power source, diode and bulb all in series.
7. Connect the galvanometer in parallel with the bulb.

## **Activity Procedure**

1. Turn on the power and watch the behavior of the galvanometer.

## **Results and Conclusions**

When AC power is connected to a galvanometer, it is seen that the current is changing direction quickly, causing the needle to jump back and forth. When the AC is passed through a half-wave rectifier, however, the current is only in one direction (positive or negative) and jumps between zero and the maximum value at half the speed that it did with AC current. This is because the AC current is being cut in half through the rectifier and is allowed to move in only one direction. If using a bulb, it will be seen that the bulb flickers quickly with AC current, but only half as quickly with half-wave rectified current.

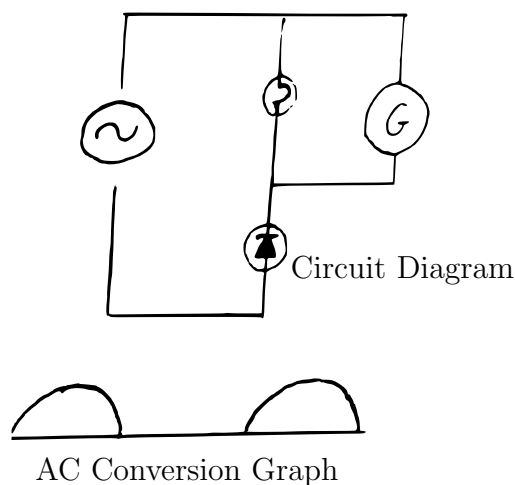


Figure 5.11: Half Wave Rectifier

### Clean Up Procedure

1. Disconnect all wires and turn off the power supply.
2. Return all materials to their proper places.

### Discussion Questions

1. What is the difference shown by the galvanometer between regular AC current and AC current when it is passed through the half-wave rectifier?
2. Is the speed of the galvanometer needle the same in both cases, or different?

### Notes

This activity is normally done with an oscilloscope, which shows the wave pattern of the AC current (it is a sine wave). If seen on the oscilloscope, the AC appears as a full sine wave, while the half-wave rectified current appears as only the positive or negative part of the sine wave (it looks like hills separated by long spaces). A half-wave rectifier, rather than converting AC directly to DC, simply removes all current in one direction and allows all current in the other direction. In this way, the product is direct current, but only half of what was produced by the AC power source.

# Waves

## Construction and Use of Slinky Spring

### Learning Objectives

- To construct a slinky spring
- To observe the propagation of transverse and longitudinal waves

### Background Information

A mechanical wave is the oscillation of particles in a medium, either side-to-side or back-and-forth along the direction of the wave's motion. A transverse mechanical wave is produced when particles oscillate side-to-side as on a guitar string. Its crests and troughs can be seen clearly. A longitudinal wave is produced when particles oscillate back-and-forth as passengers on a bus that stops and starts repeatedly. It can be seen because of the alternating compressions and rarefactions along the wave.

### Materials

Two (2) m of flexible steel or copper wire, long cylindrical object (rod, stick) at least 3 cm diameter

### Hazards and Safety

- Every spring has a maximum length that it can be stretched. If you stretch it beyond this point, it will not work again. Don't stretch the slinky too far.

### Preparation Procedure

1. Collect all materials.
2. Hold one end of the wire against the cylindrical object.
3. Use your other hand to coil the wire around the cylinder, keeping the coils close together. When you finish coiling all of the wire along the cylinder, you should have a slinky spring.

### **Activity Procedure**

1. Have one student hold one end of the spring.
2. Hold the other end with your hand and stretch the slinky slightly so that the coils separate.
3. Hold the slinky flat against the floor.
4. Move your end of the slinky quickly from side to side (the student should keep her end stationary). Observe the motion of the slinky.
5. Move your hand quickly back and forth, alternately pushing and pulling the spring. Observe the motion of the slinky.
6. Move your hand quickly to one side and then back to the center only once. Observe the progression of the wave along the slinky.

### **Results and Conclusions**

Students will see that a transverse wave progresses by alternating crests and troughs as the points on the slinky oscillate back and forth perpendicular to the direction of the wavefront. Students will see that a longitudinal wave progresses as points on the slinky alternately push and pull each other in the direction of the wavefront. Students will see that a single transverse wave (one crest and one trough) is reflected on the opposite side, or that the crest and trough trade places when reflected. Students should understand that a wave is caused when particles oscillate.

### **Clean Up Procedure**

Return the slinky to its proper place.

### **Discussion Questions**

1. What is the type of wave produced when you move your hand from side to side? Describe this wave.
2. What is the type of wave produced when you move your hand back and forth? Describe this wave.
3. When there is only one wave crest moving along the slinky, how is it reflected at the opposite end?

## Construction of a Ripple Tank

### Learning Objectives

- To construct a ripple tank

### Background Information

A ripple tank uses a container or shallow water to create waves and observe their behavior. A light source projects the shadow of the waves onto the paper below so that all behavior at obstacles and sources can be seen clearly.

### Materials

pane of glass 45 cm by 45 cm, four pieces of wood 50 cm long and 4 cm thick, nails or screws, putty or caulk, small ball of plastic or rubber, stiff wire, small motor from a car stereo or other device, connecting wires, two D-cell batteries, four thin pieces of wood about 30 cm long, two thin pieces of wood about 50 cm long, various small pieces of straight wood, glue

### Preparation Procedure

1. Obtain the 45 cm x 45 cm piece of glass.
2. Make a groove 1 cm thick along one side of each of the four pieces of wood.
3. From the groove on each piece of wood, cut the wood back at a 45-degree angle.
4. Fit the pane of glass into the grooves and join the pieces of wood at the corners with nails or screws. It should resemble a window frame.
5. Use caulk or putty to secure the glass to the wood frame so that water cannot pass.
6. Make or find a small ball of rubber or plastic (no more than 2 cm diameter).
7. Bend a 6 cm piece of wire into an L shape.
8. Attach one end of the wire to the small ball.
9. Along two opposite sides of the frame, attach two pieces of wood 30 cm tall vertically. These should be about 10 cm from the side and directly across from each other.



10. Attach the two vertical pieces of wood at the top with the 50 cm piece of wood. You should now have a beam across the ripple tank.
11. Attach the motor to a piece of wood 30 cm long. Try to balance the motor so that the piece of wood stays flat.
12. Attach the ball and wire to one side of the piece of wood just under the motor. If the wood is flat, the wire should extend out and down.
13. Suspend the wood and motor from the beam with thread so that the ball rests about 1 cm above the glass pane.
14. Connect the terminals of the motor to connecting wires and extend these wires up to the beam.
15. Attach two D-cell batteries to the beam so that the connecting wires can be easily attached.
16. Glue a screw to the motor so that it vibrates when it spins.

### **Activity Procedure**

Set up the ripple tank with water, a light source and plane paper to check that it works.

### **Results and Conclusions**

The motor on the hanging bar provides a vibration, which in turn produces waves in the water. Different objects can be attached to the hanging bar to produce different types of waves, and the waves can be seen clearly on the paper under the tank.

### **Clean Up Procedure**

1. Disconnect the wires.
2. Remove the water from the ripple tank.
3. Return all materials to their proper places.

## Discussion Questions

1. Why is it necessary to attach an object to the motor?
2. What is the shape of a wave produced by the ball?
3. What is the shape of a wave produced by a ruler?

## Notes

It is easier to ask a carpenter to make this. Bring the glass to the shop and describe the construction of a ripple tank. The motor can be found easily in broken electrical devices.

## Behaviour of Waves

### Learning Objectives

- To demonstrate and explain the reflection, refraction, diffraction and interference of waves

### Background Information

The periodic mechanism which transfers energy from one point to another is called a wave. There are two types of waves: mechanical and electromagnetic. While these are produced differently, they share similar properties of reflection, refraction, interference, diffraction, etc. Reflection occurs when a wave hits a barrier and reverses or changes its direction. Refraction occurs when a wave passes from one medium into another and changes its speed and direction. If the wave is allowed to pass only through a small opening, it will undergo diffraction which changes the shape of the wave. If two small openings are used, the two diffraction patterns will pass over each other, forming interference.

### Materials

Ripple tank (see the activity for constructing a ripple tank), two D-cell batteries, large white paper(flip chart), water, torch, various objects to place in the water

### Hazards and Safety

- Use a small source of power to run the motor.

## **Preparation Procedure**

Create the ripple tank as described in the construction activity.

## **Activity Procedure**

1. Place the ripple tank between stools.
2. Pour some water into the ripple tank so that it is about 1.5 cm deep.
3. Place the dipper on the wood beam; it should just touch the surface of water.
4. Connect the motor to the batteries.
5. Place the white screen/paper underneath the stools.
6. Light a torch above the ripple tank and observe the waves formed.
7. Exchange the dippers so as to obtain spherical and plain waves. Using these waves you can now observe the different behaviours of waves, such as reflection, refraction, diffraction and interference. You can place obstacles in the water to see diffraction and interference.

## **Results and Conclusions**

The manufactured and mounted ripple tank can be used to study the behaviour of water waves. For instance, when a round ball is used, a circular wavefront is formed, while a ruler produces a plane wave. If a barrier is placed in front of the wave, the wave is reflected back on itself or in a new direction, depending on the shape of the barrier. When the wave passes between two barriers, it diffracts and changes form. A plane wave becomes a circular wave, and two diffracted waves interfere to form points of constructive and destructive interference.

## **Clean Up Procedure**

Dismantle the ripple tank and remove the water after the experiment. If there is any water, it should be dried up.

## **Discussion Question**

Besides the ripple tank, what other method can be used to propagate the water waves?

## Notes

A ripple tank can be used to demonstrate the properties or behaviour of a wave as described above. However, you can also use it to show the relationship between wavelength and frequency, and that the speed of a wave is constant in one medium.

# Sound

## Construction and Use of a Simple Sonometer

### Learning Objectives

- To construct and use a simple sonometer
- To explain the propagation of waves on a string

### Background Information

Sound waves can be produced when a string vibrates. The frequency at which the string vibrates depends on several things, like the length of the string and the material. A sonometer consists of a metal string which can vibrate between two supports. This is a standing wave and is driven by a tuning fork or other source of sound. If the natural frequency of the string (the frequency it will have because of its length and material) is the same as the tuning fork, the string will vibrate.

### Materials

Soft wood board about 80 cm long, thin wire (steel works best) or string, nails, 2 small triangular pieces of wood(pegs) or two pencils, heavy stone

### Preparation Procedure

1. Place the soft wood on a table.
2. Fix a string/wire with a nail to one end of the soft wood.

### Activity Procedure

1. Hang the heavy mass of a stone to the free end of the string/wire so that the mass hangs below the edge of the table.

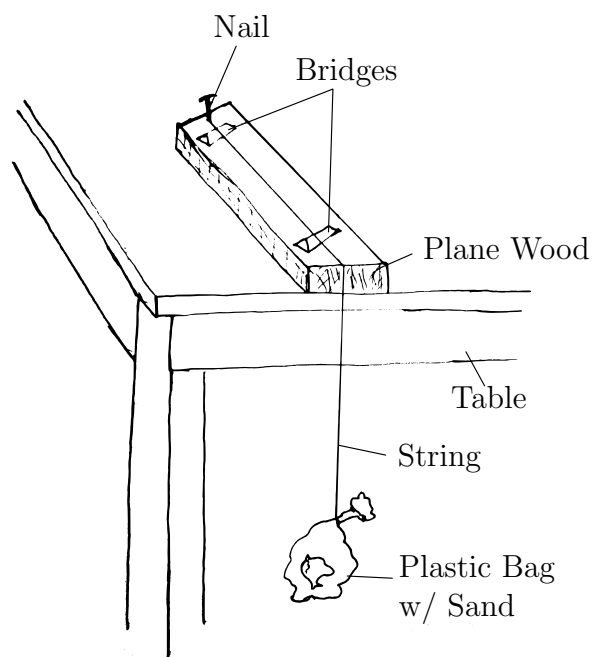


Figure 5.12: Construction of a simple sonometer

2. Insert the two pegs/triangular pieces under the string/wire so as to raise the wire off the surface of the wood.
3. Pluck the string/wire between the two pegs. If the wire does not make a clear note, add mass to the end.
4. Vary the distance between the two pegs (increase and decrease) and observe the effect on the frequency of the wire/string.
5. Vary the mass hanging on the end of the wire (increase and decrease) and observe the effect on the frequency of the wire/string.

### Results and Conclusions

A higher tone is heard/produced if the distance between the two pegs is reduced. A higher tone is also heard/produced if the mass is increased. The tone which is produced by the vibrating string/wire depends on its vibrating length and the tension on the string/wire.

### Clean Up Procedure

Remove the mass from the string/wire.

### Discussion Question

What do you hear in steps 4 and 5?

### Notes

The same activity can be used to show that the frequency of a vibrating tuning fork is inversely proportional to the length of a vibrating string. It can also show that the frequency of a vibrating tuning fork is directly proportional to the tension in a vibrating string. Using different tuning forks and finding the corresponding length and tabulating the values, a graph of Frequency against Reciprocal length can be drawn and is a straight line passing through the origin. Also, wires of different diameters can be fixed on the plane wood. Collect the plane wood, nails from a nearby carpenter and it cost about Tsh. 3, 000/= . Instead of heavy stones, dry sand packed in plastic bags can be used. Also, instead of two pegs you can use two pencils.

## Wave Propagation in Solids

### Learning Objectives

- To observe the propagation of vibrations through a solid
- To understand how sound is transmitted through a medium

### Background

Sound is a pressure wave, which means it can travel through any medium so long as the molecules in that medium are free to vibrate. In fact, this is every medium, though air and water transmit sound much more efficiently than solids. However, solids can transmit waves, as in the case of a guitar, which uses vibrating strings to produce sound waves. If a wave is produced on one end of a string, the string transmits the energy of that wave to the other end.

### Materials

Spoon, string 1 m

### Preparation Procedure

1. Tie the spoon into the middle of the length of string so that it will hang freely when you hold the string ends.

2. Have a student hold the string ends to his or her temples or the bone just under his or her ears as you strike the spoon with a pen or other object.

## **Results and Conclusions**

The student will hear a clear sound when the spoon is struck. The vibrations of the spoon propagate up the string and into the student's head. Bone, especially around the temples and outer ear, resonates readily in response to sound.

## **Cleanup Procedure**

Untie the string and return all materials to their proper places.

## **Discussion Questions**

1. What causes the sound to be loud when the string is held to your head?
2. Why does the bone in front of your ear transmit vibrations more easily than other bones?
3. What is the purpose of the string in this activity?

## **Notes**

The bone in front of your ear is the most resonant bone in the body, so it is ideal for transmitting vibrations and hearing sound. The vibrations from the spoon are transmitted easily through the string and your skull, which you hear as a sound.

## **Sound Amplifier**

### **Learning Objectives**

1. To understand the amplification of mechanical waves
2. To observe the amplification of sound in a hollow cavity

## **Background Information**

Everything can vibrate. If a wave drives the vibration of another object or surrounding air, we say that the wave is amplified as its amplification has increases with the resonating body. This principle is used when marimbas are played inside gourds.

## **Materials**

Plastic water bottle, string or thread, match or small stick

## **Preparation Procedure**

1. Make a small hole in the bottom of the bottle.
2. String one end of the thread through the hole.
3. Tie the end on the inside of the bottle to the match or small stick so that it cannot be pulled back through the hole.
4. Leave the length of string hanging out of the bottom of the bottle

## **Activity Procedure**

1. Pull the string taught and have a student hold the top of the bottle.
2. Pluck the string.
3. Try plucking just the string and then the string and bottle together.
4. Try plucking the string with the cap on or off.
5. Observe the various effects of the sound.

## **Results and Conclusions**

When the string is plucked by itself, the sound it creates is very small. However, when the string is attached to the bottle, the sound is louder. The vibration of the string causes the bottle itself to vibrate. Rather than hearing just the sound of the string vibrating, we hear the sound of the bottle, which produces noticeably greater amplitude.

## **Cleanup Procedure**

Return all materials to their proper places.



### **Discussion Questions**

1. What was the difference between the sound produced by the string and the sound produced by the string and bottle together?
2. What causes the sound you hear to be louder?
3. What was the difference in sound between using the cap and not using the cap?

### **Notes**

This effect can be difficult to detect if the bottle is small or if the frequency of the string is much higher or lower than that of the bottle. Vary the length of the string until you get clear resonance.

## **Determination of Resonance Frequency**

### **Learning Objectives**

- To explain the concept of resonance as applied to sound

### **Background Information**

Every object has a natural frequency depending on its size, shape, material, etc. If a wave drives the object at its natural frequency, the object itself will begin to vibrate along with the wave. This effect is called resonance.

### **Materials**

Fluorescent tube (tube light), thick rubber tubing, two 1.5 litre plastic water bottles, super glue, wax, turning Fork, retort stand, bucket, water, long stick, knife, metre rule, rubber or cork, piece of cloth

### **Hazards and Safety**

- Precautions should be taken when cutting the pipe as it will be sharp.
- Do not touch the fluorescent dust in the tube; it is poisonous.
- Use glue carefully, do not touch it with you bare fingers.

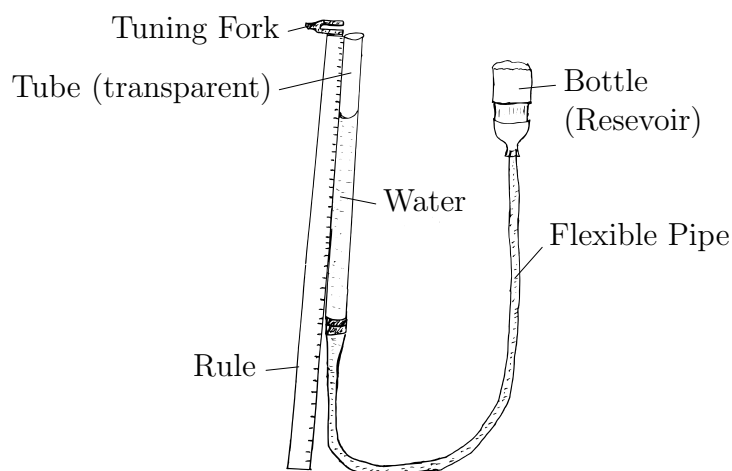


Figure 5.13: Construction of a resonance tube

### Preparation Procedure

1. Create a hollow tube from the fluorescent tube by cutting its rims off on both sides.
2. Clean the tube with a piece of cloth attached to a long stick
3. Cut the bottom 5 cm off of one of the bottles (bottle 1) and cut the top 5 cm off the top the other bottle (bottle 2).
4. Make a hole in the cap of both bottles.
5. Attach one end of the pipe with the glue and wax to the inside top of bottle 2. Insert the rubber tubing through the holes of both bottle caps.
6. Hold the tube with retort stand together with a metre rule upright(vertically)
7. Raise bottle 1 vertically until you have created a U-shape.
8. Pour water into bottle 1.

### Activity Procedure

1. Strike the turning fork with the soft material such as rubber
2. Place the turning fork at the top of the tube

3. rise and lower the water level in the tube by changing the vertical position of bottle 1
4. Repeat for the other two more different turning fork
5. For each turning fork note the fundamental note and overtone.

## **Results and Conclusions**

Student should hear the tube resonating at two or more water levels. The lowest water level is the fundamental and each smaller water level are higher harmonics. Student should understand that: The length of the tube from the water to the top can be used to calculate speed of sound in air. Resonance frequency occurs when the natural frequency of the air column is equal to the forced frequency from the tuning fork.

## **Clean Up Procedure**

1. Water from the pipe and reservoir pour in the bucket
2. Keep the system on the shelves

## **Discussion Questions**

1. Design another way to perform the same experiment.
2. Think of material that can be used instead of fluorescent tube and flexible pipe

## **Notes**

The vibrating air column in the pipe produces a loud sound when the node of a waveform is at a closed end and the anti-node at the open end. At this point the vibrating air is at resonance with the vibrating tuning fork is held at the open end. Teacher should also know that: This experience can be used to determine the velocity of sound in air. In absence of the listed materials using the tub in a bucket of water will also work.

## **Speed of Sound in Air**

### **Learning Objectives**

- To understand the relationship between a wave's frequency, speed and wavelength

- To calculate the speed of sound in air using a resonance tube

### **Background Information**

A wave's speed or velocity is directly related to the wave's frequency and wavelength. If the wavelength and frequency can be determined, the speed can be calculated easily. We can use a resonance tube or sonometer to find the wavelength and frequency of a wave, therefore allowing us to calculate the speed of the sound wave in that medium.

### **Materials**

Resonance tube (this can be made: see the activity about constructing a resonance tube in this book), tuning fork or wind instrument like a flute or recorder, water, metre rule

### **Hazards and Safety**

- If you are using tuning forks, do not hit them on a table or any other hard object. Over time, this will damage the tuning forks and changes their frequencies until they are no longer useful. Instead, hold the middle of the handle and hit one of the fork's prongs on the sole of your shoe or any other hard rubber object.

### **Preparation Procedure**

1. Set up the resonance tube with water.
2. Place the metre rule next to the resonance tube so that the 0 cm mark is at the top of the resonance tube.

### **Activity Procedure**

1. Use a tuning fork or flute to make a single musical note.
2. Place the fork or flute over the resonance tube and adjust the water level until the resonance can be heard in the tube. The note produced by the fork or flute will be heard at the top of the tube when the water is at a certain level.
3. Record the distance between the water level and the top of the tube at the level when the water reaches a level where resonance can be heard.

4. Also record the frequency of the note. If you are using tuning forks, the frequency is written on the handle. If you are using a flute, the frequency depends on the note you are playing. A table of musical notes and their frequencies can be found in any textbook. The easiest to use is A, which has a frequency of 440 Hz.
5. Use your values of length (wavelength) and frequency to calculate the speed of sound in the tube.
6. Repeat these steps for several notes and compare your values of speed of sound.

## Results and Conclusions

It will be seen that the product of wavelength and frequency will be almost the same. This is because the speed of sound in air is constant (depending on humidity and density). Therefore, the product of wavelength and frequency must be constant. As frequency increases, the wavelength (the length of the tube above the water level) decreases.

## Clean Up Procedure

1. Empty the water from the resonance tube.
2. Return all materials to their proper places.

## Discussion Questions

1. What was your average value for the speed of sound in air?
2. As the frequency of the musical note increased, did its wavelength increase or decrease?
3. If the speed of a wave remains constant, what is the relationship between wavelength and frequency of a wave?

## Notes

There is room for error in this experiment because you are trying to measure length as the water level is moving. Also, the flute or other instrument you are using to create a note may not be perfectly in tune and so may have a slightly different frequency. Do several experiments in order to find a consistent value for the wavelength.

# Electromagnetism

## Simple Motor

### Learning Objectives

- To use Fleming's left-hand rule to determine the motion of the coil in the circuit
- To explain the principle of magnetic induction, which explain the motion of the rotating coil

### Background Information

The magnitude of the force acting on a current loop inside a magnetic field depends on the strength of the magnetic field, the amount of current flowing through the wire and the direction of the current and magnetic field.

### Materials

Insulated copper wire, cello tape, clothes pegs, magnet, dry cells, connecting wires, two pieces of magnetic materials, switch

### Preparation Procedure

1. Construct a ring of copper wire with lots of loops by wrapping the wire around any circular object with the desired diameter. Tape the coils together using cello tape so that the circular object can be removed and the ring does not fall apart. Make sure that two ends of the copper wire stick out from two opposite sides of the ring.
2. Take one end of the wire and scrape off all of the insulation coating using a razor. Take the other side and ONLY scrape off the insulation coating from half the circumference of the wire.
3. Attach the two magnetic materials to two opposite sides of the speaker magnet.
4. Attach the clothes pegs to the magnetic materials and suspend the coil above the magnet by placing it between the two wire loops of the pegs.
5. Join the two dry cell together

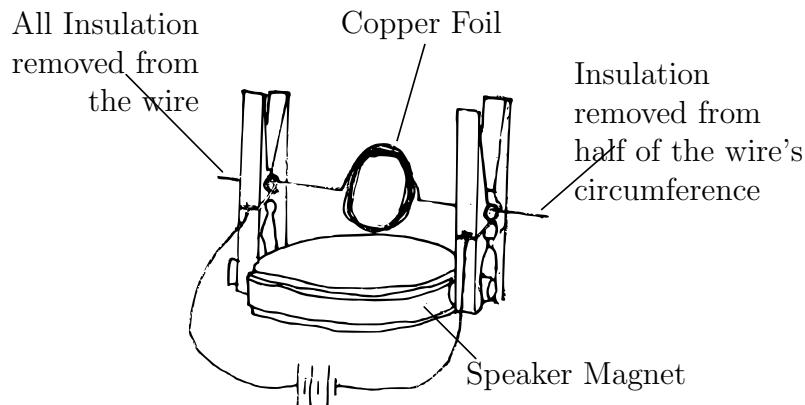


Figure 5.14: A Simple Motor

### Activity Procedure

1. Connect the coils of the pegs to the terminals of the battery through the switch using the connecting wires.
2. Close the switch to observe the effects

### Results and Conclusions

When the switch is on, the magnetic field applies a force to the current carrying wire following Fleming's left-hand rule and causes the loop to spin. If the current is increased the coil spins faster showing the force is proportional to the current. If the current is reversed the coil will rotate in the other direction, this is apparent from Flemming's left hand rule. If there is a stronger magnet the coil spins faster which shows the force is proportional to the magnetic field strength. If the insulation is left on the current from the battery can not flow into the wire so there will be no spinning. If all of the insulation is scratched off from both sides then the loop will not spin but will instead reach an equilibrium position where the force acting on the top and bottom of the loop are balanced.

### Clean Up Procedure

Disconnect the components and keep them in their proper places.

## Discussion Question

Explain the motion of the coil of current in the magnetic field. What happens when the current in wire is increased? What happens when the current is reversed in the coil? What happens when if we use a stronger magnet? What would happen if we did not scrape off the insulation coating? What would happen if we scraped off all of the insulation coating on both sides?

## Notes

During the preparation of a commutator, on one end scratch around the whole wire, but on the other end only half the circumference should be scratched Magnet must be pretty strong to have an obvious effect. Make the coil with as many turns as possible.

## Construction of Galvanometer

### Learning Objectives

- To construct a galvanometer
- To explain the uses of a galvanometer
- To explain the mode of action of a galvanometer

### Background Information

A galvanometer uses the principle of electromagnetism to detect the presence of electric current. Whenever there is a flow of current in a wire conductor, magnetic fields are created around it. The magnetic fields produced are perpendicular to the direction of current and concentric around the current itself. For this reason, a coil produces a strong magnetic field through its center, and a magnet suspended in that coil will pivot to show the direction of the magnetic field. A suspended magnet, when not placed in another field, will always face in the direction of the earth's magnetic field.

### Materials

Magnet; sewing needle, pin or the metal part of a syringe needle; coated copper wire or speaker wire; dry cells; water; empty water bottle; small piece paper; knife, connecting wires



### **Preparation Procedure**

Cut the empty water bottle so that the bottom 3 cm act as a shallow dish.

### **Activity Procedure**

1. Instruct students to rub the pin/needle on the magnet several times in one direction without scratching it. This is magnetization by stroking and may take a minute depending on the strength of the magnet.
2. Have students coil the wire around the water bottle dish about 20 times and secure it with cello tape so that it is secure.
3. Use a knife or razor blade to scrape at least 2 cm of the insulating coating off of each end of the copper wire.
4. Have students pour water into the dish so that it is about half full.
5. Stitch the pin into a small piece of paper so that the pin is secure against one side of the paper.
6. Place the pin and paper gently onto the surface of the water in the dish so that it floats. The pin will rotate on the water to point North and South because it is a magnet and is following the earth's magnetic field.
7. Use connecting wires to connect the dry cells to both ends of the coiled wire. Observe the reaction of the needle.

### **Results and Conclusions**

The needle/pin will rest pointing in the N-S direction. After connecting the dry cells, the needle/pin deflects because the magnetic field produced by the coil is stronger than the earth's field. The galvanometer detects whenever there is the flow of current in the wire.

### **Clean Up Procedure**

1. Pick up magnetized pin/needle, keep it in a safe place. Pour the water from the cap.
2. Return all materials to their proper places

## Discussion Questions

1. What causes the needle/pin to deflect?
2. Why does the pin face one direction when there is no current in the coil?
3. Use the Left Hand Rule to predict explain which end of the pin/needle is North and which end is South.

## Notes

The stitched magnetized pin should rest parallel to the coiled wire so that it can be easy to observe the deflection. The pin will turn until its direction is perpendicular to the turns in the coil. Also, the paper on which the pin is resting will eventually sink, so you will need to replace it.

## Force on a Current-Carrying Wire in a Magnetic Field

### Learning Objectives

- To observe the deflection of a current-carrying wire in a magnetic field
- To use the Left Hand Rule to predict the direction of deflection or force on a current-carrying wire in a magnetic field
- Students will be able to explain the relationship between motion, electric current and a magnetic field

### Background Information

Electromagnetism is the relationship between three quantities: electric current, magnetic fields and motion. When two of these quantities are present and perpendicular to each other, the third quantity is created. When electric current is running perpendicular to a magnetic field, a force is produced which pushes the wire in a third perpendicular direction to the current and field. The Left Hand Rule can be used to predict the direction of force and therefore the direction that the wire will move.

### Materials

Speaker magnet from a broken radio or speaker, thin copper wire about 20 cm long, books or other objects to use as supports, two stones, two clothes pegs, knife, connecting wire, two D-cell batteries, white paper, pen.

### **Preparation Procedure**

1. Rip off a small piece of paper the size of the magnet or smaller.
2. Use a straight-edge to draw a grid on the paper like graph paper.
3. Place the speaker magnet flat on the table so that one of the poles is facing up.
4. Stack books or other solid objects to either side of the speaker magnet to the same height of the magnet.
5. Scrape the ends (about 2 cm) of the copper wire so that the conductor is showing.
6. Stretch the copper wire across the magnet so that it is resting on top of the books on either side but not quite touching the magnet.
7. Secure the copper wire on either end with clothes pegs.
8. Place stones or other heavy object on the clothes pegs so that the wire is pulled tight and cannot move easily.
9. Attach connecting wires to each end of the copper wire.
10. Place the paper with the grid on top of the magnet just below the copper wire.

### **Activity Procedure**

1. Position yourself directly over the copper wire and magnet so that the wire's position in relation to the grid is clearly visible.
2. Connect the connecting wires to the battery terminals to start a current in the wire.
3. Observe any movement by the wire.

### **Results and Conclusions**

It can be seen that the wire is deflected to one side the current is allowed to pass through it. When the current is disconnected, the wire returns to its original position. This deflection is the result of the force on the wire which is produced by a combination of the electric current and the magnetic field. If the direction of current is switched, the direction of the wire's deflection is also switched.

## **Clean Up Procedure**

Disconnect all wires and return all materials to their proper places.

## **Discussion Questions**

1. Explain the the sources and directions of both the magnetic field and the electric current that are present.
2. In what direction is the wire deflected when the circuit is completed?
3. Use the Left Hand Rule to find the direction of the magnetic field assuming that the direction of force and the direction of electric current are known.

## **Notes**

This activity demonstrates the same concept which powers a motor, namely that an electric current running perpendicular to a magnetic field feels a perpendicular force. The deflection of the wire, while small, is observable and obviously in a direction perpendicular to both the current and magnetic field. If the direction of the field is known, students can use the LHR to predict the direction of motion. If the direction of the field is not known, students can find it by observing the direction of force and then using the LHR to find the magnetic field. It will be seen that the wire vibrates when it first deflects. This is simply because of the sudden motion to one side, not because the current is producing a wave. However, if alternating current is used, it will be seen that the repeated back-and-forth deflection of the wire does produce a standing wave. If an AC source is available, this is a good demonstration of standing waves.

## **Water Energy**

### **Learning Objectives**

- To construct a simple water wheel and generator
- To explain and show the conversion of mechanical energy to electrical energy by use of a generator coil
- Students will be able to show the direction of current produced by a generator

## Background Information

Electromagnetism is the relationship between three quantities: magnetic force, electric current and motion. When two of these quantities are present and perpendicular to each other, the third is produced. In a motor, we use electric current in a magnetic field to produce motion: the rotation of the motor coil. In a generator, we use motion in a magnetic field to produce electric current. The structure of a motor and generator are therefore almost the same. This is the mechanism behind gas generators, wind turbines, tidal generators, and many others.

## Materials

Plastic water bottle (any size), small motor from a car stereo or other device, super glue, large nail or soldering iron, heat source, 9 water bottle caps, 8 syringe needle caps, scissors, water and pitcher, connecting wires, galvanometer.

## Hazards and Safety

- Be careful when melting the plastic pieces together. Melted plastic can quickly cause second degree burns. If it is easier, you can use super glue to connect the plastic pieces together.

## Preparation Procedure

1. Making the water wheel: Using a hot nail or soldering iron, melt the open end of a syringe needle cap to the side of a water bottle cap to create a sort of spoon.
2. Repeat this step 7 more times to create a total of 8 identical pieces: these are the spokes and cups of the water wheel.
3. Cut the top off of a water bottle just below the lip which holds the cap making sure that the edges are even.
4. Melt a plastic cap over the cut end of the water bottle top so that the piece is closed on one end by the plastic bottle cap and open on the other end where a bottle cap would normally be screwed on.
5. Use the hot nail or soldering iron to melt 8 holes evenly around the side of the bottle cap used in step 4. Each hole should be just wide enough to admit the thin end of a syringe needle cap; you can insert a needle

cap each time you melt a hole in the bottle cap, removing the needle cap before the plastic cools.

6. Insert the 8 spokes from steps 1 and 2 into the holes so that they create an 8-spoke wheel with all of the cups facing in one direction (either clockwise or anticlockwise) and at equal distances from the center.
7. Melt the plastic around each spoke in the bottle cap so that they are all secure and will not come out of the center cap.
8. Making the generator: Use a pin to make a small hole in the center of a plastic water bottle cap. Glue the top of the cap to the wheel of a motor so that the center of the cap and the center of the motor wheel are perfectly aligned. Note: if you have already made the wind generator, you do not need to complete these steps.
9. Attach connecting wires to each terminal on the motor.
10. Screw the water wheel into the motor as you would screw a bottle cap onto a bottle so that the water wheel is free to rotate about the motor's axis of rotation.

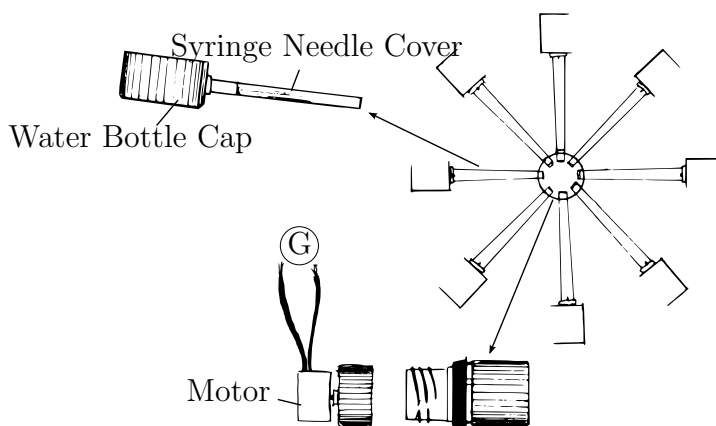


Figure 5.15: Generating Electrical Current from Falling Water

### Activity Procedure

1. Make sure that the water wheel is free to rotate on the motor.
2. Make sure that the galvanometer is working.

3. Connect the wires on the generator to the terminals on the galvanometer.
4. Pour water from a pitcher or spout and place the water wheel under the water so that it turns vertically.
5. Observe any deflection in the galvanometer.

## **Results and Conclusions**

Students will see that while the water wheel is turning, a current is created in the wire around the galvanometer. They should understand that the mechanical energy of the rotating wheel (or of the water falling) is being converted to electrical energy which can be read by the galvanometer. The conversion must be taking place in the motor, which they understand involves a magnetic field and a rotating coil.

## **Clean Up Procedure**

1. Disconnect the galvanometer and return it to its proper place.
2. Unscrew the water wheel from the generator and return both to their proper places.

## **Discussion Questions**

1. What causes the water wheel to turn?
2. What is happening inside the motor to convert mechanical energy (rotation) into electrical energy (electric current)?
3. If the water wheel is turning but the galvanometer does not deflect, what are some possible causes?

## **Notes**

We convert electrical energy to mechanical energy using a motor, and we convert mechanical energy to electrical energy using a generator. In fact they are the same thing, except that the energy being put into the system is different in each case. For a water generator, the falling water (gravitational mechanical energy) causes the water wheel to rotate (also mechanical energy). The rotating wheel causes the wire coil in the motor to rotate. A rotating coil in a magnetic field produces an electric current in the coil, which can then be detected by the galvanometer.

## Wind Energy

### Learning Objectives

- To explain the conversion of mechanical energy to electrical energy using a generator coil
- To construct a simple wind turbine and generator

### Background Information

The mechanism for the wind-powered generator is the same as that of a water-powered generator. The force of the wind on a turbine causes the turbine to rotate. This, in turn, causes a coil to rotate in a magnetic field, producing electric current. These types of generators are used all over the world to produce electricity for use.

### Materials

A 1' x 1' piece of flexible plastic sheet, pin, scissors, super glue, plastic water bottle (any size) with cap, small motor from a car stereo or other device, connecting wires, galvanometer

### Preparation Procedure

1. Making the propeller: Make 5 small holes in the plastic sheet: one in the middle and one at each corner.
2. Cut curved lines from each side near the right-hand corner inward towards the center hole (see diagram).
3. Fold each corner in towards the center so that the five holes are aligned and glue them in place.
4. Remove the cap from the water bottle and cut the top of the bottle off just below the lip where the cap sits.
5. Glue the water bottle top to the center of the back of the propeller so that the side of the bottle which holds the cap is facing backwards and the propeller is facing forwards.
6. Making the generator: Make a small hole in the center of the bottle cap with the pin.



7. Glue the top of the bottle cap to the motor wheel; use the hole to line up the center of the cap with the center of the wheel. When the motor turns, the cap should turn evenly.
8. Screw the propeller into the generator as you would close the cap on a bottle. Now the propeller should be able to turn freely on the motor.
9. Connect the terminals of the motor to the terminals of your galvanometer.

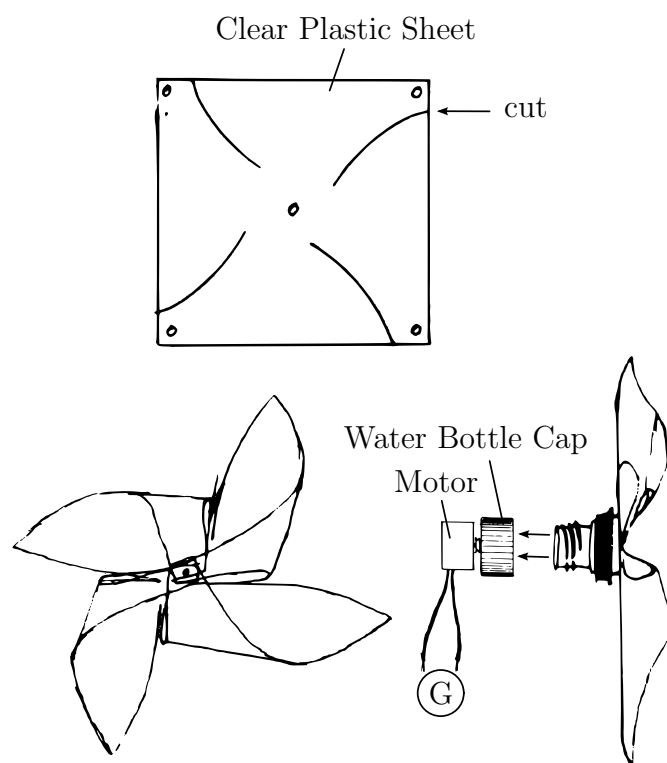


Figure 5.16: A Wind Generator

### Activity Procedure

1. Make sure that the wind generator can turn freely and that it is connected to the galvanometer.
2. Hold the propeller upright into the wind so that it spins; the galvanometer will deflect to show that a current is being created in the wire.

## **Results and Conclusions**

When the generator and galvanometer are working and connected properly, it will be seen that as the propeller turns, a current is created in the wire causing the galvanometer to deflect. If the propeller turns just a little, the galvanometer will show a small deflection; if the propeller turns quickly, the galvanometer will show a large deflection. Students will observe that mechanical energy (wind) is being converted into electrical energy (electric current) using a generator. The generator uses a magnet and motion to produce an electric current, so students will see that, as with a motor, a Magnetic Field, Electric Field and Motion are related.

## **Clean Up Procedure**

1. Disconnect the galvanometer and connecting wires and return them to their places.
2. Unscrew the propeller from the generator and return them to their places.

## **Discussion Questions**

1. Why does wind, which moves in one direction, cause the propeller to spin?
2. What type of energy is being used, and what type of energy is being created in this system?
3. What is happening in the motor to convert between the two types of energy?
4. If the propeller is turning but the galvanometer does not show the presence of a current, what are some possible causes?

## **Notes**

If you have constructed the water-powered generator, this activity will be very simple. The motor used in the other generator can be used again here; simply unscrew the water wheel and replace it with the wind turbine.

# **Astronomy**

## **Solar System Mobile**

### **Learning Objectives**

- To understand the arrangement of celestial bodies in our solar system

### **Background Information**

A solar system is the group of bodies that surround a star. In our solar system we have 8 planets as well as comets, asteroids and asteroid belts, dwarf planets, and many moons. All of these objects move in ellipses around our star, the Sun. There are too many objects in our solar system to count, but we have names for the largest of these: the planets, their moons and some of the comets and asteroids. Outward from the sun, the planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. Pluto was once a planet but has since been reclassified a dwarf planet. Each planet has a unique size, environment and history, though Earth is the only planet that we know of with life.

### **Materials**

Flour, water, balloons, mixing bowl, newspaper or old papers, string, sticks

### **Preparation Procedure**

1. Blow up nine balloons, one for each of the 8 planets and sun.
2. Make the paper mache mixture with flour and water; you want a watery glue texture.
3. Wet the paper in this mixture and apply artistically to the balloons until you have a layer a couple papers-thick on each balloon.
4. Leave each balloon slightly exposed at the bottom.
5. When the papers are dried, pop the balloons inside.
6. Use paint or marker pens to make the paper balls look like planets.
7. Attach string to each of the planets.
8. Hang the planets on sticks with the sun in the middle and each of the planets at different points moving away from the sun.

### **Activity Procedure**

1. Hang the mobile from a beam or ceiling so that the planets are suspended around the sun at different distances.
2. Identify each of the planets and discuss them.

### **Cleanup Procedure**

1. Dispose of any remaining liquid before it dries. Do not pour it down a sink because it might clog.
2. Cap any markers or paint and return all materials to their proper places.

### **Discussion Questions**

1. Name the eight planets.
2. Which planet is the largest? Is it solid or gas?
3. Which planet is the smallest? Is it solid or gas?
4. What do the first four planets have in common?
5. What do the last five planets have in common?

### **Notes**

This activity is helpful to explain to students what is actually happening outside of the world. This model reminds students that there are other objects in the solar system besides Earth. Remember that the planets are all at different distance from the sun, but they are all in the same plane. For this reason, hang the planets at about the same height.

## **Star Gazing**

### **Learning Objectives**

- To identify objects in the night sky
- To understand various structures and bodies in the galaxy and universe in relation to the earth

## **Background Information**

Astronomy is one of the oldest sciences. It has been used for thousands of years in navigation and has provided the proof or evidence for many laws and theories of nature such as gravitation and relativity.

## **Activity Procedure**

1. Take the students out at night where there is little light from lamps and fires.
2. Look for constellations, stars, planets and satellites. Discuss the reason for having constellations and the motion of the sky over the course of a night and a year.

## **Results and Conclusions**

Especially in rural areas, the stars and other celestial bodies are very clear. Depending on the time of year, different planets and constellations will be visible. The most obvious constellations are Orion, Ursa Major and the Southern Cross. The brightest star is Sirius. If the sky is clear then our galaxy, the Milky Way, is visible as a bright stripe across the sky.

## **Discussion Questions**

1. What objects did you observe in the night sky?
2. What are the brightest objects?
3. Is it easier to see the stars when the moon is present, or when it is absent?
4. What constellation could you use to know which direction is North?

## **Notes**

Before going outside at night, check a star chart and planet charts to find out which objects should be visible that night. This will make it easier to identify objects and help students to see them. If you have binoculars, they can be used to see planets easily or to see the difference between a single star system and a binary star system, or between a star and a distant galaxy. If possible, tell students the stories behind the constellations and see if they can make their own constellations.