Shika Express - Physics
Version 1.0 TZ

Hands-On Activities Companion Guide

Tanzania

Teacher's Guide

April 2, 2014

Contents

Part I

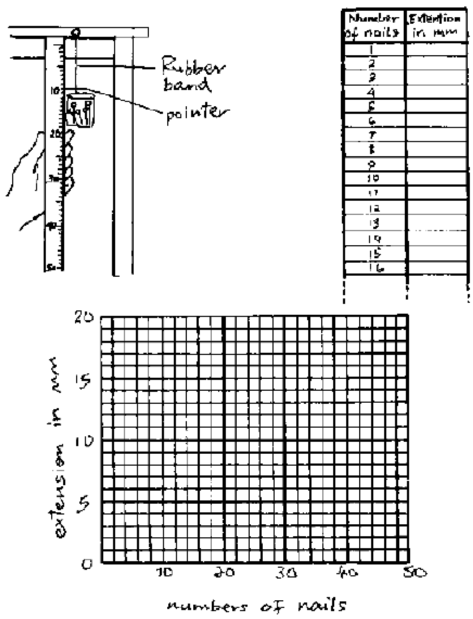
Hands-On Activities

Physics Activities for Form I

1.1 Measurement and Density/Relative Density

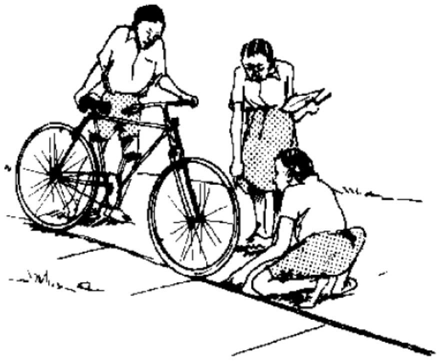
Collection of Data

1.1.1 Data on Weighing



Fix a rubber band at one end to a table or retort stand. At the other end, attach a paper clip to act as a pointer and a small bag or scale pan. Fill the bag or scale pan with successive numbers of nails. Have students measure the extension of the rubber band each time they add more nails. Record the readings and use the data to draw a graph as shown in the figure.

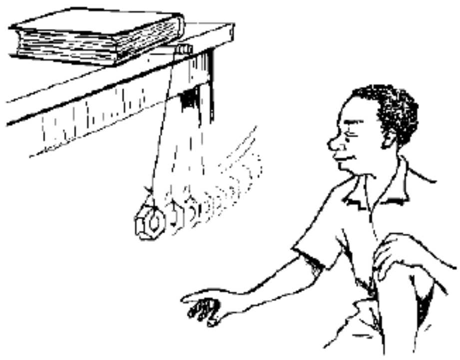
1.1.2 Data on Distance



TURNS	DISTANCE

Make a mark on the tyre of a bicycle at the point where it touches the ground. Turn the tyre by moving the bicycle forward and record the length of one turn. Repeat the experiment several times for various numbers of turns, each time recording the horizontal distance covered. Draw a graph to show the data.

1.1.3 Data on Time



LENGTH OF PENDULUM	SWINGS 5 CM	10 CM	15 CM
50 cm			
75 cm			
100 cm			

Fix a string just off the edge of a table and hang a small weight (e.g. a nut or nail) at a distance of

50 cm. This is a simple pendulum. Pull the pendulum to one side so that its horizontal displacement is 5 cm. Count the number of oscillations (back and forth) made in one minute. Repeat by increasing the horizontal displacement to 10 cm and 15 cm. Then try varying the length of the string. How long must the pendulum be to oscillate 60 times in one minute?

Measuring Instruments

1.1.4 Construction of a Metre Rule

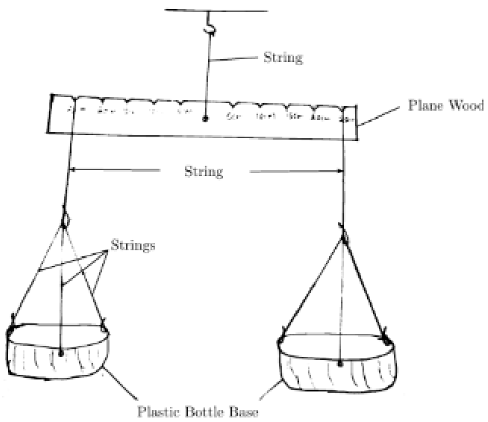
Materials: Wooden board, pen/pencil, a handsaw, ruler or tape measure

Procedure: Use the handsaw to cut a piece of wood 100 cm × 3.5 cm × 0.5 cm. Use a ruler or tape measure to mark a scale in cm on the wood.

Applications: Students can record data on their height, dimensions of the classroom, etc.

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

1.1.5 Construction of a Beam Balance



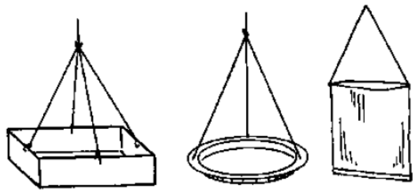
Materials: Ruler or wooden bar 30 cm × 2 cm, nails, heat source*, razor/knife, string/wire, pen, 2 Scale Pans

Procedure: Find the balancing point of the ruler/wood block and mark it with a pen. Use a heated nail to make a hole through this point. Make notches at 5 cm intervals on either side of the center hole using a razor/knife to suspend scale pans. Use a string/wire tied through the center hole to suspend the balance.

Applications: Principle of Moments

Notes: Use locally available to find the mass of everyday objects, e.g. notebooks, pens, rulers.

1.1.6 Scale Pans



Materials: Match boxes, large plastic bottles, tin can lids, small plastic bags, knife, string

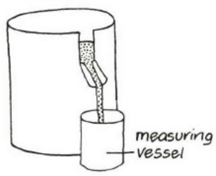
Procedure: Use a knife to poke 3 - 4 holes in the sides of one of the above materials. If using plastic bottles, cut them about 3 - 4 cm from the bottom. Cut equal lengths of string and tie them through the holes in the scale pan. Join the strings together at the upper end.

1.1.7 Construction of a Measuring Cylinder

Materials: Plastic bottles of different sizes, syringes (10 mL - 50 mL), marker pen, ruler, bucket of water

Procedure: Using the syringe, transfer a known volume of water from the bucket to the empty bottle. Use the marker pen to mark the level of water on the bottle. Repeat for a range of volumes, using a ruler to complete the scale.

1.1.8 Construction of a Eureka Can



Materials: Plastic bottle, knife

Procedure: Cut a plastic bottle about 10 cm from the bottom. Cut 2 slits at the top of the bottle and bend the strip forward to form a spout.

Applications: Measuring the volume of irregular objects, Archimedes' Principle

Notes: Alternatively, use a bottle or tin can and poke a hole near the top using a heated nail. Attach a straw/hollow pen tube/tube of aluminum foil, using super glue to ensure an airtight seal.

1.1.9 Errors in Measurement

Materials: Metre rules, stopwatches

Procedure: (a) Draw a line on the board or floor. Have several students measure the length and secretly record their results. Collect the results and record them on the board, noting any differences.

(b) Distribute stopwatches to several students. Clap twice and have students measure the time betweeen claps and secretly record their results. Collect the results and record them on the board, observing any differences.

Questions: What is the best result to use for each of the collected measurements?

Theory: Measurements vary from person to person. Every measurement comes with some level of error, and so it is important to take care when measuring to increase accuracy. The best result to use is the average of all the measurements.

Density/Relative Density

Density can be found by taking the ratio of a body's mass to its volume. Common units of density are g/mL and kg/L.

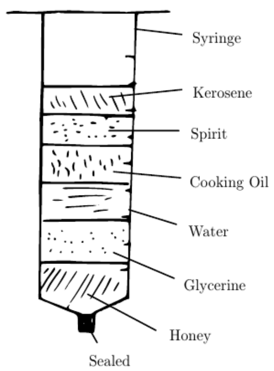
$$\text{Density} = \text{mass} \div \text{Volume}$$

$$\rho = \frac{m}{V}$$

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/cm^3 (or 1 000 kg/m^3), so all other densities are compared to water. Because relative density is a ratio of two densities, it has no units.

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

1.1.10 Density Column



Materials: Syringes, water, honey, glycerine, cooking oil, spirit, kerosene, erasers, paper clips, nails, other small objects

Procedure: Add each liquid into the syringe, one by one, observing the relative depths of each liquid. Place small solid objects e.g. rubber erasers, paper clips, small nails, etc. into the syringe and observe their positions relative to the various liquids.

Questions: Which liquid is the most dense? Which is the least dense?

Observations: The denser liquids sink to the bottom while the less dense liquids rise to the top. The solid objects settle among liquids of comparable density.

Theory:

Applications: Relative densities of liquids and solids help to identify certain substances, e.g. whether a ring is really made of gold.

Notes: Food coloring can be added to colorless liquids such as water, kerosene and glycerine to help distinguish among them.

1.1.11 U-Tube Apparatus

Materials: 3 clear plastic pen tubes, cardboard, heated nail or knife, tape, pen, super glue, water, kerosene.

Setup: Cut two of the tubes at one end to make a 45° angle, and cut the third tube (shorter than the other two) to make a 45° angle at both ends. Attach the two longer tubes to either side of the short one so that they make right angles and form a U-shape. Melt the angled ends together with a hot knife, soldering iron, etc. so that the apparatus is watertight. Glue the assembly to a cardboard base so that it stands upright.

Place thin strips of tape along each side of the U-tube and mark with identical scales. Do this by adding known volumes of water and marking the levels on each scale. Label these marks from top to bottom as 0, 1, 2, etc.

Procedure: Place an amount of water into the U-tube such that the water rises about half way on either side of the tube. The actual volume of water is not important as long as you can see the levels clearly. Stand the tube upright and slowly drip about 1 mL of kerosene into one side of the U-tube. Measure the relative heights of water and the kerosene from the bottom level of the kerosene.

Observations: The kerosene will displace the water, so you should see the water level on the other side rise slightly.

Theory: If a fluids density is less than that of water, it will float on top, displacing the water on the other side of the tube. From Archimedes principle and the Law of Flotation, we know that

$$\frac{\text{height of water}}{\text{height of kerosene}} = \frac{\text{density of kerosene}}{\text{density of water}}$$

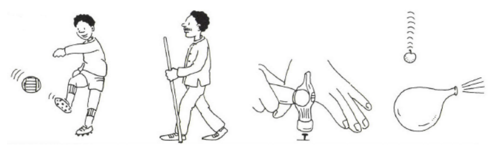
. The scales drawn on the outside of the U-tube allow us to find the ratio of the heights without needing units, and the density of water is known to be 1.0 g/mL, so the density of the other fluid can be calculated.

Notes: If the other fluid has a higher density than water, the experiment can still be done, but the fluid with higher density must be added first, then displaced with water, performing the same calculation.

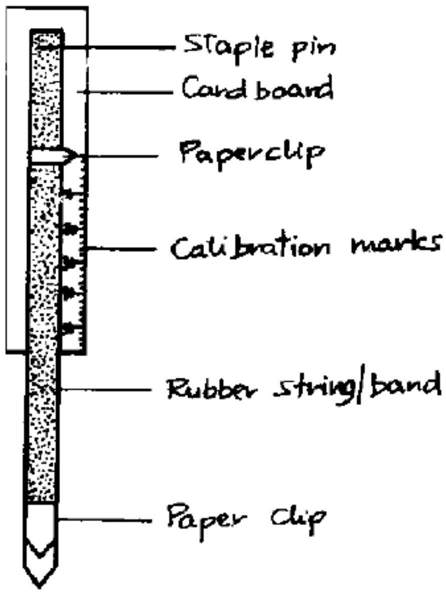
1.2 Force

Concept of Force

1.2.1 Examples of Forces



1.2.2 Making a Spring Balance



Materials: Cardboard, strong rubber band, staple pin, 2 paper clips, *

Setup: Take a strip of cardboard or wood and fix a strong rubber band to it using a staple pin. (The stronger the rubber band, the larger the force you can measure.) Attach one paper clip as a pointer as shown in the figure. Then fix another as a hook at the bottom end of the rubber band.

Procedure: Calibrate the balance in *Newtons* using either a standard set of or another spring balance. A mass of 10 g has a weight of 0.1 N; a mass of 100 g has a weight of 1 N, etc. Draw marks accordingly on the scale of the balance.

Hazards: Never apply such a large force that the pointer does not return to the zero mark when the force ceases.

Applications: Use the spring balance to measure the weight of small objects or the force of pulling an object along a table.

Effects of Forces

Forces can have a variety of effects on objects, including *stretching*, *compression* (or *restoring*), *attraction*, *repulsion*, *torsion*, *friction*, *viscosity* and *air resistance*. These effects are seen all around us in our daily lives.

1.2.3 Observing Effects of Forces

Materials: Rubber bands, springs, magnets, ruler, honey, water, paper

Procedure: Have students investigate different effects of forces using common materials.

Observations: Rubber bands and springs stretch when pulled and then restore their shape. Magnets attract and repel each other. A ruler can be twisted under torsion. Rubbing hands together produces heat from friction. Honey pours more slowly than water due to a higher viscosity. A sheet of paper falls to the ground slowly because of air resistance.

Applications: Brainstorm various applications of the effects of forces with the class.

1.2.4 Presence of Gravity

Materials: Pen, ruler, sheet of paper, book (same size as paper)

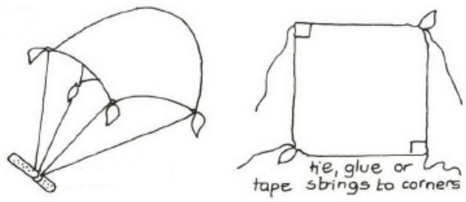
Procedure: Drop the pen and ruler side by side from shoulder height. Repeat with a pen and sheet of paper. Then place the paper on top of a book and drop side by side with a regular sheet of paper. Bunch the paper into a tight ball and drop it again with the book.

Questions: Which objects fell at the same rate? Which ones fell more slowly?

Observations: All objects, with the exception of paper and other light, wide objects, fall at exactly the same rate.

Theory: Gravity pulls on all objects on earth the same. The paper falls slowly 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 with a large surface area. Placing a book under the paper reduces air resistance by blocking all of the air which would normally push against the paper. Thus they 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.

1.2.5 Parachutes



Materials: Paper/newspaper/plastic bags, string, paper clips

Setup: Tie pieces of string (about 30 cm) to each corner of the paper/bag. Join the four strings together and attach a paper clip or other small weight.

Procedure: Drop the parachute side by side with a normal paper clip.

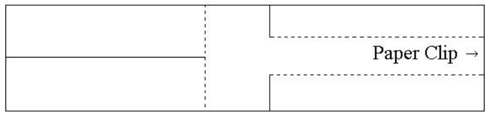
Questions: Which one reaches the ground first? If the paper clip were a person, which one would arrive safely to the ground? Does a person using a parachute want to make it as large as possible or as small as possible?

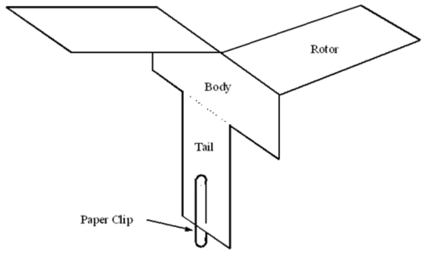
Observations: The parachute falls more slowly because there is a larger space for air to enter and counteract the force of gravity pulling it to the ground.

Applications: Skydivers, military personnel, air-dropped aid packages

Notes: Poke a small hole in the top of the parachute and ask students what will happen.

1.2.6 Helicopters





Materials: Paper, scissors, paper clip

Procedure: Copy the following design onto a piece of paper. Cut along the solid lines and fold along the dotted lines, attaching the paper clip to the bottom. Drop the helicopter with the paperclip down and watch it spin!

Questions: Does the helicopter spin more if you add more paper clips? If you change the size/number of wings?

Observations: Adding more paper clips causes the helicopter to spin faster. Increasing the surface area of the wings also increases the rate of spin.

Theory: The helicopter spins because the force of air resistance pushing up on the wings creates a moment about the vertical axis of rotation. Increasing the force of air resistance thus increases this moment and hence the helicopter spins faster.

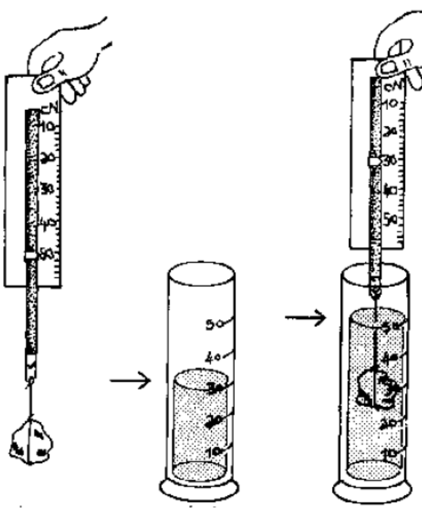
1.3 Archimedes' Principle and the Law of Flotation

Concept of Upthrust

Archimedes' Principle states that any object partially or totally immersed in a fluid experiences an upthrust equal to the weight of the fluid displaced by the body.

$$\text{Upthrust} = \text{Weight of displaced fluid}$$

1.3.1 Verifying Archimedes' Principle



Materials: *, stone, string, *, water, **??***, syringe

Procedure: Tie a string around a stone and measure its weight in Newtons using a spring balance. Fill the measuring cylinder partially with water and record the reading. Immerse the stone fully into the water (without touching the bottom) and record the reading on the spring balance, as well as the new water level of the measuring cylinder.

Questions: What is the change in weight of the stone as read from the spring balance? What is the weight of the displaced water (1 mL = 0.01 N)?

Theory: The change in weight of the stone is known as its *Apparent Loss in Weight*, which is equal to the *Upthrust* exerted on the stone by the water. Archimedes' Principle tells us that this is equal to the weight of the water displaced by the stone.

Notes: A Eureka can and syringe may be used to measure the displaced fluid in place of a measuring cylinder.

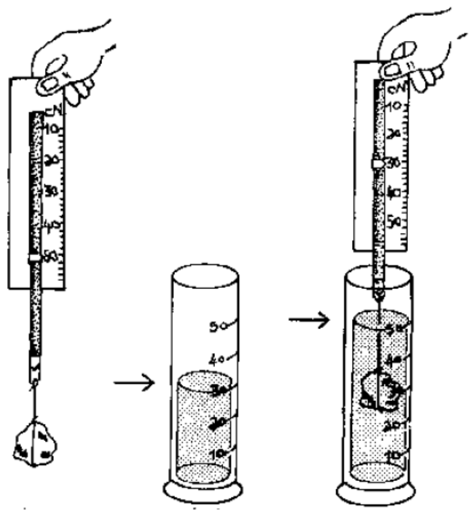
Sinking and Floating

If the density of an object is less than that of the surrounding fluid, the object will float. If the density is greater than that of the fluid, it will sink.

The Law of Flotation states that a floating body displaces its own weight of the fluid in which it floats.

$$\text{Weight of body} = \text{Weight of displaced fluid}$$

1.3.2 Verifying the Law of Flotation



Materials: *, matchbox, stone, string, *, */syringe

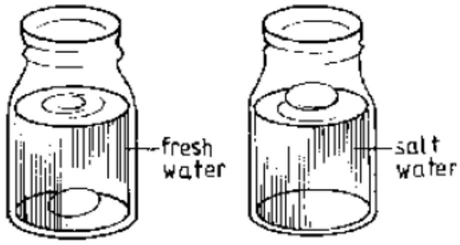
Procedure: Load a matchbox with a small stone so that it still floats in water. Record the weight of the matchbox and stone in Newtons using a spring balance. Fill the Eureka can with water and allow the matchbox to float on it. Collect the overflow in a measuring cylinder or syringe. Calculate the weight of the overflow (1 mL = 0.01 N).

Questions: How does the weight of the matchbox and stone compare to that of the displaced water?

Observations: The values should be equal, thus verifying the Law of Flotation.

Applications: Submarine, hot air balloon, ships. Design and selection of materials for these vessels are done using the Law of Flotation.

1.3.3 Egg Float



Materials: 2 fresh eggs, 2 containers (bottles cut in half), salt (less than half a cup)

Setup: Fill the two containers with water and place a fresh egg in each.

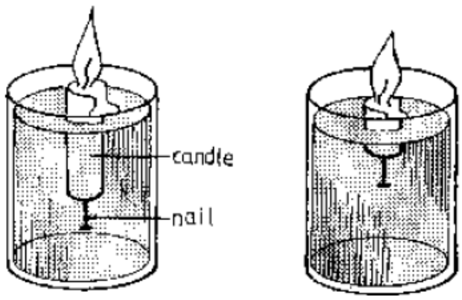
Procedure: Leave one as it is and add salt to the other. Add and mix salt until the egg floats in the saltwater container.

Questions: Why does the egg float in saltwater but sink in fresh water?

Theory: Saltwater has a greater density than fresh water. A fresh egg has a density between fresh water and saltwater. Since an egg is denser than freshwater, it sinks. Since an egg is less dense than saltwater, it floats.

Applications: This is the same reason why it is easier to stay afloat when swimming in the ocean (saltwater) as opposed to a lake (fresh water).

1.3.4 Floating Candle



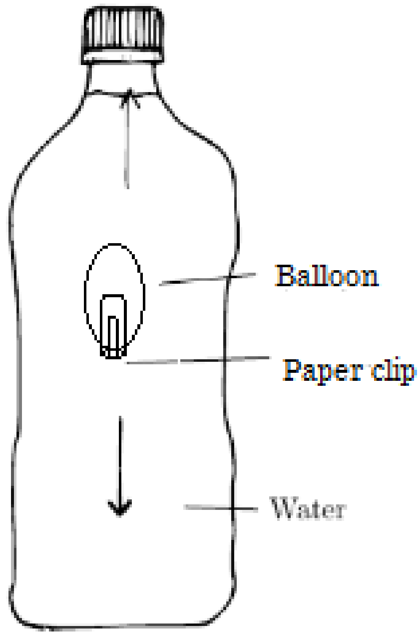
Materials: Candle, nail, container, water

Procedure: Put a nail into the bottom end of a candle so that the candle just floats with its top a bit above the surface of the water. Light the candle and watch as it burns up.

Questions: Why does the candle continue to float even though it loses weight as it burns up?

Theory: The candle continues to float because its density remains less than that of the surrounding water.

1.3.5 Cartesian Diver



Materials: 1.5 L plastic bottle, balloon, paper clips (large), water

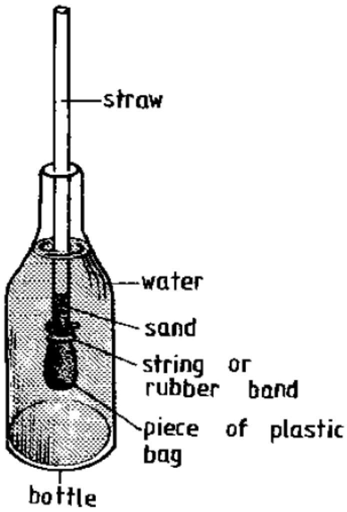
Setup: Fill the bottle with water. Fix a large paper clip to the lip of a balloon. Making sure to keep all air out of the balloon, insert it into the bottle. It should just float at the top while remaining completely submerged. Adjust depending on type of balloon and paper clips.

Procedure: Screw the cap on the bottle and squeeze the middle of the bottle, then release.

Observations: The balloon should begin to sink when you squeeze, but float again when you release.

Theory: While water is nearly incompressible, the balloon (and any small amount of air inside) is compressible. This means when you squeeze the bottle, the water remains unchanged, but the balloon is compressed, decreasing its volume and so increasing its density. Before squeezing, it was less dense than the water and so it floated. After squeezing, it becomes denser than the water and sinks.

1.3.6 The Hydrometer



Materials: Bottle, straw, plastic bag, dry sand, rubber band/string, pen, ruler, water, kerosene, other liquids

Setup: Close one end of the straw with the plastic bag and secure it with the rubber band so that water cannot enter. Pour sand into the straw until it floats upright in the bottle of water without touching the bottom or leaning.

Procedure: Use a pen to mark the water level on the outside of the straw. Label it 1.0 (the density of water in g/cm^3). Place the straw upright in a container of kerosene. Mark the kerosene level on the straw as 0.8 (known density of kerosene). Remove and clean the straw, without getting any liquid inside. Use a ruler to complete the scale above 1.0 and below 0.8, beginning with 0.9 at the midpoint. Use the hydrometer to measure the densities of other liquids.

Questions: Why do smaller numbers appear at the top of the hydrometer scale?

Theory: Liquids with a lower density allow the hydrometer to sink deeper, and thus the liquid reaches a higher point on the scale.

1.4 Structure and Properties of Matter

States of Matter

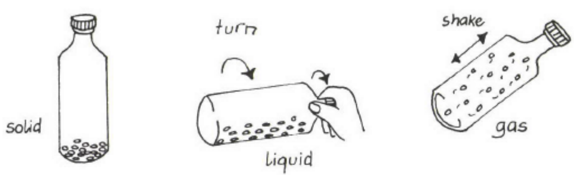
All matter is made up of particles. These particles are in constant motion which increases with their temperature. Depending on temperature, matter may exist in three states: *solid*, *liquid* or *gas*.

1.4.1 Student Particles

Procedure: Use students to demonstrate the concept of states of matter.

Theory: When students or objects are close together, they represent particles in the *solid* state. As they move apart and past each other they represent particles in the *liquid* state. Fast and randomly moving pupils or objects represent particles in the *gaseous* state.

1.4.2 A Model of Motion

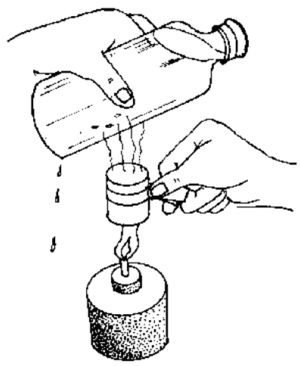


Procedure: Put some dry beans, rice or stones in a clear bottle. Hold the bottle still, then turn it, then shake it vigorously.

Questions: Which activity corresponds to which state of matter?

Theory: The movement of particles in solids is small and hence they are in fixed order. In liquids the particles move past each other and have lost the stiff order. In gases they move very fast and randomly, losing all order.

1.4.3 Changes of State



Materials: Tin can, glass bottle, water, *

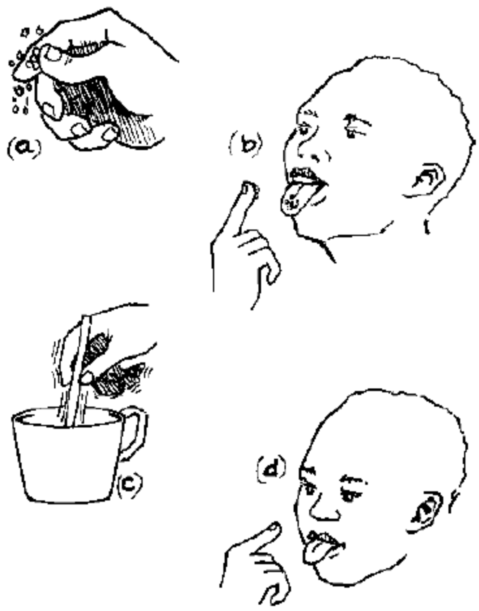
Procedure: Pour a small amount of water into a tin can and heat it until it boils. Fill a bottle with cool water and hold it above the tin can.

Observations: Water drops form on the outside of the cool bottle when it is touched by the steam of the boiling water.

Theory: Water particles escape from the boiling water as vapour and condense on the lower surface of the bottle to form water droplets. This is indirect evidence that water is made up of small particles.

Particulate Nature of Matter

1.4.4 Salt is Made of Particles



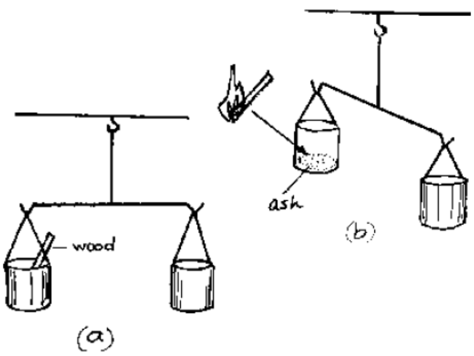
Materials: Salt/sugar, cup, water

Procedure: Roll some salt or sugar crystals between your fingers to feel their hardness. Taste the crystals. Take a sip of the water. Now put the salt or sugar crystals in the water and shake it. Taste again.

Observations: The crystals are hard and of cubical shape. They dissolve in water and the solution tastes like salt or sugar.

Theory: Sugar and salt are made up of tiny particles that can be identified by tasting even though they can not be seen as a solution.

1.4.5 Weighing Particles



Materials: Construction of a Beam Balance*, small pieces of wood,

Procedure: Weight pieces of wood and record the weight. Then burn the wood and weigh the ash.

Questions: Is there a difference between the two weights?

Theory: The weight of the ash is less than that of wood. The loss in weight is due to particles which escaped as soot and gas.

Applications: This is why garbage reduces in size when burned. Burning wood and garbage releases carbon dioxide and other harmful gases into our environment. This is one form of *pollution.*

Elasticity

1.4.6 Hooke's Law

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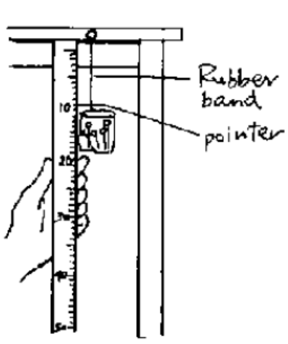


Number of nails	Extension in mm
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	

Materials: Rubber band/elastic strip, ruler, staple pin, *, Scale Pans*, nails/small *

Setup: Fix a rubber band at one end to a table or retort stand. At the other end, attach a paper clip to act as a pointer and a small bag or scale pan.

Procedure: Fill the scale pan with successive numbers of nails or known weights. Have students measure the extension of the rubber band each time they add more weights. Record the readings and use the data to draw a graph of force (weight) against extension.

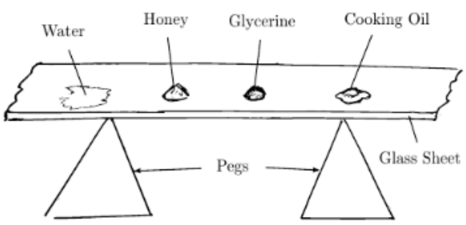
Questions: What is the relationship between number of weights added and extension of the rubber band? What does the slope of the graph represent?

Theory: Hooke's Law states that the force applied to an elastic object is directly proportional to its extension ($F = kx$). Graphing the applied *weight* (in Newtons) against the extension (in metres), the slope represents the spring constant of the elastic material in N/m.

Adhesion and Cohesion

Forces between particles of the same material are called *cohesive forces* while those between particles of different materials are called *adhesive forces.*

1.4.7 Exploring Adhesion and Cohesion



Materials: Sheet of glass, water, honey, glycerin, cooking oil, syringe, and 2 wooden blocks

Procedure: Place a sheet of glass over two wooden blocks on a table. Using a syringe, place a drop of different liquids on the glass.

Observations: Water spreads and wets the glass, while honey, glycerin and cooking oil remain in a spherical shape.

Theory: The adhesive forces between the water molecules and glass molecules are greater, while the cohesive forces between the molecules of honey, glycerin and cooking oil are larger.

1.4.8 Pinching Water

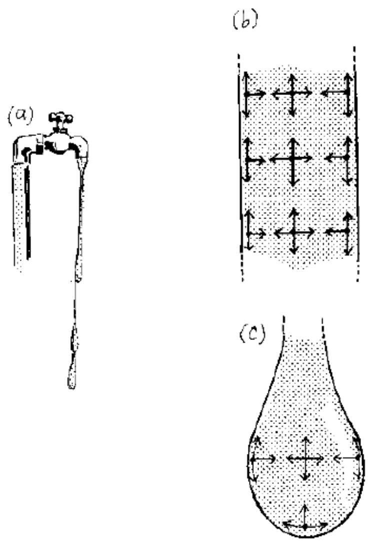
Materials: 500 mL water bottle, needle/pin/small nail

Setup: Make 5 small holes at the bottom of the bottle with a syringe needle or nail. Make them close together (about 5 mm apart).

Procedure: Fill the bottle with water and allow it to flow through the holes at the bottom. Use your thumb and forefinger to pinch the streams together to form a single stream. Pass your hand in front of the holes and all five will appear again.

Theory: 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.

1.4.9 Water Drops



Materials: Syringe or water dropper

Procedure: Slowly drip water from the syringe or water dropper. Observe how the drop forms.

Observations: The water stream grows thinner and thinner as it moves further down and finally breaks to form drops.

Theory: Strong cohesive forces hold the water molecules together, until they are overcome by gravity and the water breaks off as drops.

Surface Tension

1.4.10 Pin Float

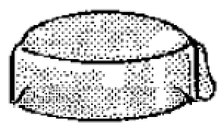
Materials: Cup or small dish, straight pin/razor/paper clip, water, detergent

Procedure: Fill the cup with clean water and carefully float a pin, razor or small paper clip. Now add a small amount of detergent to the water and observe what happens.

Observations: The objects float on the surface of the water initially, but after adding detergent, they sink to the bottom.

Theory: The surface tension of the water acts as an elastic membrane and is strong enough to support the small objects. Soap lowers the surface tension of water and therefore the objects sink.

1.4.11 Water Dome



Materials: Coin, water, syringe or eyedropper

Procedure: Place the coin flat on a table. Use the syringe or eyedropper to carefully drop individual water drops onto the coin.

Questions: How many drops do you think the coin can hold?

Observations: The coin holds a surprising number of drops and forms a dome shape before the water spills over.

Theory: The surface tension of the water holds it together against the force of gravity, which is trying to pull the water off the coin.

1.4.12 Blowing Bubbles

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

Setup: Bend the wire to form a loop of 2 to 3 cm in diameter, circling this loop many times. Leave a straight piece several cm long as a handle. Make a concentrated solution of detergent in water with a small amount of glycerin.

Procedure: Dip the circular part of the wire into the detergent. You should see a thin soapy film across the circle upon removal. Gently blow through the circle until a bubble separates from the wire.

Observations: While blowing, the solution is being pulled back towards the surface. Once it breaks free as a bubble, it forms a spherical shape.

Theory: The surface tension of water causes the bubble to form the shape with the minimum surface area, which is a sphere.

Capillarity

1.4.13 Capillary Rise

Materials: Clear thin plastic straws with different diameters, shallow container (bottom of a water bottle/jar cap), various liquids, e.g. water, spirit and cooking oil

Procedure: Place one end of a straw into a container of water 1 cm deep so that the end is submerged but not touching the bottom. Mark the change in water level in the straw after about a minute. Repeat for different liquids and different size straws.

Questions: Which liquid rises the farthest up the straw? Do liquids rise faster in wide or thin straws?

Observations: The spirit rises to the greatest height while water rises the least. Liquids rise faster in thin straws compared to thick ones.

Theory: Capillary rise results from adhesion, allowing the liquid to climb along the surface of the tube, as well as cohesion, which pulls the remainder of the 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.

1.4.14 Moving Matches

Materials: Matches, water, straw, plastic lid

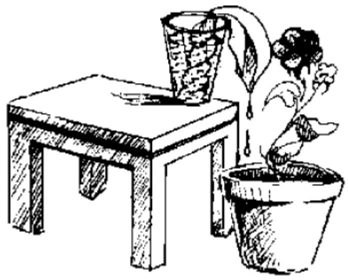
Procedure: Break several matches near the middle, but not so that they come apart. They should make acute angles. Place them on the plastic lid and place a few drops of water on the broken joints of the matches using the straw.

Observations: The matches close and return to their original straight shape.

Theory: Water gets absorbed in the wooden matchstick and causes it to expand.

Applications: This is why it is difficult to open a wooden door after it rains. The water rises up the wood causing it to expand into its frame.

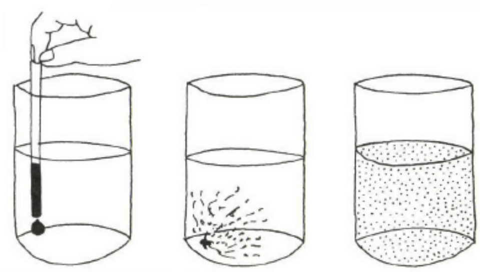
1.4.15 Automatic Irrigation



Capillary action can be used to provide automatic irrigation for plants. Students can perform irrigation by dipping a porous material such as paper or cotton cloth in water.

Diffusion

1.4.16 Diffusion in Liquids



Materials: Plastic water bottle, food colour (liquid or powder)

Procedure: Put a drop or small amount of powdered food colour into the water without shaking and observe what happens.

Observations: The colour gradually spreads throughout the water.

Theory: This spreading is due to the motion of the particles of food colour. This process is called *diffusion*.

Applications: Organisms utilize diffusion to balance nutrient concentrations in cells and to transfer oxygen into the bloodstream during respiration.

1.4.17 Smelling Particles

Materials: Orange or other citrus fruit, box

Procedure: Peel and orange and have students raise their hands when they begin to smell it. Now place a box in front of the orange and repeat the test.

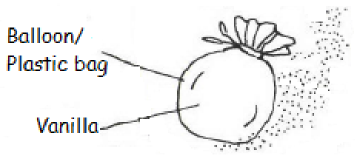
Observations: Students in the front center of the room should be the first to raise their hands, followed by those near the sides and in the back. When the orange is peeled behind the box it takes longer for the smell to reach the students.

Theory: Tiny particles from the orange peel spread by diffusion to students' noses. The box hinders the motion of the particles and so they reach the students more slowly.

Applications: Air fresheners and other sprays

Osmosis

1.4.18 Vanilla Balloon



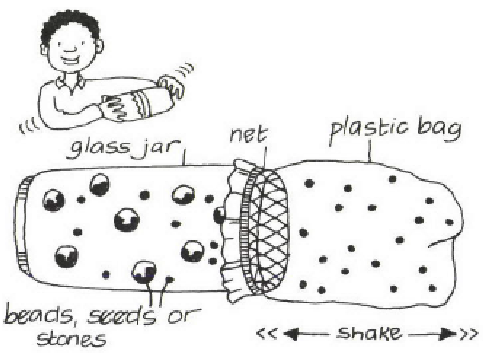
Materials: Balloon/plastic bag, vanilla, straw/syringe

Procedure: Place a few drops of vanilla in a deflated balloon. Now blow up the balloon and tie it shut.

Observations: You can smell the vanilla through the surface of the balloon.

Theory: The balloon acts as a *semi-permeable membrane* which allows some of the vanilla particles to pass through and reach your nose. Other particles remain inside the balloon.

1.4.19 Semi-Permeable Membranes



Materials: Glass jar, clear plastic bag, small beads or stones, beans, netting, string/rubber band

Setup: Place the mixture of beads and beans in the jar. Place the net and plastic bag over the top and tie them on securely.

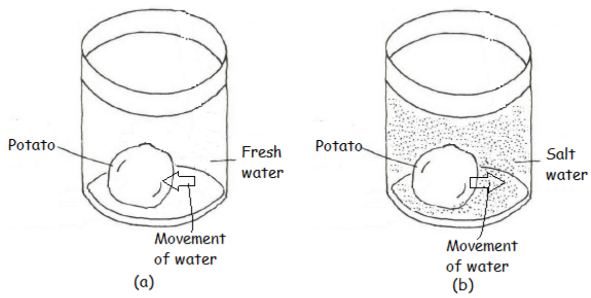
Procedure: Shake the apparatus for a few seconds.

Observations: Only the small beads pass through the netting. The beans remain in the jar.

Theory: The beads represent small molecules and the net is a semi-permeable membrane. The beans are too large to pass through and hence remain in the jar.

Applications: Water filters, organism cell membranes

1.4.20 Potato Osmosis



Materials: Potato, 2 water bottles, salt, water

Setup: Cut two equal size pieces of potato. Fill one bottle with fresh water and the other with a salt water solution.

Procedure: Put one piece of potato in each bottle. Observe over the next few hours.

Observations: The potato in fresh water swells while the potato in salt water shrivels up.

Theory: Through osmosis, water moves from a region of low concentration to one of high concentration through a semi-permeable membrane (the potato). In fresh water, the potato has the higher salt concentration, so water enters in order to make a balance. In salt water, the concentration of the surrounding water is higher than that of the potato, so water inside the potato moves outside to dilute the salt solution.

Notes: Try this experiment again with a boiled potato. Do you observe any differences?

1.5 Pressure

Concept of Pressure

Pressure is the force acting normally per unit surface area.

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

1.5.1 Balloon Pop

Materials: 2 piece of wood, nails, balloons, water

Setup: Put a single nail through one piece of wood and for the other, put many nails closely spaced. Blow up 2 balloons or fill them with water.

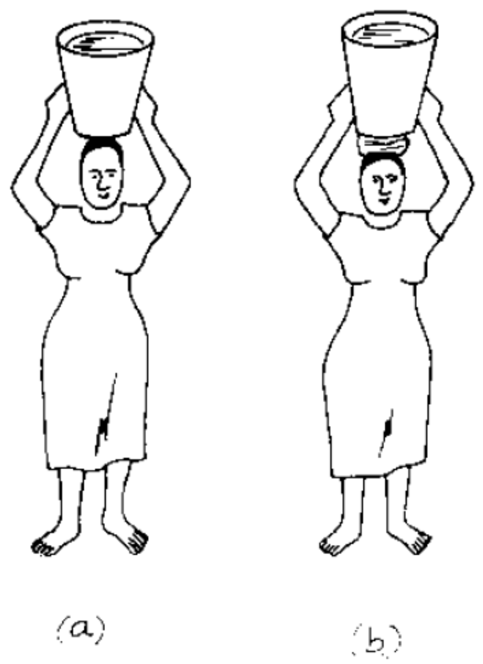
Procedure: Slowly press one balloon against the single nail until it pops. Then repeat for the cluster of nails.

Observations: The balloon pops easily on the single nail, though it may not pop at all on the cluster of nails.

Theory: Using many nails increases the area over which the force of the nails act, thus decreasing the pressure and requiring a greater force to make the balloon pop.

Notes: You can also hang the balloon from a spring balance as you lower it onto the nails. The difference in weight gives the force needed to pop the balloon.

1.5.2 Carrying a Load on the Head



Procedure: Carry a bucket on your head without (a) and with (b) a cloth or khanga.

Questions: Which is more difficult?

Theory: Using the cloth causes the force of the bucket to be more evenly distributed across a larger area. Hence the force felt at any single point is reduced.

1.5.3 Potato Poke

Materials: Straw, potato

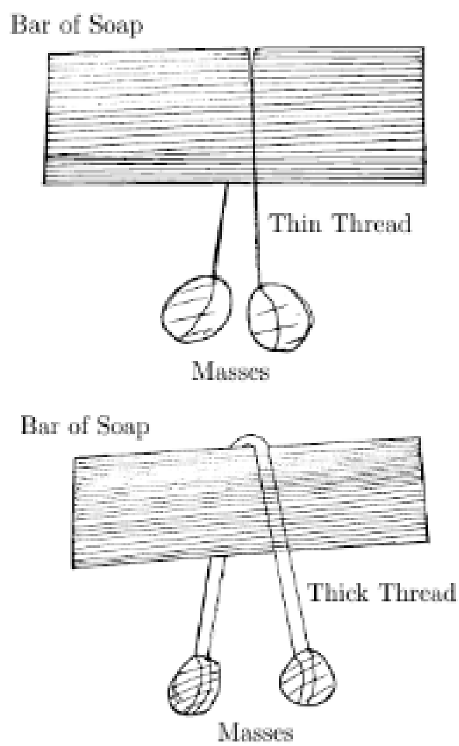
Procedure: Try to stab a straw into the potato. Now place your thumb firmly over one end of the straw and try again.

Observations: The straw bends easily and does not harm the potato the first time. When you cover one end of the straw, it enters the potato easily and may even break through the other side.

Theory: Holding your thumb over the straw traps air inside which increases the pressure in the straw. When it strikes the potato, the increased pressure prevents it from bending and so it is able to poke through the potato.

Pressure in Solids

1.5.4 Effect of Surface Area on Pressure



Materials: Bar of soap, thin thread, thick string, 4 heavy stones of approximately equal weight

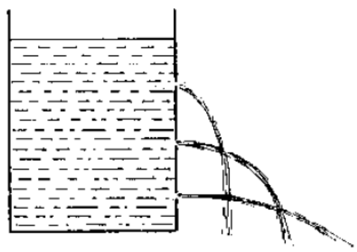
Procedure: Tie a heavy stone to either end of both the thin thread and thick string. Hang each thread across the bar of soap so that the weights hang freely.

Observations: The thin thread easily cuts through the soap, but the thick string does not.

Theory: The smaller area of the thin thread, acting with the same force, results in an increased pressure which is enough to cut through the soap.

Pressure in Liquids

1.5.5 Pressure Increases with Depth



Materials: 1.5 L bottle, syringe needle or pin/nail, water

Setup: Poke three holes into a bottle. Put one hole near the bottom, one near the middle, and the last hole between them.

Procedure: Fill the bottle with water and place on a table. Observe the trajectories of water coming from the three holes.

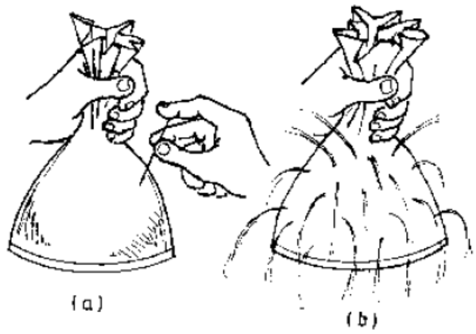
Questions: Which stream goes the farthest distance horizontally? Which hole has the highest pressure?

Observations: The water flowing from the lower holes travels farther.

Theory: The added weight of the water above the lower holes increases the pressure there, resulting in an increased horizontal velocity. It is shown that pressure increases with depth ($P = \rho g h$).

Applications: he wall of a dam is made much thicker at the bottom than at the top. This is to reinforce against the increased water pressure at greater depths.

1.5.6 Pressure Acts in All Directions



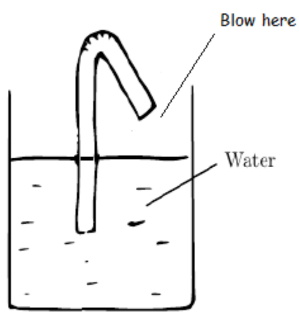
Materials: Water bottle/balloon/plastic bag, pin/needle, water

Procedure: Fill a bottle, balloon or plastic bag with water. Poke several small holes around the surface.

Observations: Water is expelled equally through all of the holes.

Theory: Pressure in a liquid acts equally in all directions.

1.5.7 Straw Fountain



Materials: 500 mL water bottle with cap, water, straw, glue, hot nail/pin

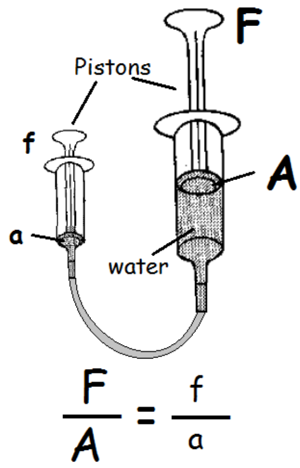
Setup: Poke a hole the size of the straw in the bottle cap using a heated nail or pin. Stick the straw through the hole and screw on the cap so that the straw reaches near the bottom. Glue around the straw so that it is air tight.

Procedure: Fill the bottle about half way with water and close the cap with the straw inside. Have a student blow as hard as they can through the straw into the water and then stop.

Observations: When the student stops blowing, they get sprayed in the face by water.

Theory: Blowing into the bottle greatly increases the pressure inside. When you stop blowing, the pressure equalizes by forcing water back out through the straw.

1.5.8 Hydraulic Press



Materials: 2 syringes of different size (5 mL and 20 mL), *, water

Setup: Fill the larger syringe with water and attach one end of the rubber tubing to its end. Attach the other end of the tubing to the smaller syringe (with its plunger inserted all the way).

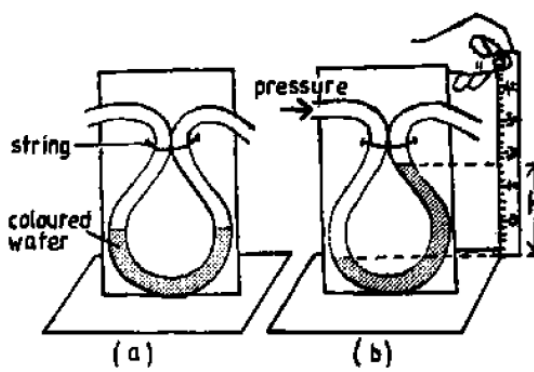
Procedure: Pushing the plunger of the larger syringe will cause the plunger of the smaller syringe to go out, and vice-versa.

Observations: It is easier to push the plunger of the small syringe than that of the larger syringe.

Theory: Pascal's principle states that pressure is distributed equally throughout a liquid. Thus, the pressure at one plunger must be equal to the pressure at the other plunger. Setting the two ratios equal, we can see that a small force over a small area can overcome a large force over a large area.

Applications: Industrial machinery, hydraulic breaks

1.5.9 The Manometer



Materials: *, ruler, cardboard, string, water, food colour, water bottle

Setup: Create the manometer as shown by attaching thin tubing in a U-shape to a cardboard stand and filling with a small amount of coloured water. Make sure there is sufficient length of tubing left over on either side.

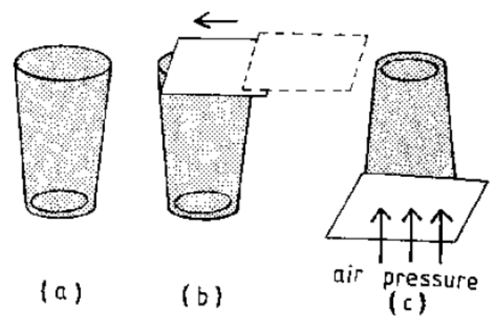
Procedure: Insert each arm of the manometer to a different depth in a bottle of water.

Observations: When both arms are at equal pressure, the water levels are equal. When one side experiences a higher pressure, there is a noticeable difference in the height h of coloured water on the opposite side.

Theory: A manometer is used to measure fluid pressure. When the pressure is higher on one side, it is shown by a difference in height on the manometer which can be measured. The greater the pressure difference, the higher the value of h.

Atmospheric Pressure

1.5.10 Overturned Glass



Materials: Cup/glass, card, water

Procedure: Fill a cup to the rim with water. Push a smooth card from the side to cover the glass so that no air bubbles are included. Turn the glass upside down.

Questions: Why can there be no air bubbles inside the glass?

Observations: The card remains attached to the glass and the water does not fall out.

Theory: The card is held in place by atmospheric pressure pushing upwards, which is larger than the weight of the water pushing downwards, so the card does not fall.

1.5.11 Holey Bottle

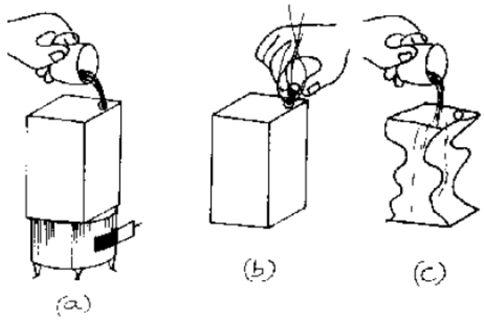
Materials: Water bottle, pin, water

Procedure: Poke 4 or 5 small holes in the bottom of the bottle. Fill it half way with water, allowing it to spill out the holes in the bottom. Then cap the bottle and observe what happens.

Observations: When the bottle is capped, the water stops flowing through the holes.

Theory: When the bottle is open, gravity is strong enough to pull the water through the bottom holes. When closed, however, the low pressure inside the bottle and the high atmospheric pressure outside creates an upward force that is able to overcome gravity and prevent water from flowing.

1.5.12 Bottle Crush



Materials: Plastic water bottle, boiling water, cold water

Procedure: Pour some boiling water into the bottle and cap it immediately. Shake it to make sure all the air inside is heated. Then pour cold water on the bottle.

Observations: Upon pouring the cold water, the bottle crushes.

Theory: When the hot air inside the water bottle is cooled off, its volume decreases, leaving a partial vacuum inside the bottle. The greater atmospheric pressure outside crushes the bottle inwards.

1.5.13 Madgeburg Hemisphere

Materials: 2 equal size cooking pots, oil, matches, small pieces of paper

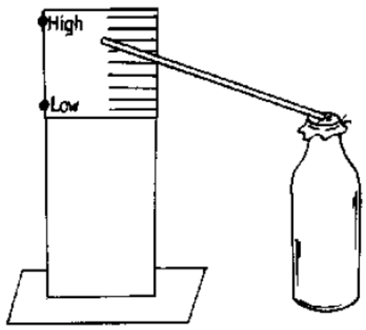
Setup: Spread oil or grease around the edge of one of the cooking pots.

Procedure: Place small papers in the un-greased pot and light them on fire. Allow them to burn about half way and then cover with the greased pot so that no air can escape. Allow the pots to cool and try to separate them.

Observations: After the pots have cooled it is very difficult to separate them.

Theory: 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.

1.5.14 The Barometer



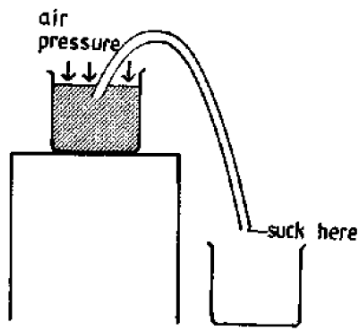
Materials: Bottle, plastic bag, string/rubber band, straw, glue, cardboard, pen

Procedure: Close a bottle air-tight using a piece of plastic bag and string/rubber band. Glue the straw onto the middle of the plastic and point it to a vertical scale written on paper or cardboard.

Theory: When the air pressure increases, it pushes downward on the plastic and the straw dips down. When the air pressure decreases, the relatively high pressure inside the bottle pushes the plastic up, raising the straw.

Applications of Atmospheric Pressure

1.5.15 The Siphon



Materials: 2 containers/bottles, *, (1 m), water

Procedure: Place one bottle full of water on a table and the other below. Place one end of the tubing into the water and suck on the other end until water starts coming out. Place this end of the tube into the empty bottle and observe what happens.

Hazards: Clean off the tube thoroughly between uses.

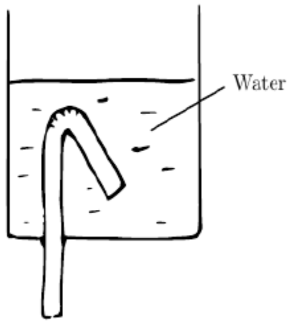
Observations: The water continues to flow to the empty bottle despite an initial uphill climb.

Theory: Sucking on the tube creates a low pressure on that end. The higher atmospheric pressure on the water end causes the water to flow from high pressure to low pressure, overcoming gravity.

Applications: Toilets, drainage systems, Automatic Flushing Tank

Notes: Alternatively, submerge the entire tube initially, then pinch on end and remove from the water. Upon releasing the pinched end outside of the water, the water will flow.

1.5.16 Automatic Flushing Tank



Materials: Empty water bottle, straw, water, bucket, super glue

Setup: Cut the top off of a water bottle and make a hole at the bottom for a straw to fit through. Bend the straw inside the bottle as shown and seal with super glue.

Procedure: Fill the bottle up to and above the bend in the straw and observe what happens.

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

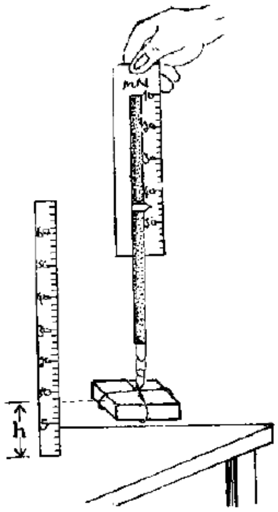
Theory: The combined pressure of the water and the atmosphere pushing down on the water is greater then the air pushing up on the straw. The tank does not require a handle to trigger the flush. Once the water flows into the tank up to the level of the siphon, the tank will flush automatically.

1.6 Work, Energy and Power

Work = Force × distance in direction of Force
Unit = 1 N × m = 1 J (Joule)
Energy is the ability to do work. Unit = 1 J (Joule)
Power = Work Done ÷ time
Unit = 1 J ÷ 1 s = 1 W (Watt)

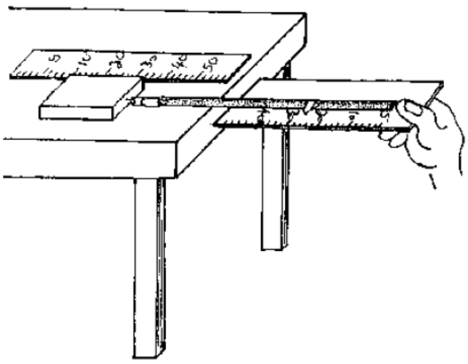
Work

1.6.1 Work Done by Lifting



Materials: *, block of wood, ruler
Procedure: Raise a block of wood from a table using a spring balance. Read the balance while lifting at *constant velocity*, not when starting or stopping. Compare this to the weight of the block. Measure the vertical distance raised h.
Questions: Calculate the work done when the block is raised a vertical distance h.
Theory: Work done = Weight × h

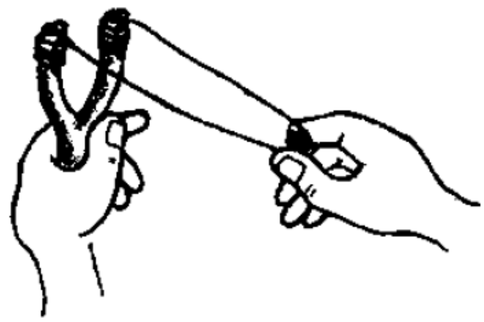
1.6.2 Work Done by Friction



Materials: *, block of wood, ruler
Procedure: Place the block of wood on a table and pull with constant velocity using a spring balance. Measure the distance moved by the block.
Questions: Calculate the work done from the spring balance reading and measured distance x.
Theory: Because the block is moving at constant velocity (no net force), the force which pulls the block is equal to the force of friction and opposite in magnitude. Thus, Work done = Force of friction × x

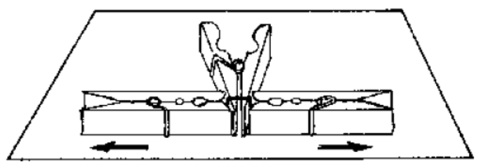
Energy

1.6.3 A Slingshot



Materials: Rubber band, branched stick, stone
Procedure: Tie either end of a rubber band to the branches of the stick. Place a stone in the middle of the band, pull back and release.
Hazards: Aim the slingshot away from all people.
Theory: The rubber band stores potential energy when stretched, which is transferred to the stone as kinetic energy upon release.
Notes: Conduct an experiment to determine the relationship between stretched length of the rubber band and distance traveled by the stone.

1.6.4 Potential Energy of a Clothespin



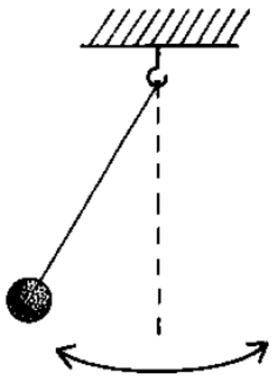
Materials: Three clothespins, scissors

Procedure: Tie the handles of a spring clothespin together with one loop of string. Place it in between two other clothespins on a flat table as shown. Cut or burn the string.

Observations: The two clothespins on either side fly off in opposite directions.

Theory: The spring in the clothespin stores potential energy which is released when the string is cut. This energy is converted into kinetic energy, seen by the movement of the other clothespins.

1.6.5 The Simple Pendulum



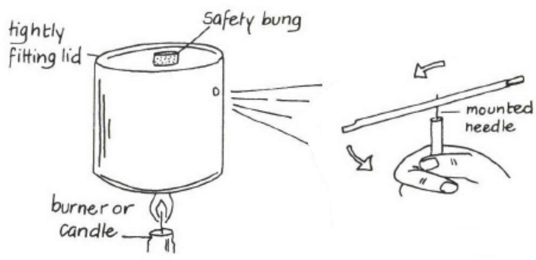
Materials: Stone, string

Procedure: Suspend a stone on a long string and hang from a table. Displace the pendulum to one side and release.

Observations: The pendulum swings back and forth at near regular intervals.

Theory: When the pendulum is released from one side, it has a maximum height and hence potential energy (P.E.), but no kinetic energy (K.E.). When it reaches the low point of its swing, it has maximum velocity and hence K.E., but its P.E. is a minimum. Thus the pendulum's energy is constantly being converted between P.E. and K.E.

1.6.6 The Steam Engine



Materials: Tin can with lid, pin, cork, *, 2 straws

Setup: Poke a small hole near the top of the tin can. Make sure the lid fits tightly, but has a safety bung (i.e. cork). Mount a straw on a pin so that it may spin freely.

Procedure: Fill the can half way with water and heat until boiling. Hold the straw spinner near the hole in the tin.

Hazards: Make sure the safety bung is not too tight and that the tin is not filled with water.

Theory: The candle or burner transfers heat energy to the tin and hence water. This heat energy in the water molecules is converted to kinetic energy as they are forced out of the tin hole. This mechanical energy is transferred to the spinner and makes it turn.

Applications: Mount the steam engine to a small raft and place in water to make a steam boat.

1.6.7 Windmills

Materials: Paper/thin cardstock, scissors, pen, glue, paper fastener/thumb tack, straw or stick, colored pencils (optional)

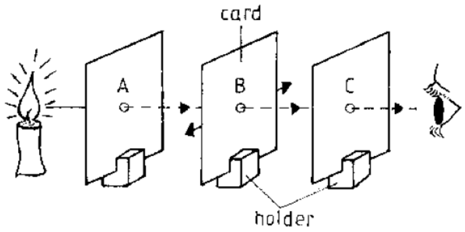
Procedure: Copy the illustration onto a sheet of paper or thin cardstock. Cut along the lines and make holes with a pen. Bend the four corners together into the center and glue them in place. Push the fastener through the center into a straw or stick.

Applications: Wind energy, wind turbines (see **??**.

1.7 Light

Propagation of Light

1.7.1 Light Travels in a Straight Line



Materials: Candle, cardboard/3 toilet paper tubes, nail, string

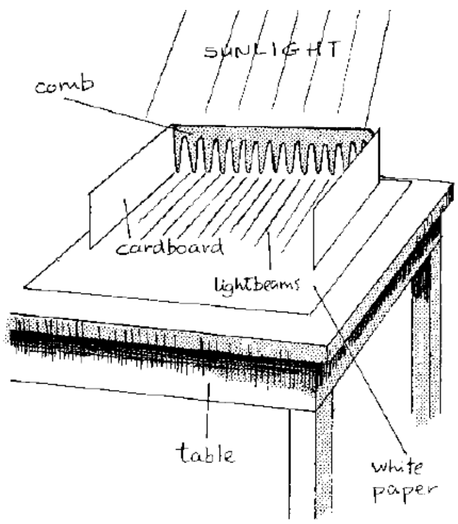
Setup: Cut 3 rectangular pieces of cardboard or use 3 toilet paper tubes. Poke a hole at the center of each using a nail. The holes should all be equal distance from the bottom.

Procedure: Arrange the cardboard pieces in a straight line - pass a string through the holes and pull tight to do this. Place the candle or light source near card A and look through card C. Displace any of the 3 cards and look again.

Observations: The light can be seen when all holes are in a straight line, but not when any card is moved.

Theory: Light travels in a straight line. The ray of light cannot be seen through card C when there is an obstruction in its path.

1.7.2 Light Through a Comb



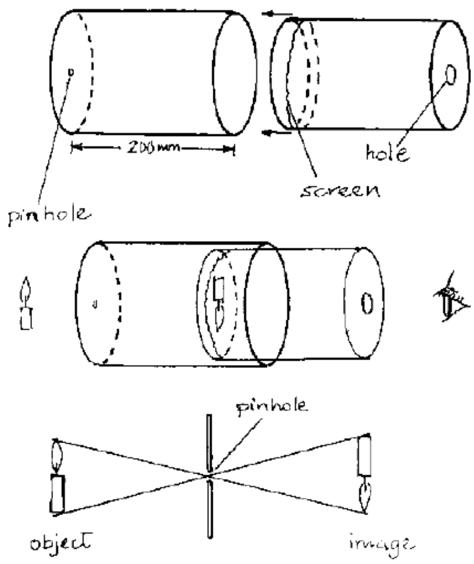
Materials: Comb, light source, paper, cardboard

Procedure: Hold a comb on a white paper placed on a table near a window. Place cardboard on either side of the comb.

Observations: Parallel beams of light can be seen on the paper.

Theory: Light travels in a straight line, so beams of sunlight passing through the slits in the comb appear in parallel lines on the paper.

1.7.3 Pinhole Camera



Materials: Tin/cardboard box/manila paper, glue, pin, candle

Setup: Roll a piece of manila paper to make a cylinder. Glue a circular piece of card on one end and poke a hole with a pin. Make a second cylinder to fit tightly in the first. Cover one end with plain paper to act as a screen, and close the other end with a card. At the center of the card make a large 2 cm diameter hole.

Procedure: Observe a burning candle by looking through the large hole. Adjust the inner cylinder to get a sharp image. Adjust the distance between screen and pinhole, as well as between candle and pinhole.

Observations: The image of the candle is real and inverted. When the distance from screen to pinhole is increased, the image becomes larger and more blurred. When the candle is closer to the pinhole, the image gets smaller and sharper.

Theory: The rays of light from the candle cross at the pinhole and thus show up on the screen as an inverted image.

Reflection of Light

1.7.4 Laws of Reflection

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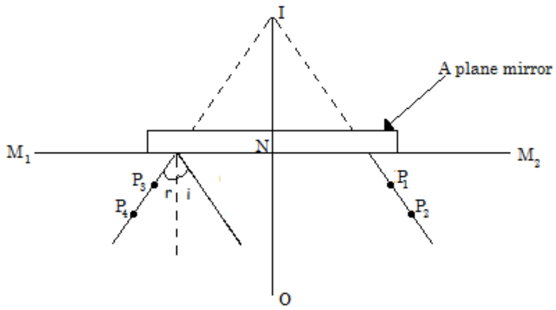

Materials: Plane mirror, pins/syringe needles, paper, ruler, protractor

Setup: Attach a plane mirror to a block of wood.

Procedure: Stand up the mirror and trace a straight line along its base. Place a pin at O a few cm from the mirror. Look at the mirror from the right side and place to pins P_1 and P_2 so that they appear in a straight line with the image. Repeat for the left side using pins P_3 and P_4. Remove the mirror and pins and join the straight lines to meet at I behind the mirror.

Questions: Measure and compare the distances ON and NI using a ruler. Measure angles i and r with a protractor.

Observations: The distances ON and NI are equal. The angles i and r are equal.

Theory: The laws of reflection for a plane mirror state that: (1) object distance (ON) and image distance (NI) are equal; and (2) the angle of incidence (i) and angle of reflection (r) are equal.

1.7.5 Images Formed in Multiple Mirrors

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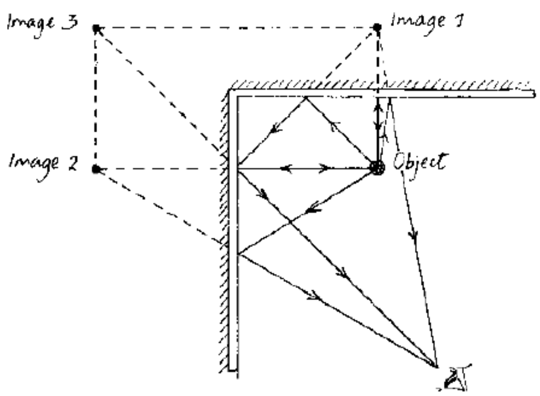


Materials: 2 plane mirrors, pin, paper, protractor

Procedure: Place to mirrors upright at right angles to each other. Place a pin (Object) in between them. Look at the mirrors and count the number of images seen. Repeat with mirrors at angles of 60° and 45°.

Questions: How many images can be seen in each case?

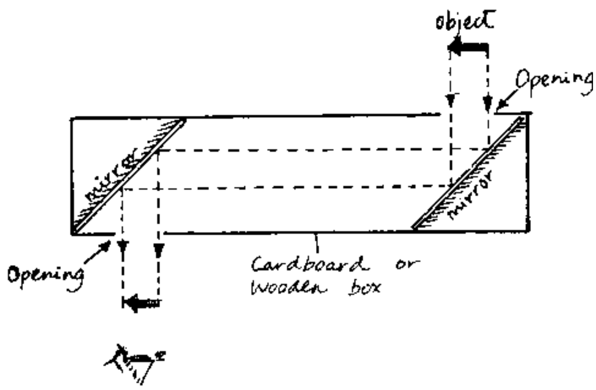
Observations: At right angles, 3 images are produced; at 60°, 5 images; and at 45°, 7 images.

Theory: For an angle θ between the mirrors, the number of images produced n follows the relationship $n = \frac{360^\circ}{\theta} - 1$.

Applications: Kaleidoscope

Applications of Reflection

1.7.6 Periscope



Materials: 2 mirrors, rectangular box, glue/tape, scissors

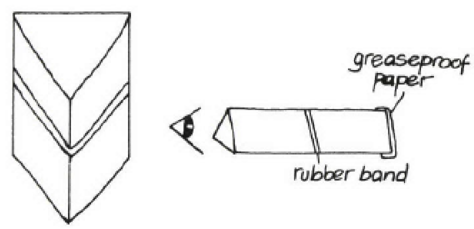
Setup: Arrange two mirrors in the box as shown. The mirrors should be at 45° angles to the walls.

Procedure: Look through the periscope to view objects above walls and around corners.

Observations: Images produced are upright.

Applications: Submarines

1.7.7 Kaleidoscope



Materials: 3 mirrors of equal size, tape, cardboard, rubber bands, coloured objects (optional)

Setup: Tape the 3 mirrors together so that they form a triangular tube with the reflective sides facing inwards. Wrap them in cardboard and fix with rubber bands.

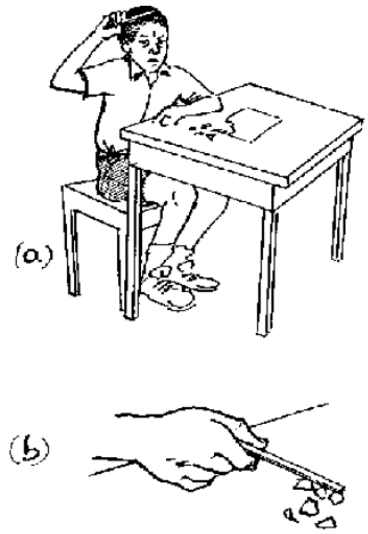
Procedure: Look through the kaleidoscope at any objects, especially coloured beads or paper, and turn to watch the colors change.

Physics Activities for Form II

2.1 Static Electricity

Concept of Static Electricity

2.1.1 Paper Jump



Materials: Small pieces of paper, ruler, pen, balloon, salt and pepper (optional)

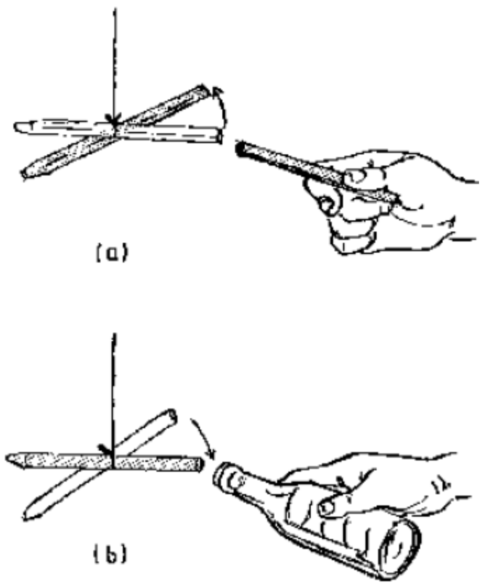
Procedure: Rub a pen, ruler or blown up balloon against your hair for about 30 seconds. Then bring it close to the small papers on a table.

Observations: The small papers jump and cling to the object.

Theory: When you rub the object against your hair, electrons are transferred by friction to the object, giving it a negative charge. When the negatively charged object approaches the papers, the electrons in the papers are repelled downwards and the protons are attracted towards the top. When the object is close enough the positive charges on the tops of the papers jump and cling to the negatively charged object.

Notes: Try also with salt and pepper. The pepper jumps but the salt is too heavy and does not.

2.1.2 Law of Electrostatics



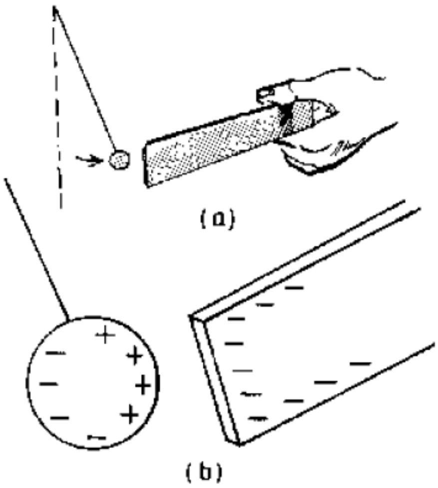
Materials: Plastic pens, wool cloth, sting, glass bottle, silk cloth (inside of a suit)

Procedure: Rub a plastic pen on your hair and bring it near a suspended pen charged in the same way. Repeat by bringing a glass bottle charged with silk or polyester near the suspended charged pen.

Observations: The two charged pens repel each other, but the glass bottle attracts the charged pen.

Theory: *Like charges repel and unlike charges attract.* The two pens are negatively charged after gaining electrons from the hair. The glass bottle is positively charged after giving up electrons to the silk.

2.1.3 Electrostatic Induction



Materials: Ruler, aluminum foil, string

Procedure: Crumple a piece of foil into a ball and suspend it from a string. Charge a ruler by rubbing on your hair and bring it close to the foil ball without touching it.

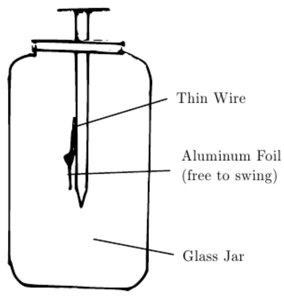
Observations: The aluminum ball is attracted by the charged plastic ruler.

Theory: The negatively charged ruler repels the electrons in the foil ball and attracts the protons, creating an induced *dipole* in the ball. This is called *electrostatic induction.*

Notes: Try different materials such as rubbing plastic on nylon, glass on silk, or latex on fur.

Electroscope

2.1.4 Construction of a Simple Electroscope



Materials: Clear jar with a plastic cap, iron nail, small piece of aluminium foil, glue, ruler or glass and silk

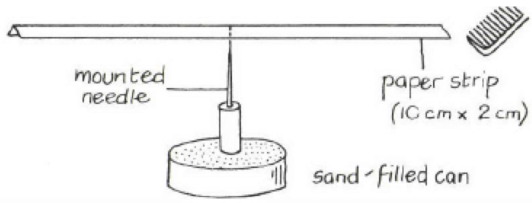
Setup: Insert the nail into the cap so that about 1 cm remains above the top. Use glue to secure it in place. Cut a piece of aluminium foil 0.5 cm by 2 cm. Glue one end of the foil (only the tip) to the nail about 2 cm from the bottom. Bend the foil so it can swing easily. Close the cap with the nail and foil.

Procedure: Bring a charged object near the nail and notice any deflection in the leaf.

Observations: The leaf deflects from the nail.

Theory: The charged object repels the opposite type of charge in the nail, which moves down the nail and into the leaf. The like charges on the nail and leaf repel each other, causing a deflection to occur.

2.1.5 Simple Detector



Materials: Paper, needle/pin, sand-filled can, ruler

Setup: Mount a strip of paper 10 cm by 2 cm on a needle supported by a sand-filled can.

Procedure: Bring a charged object (ruler or pen rubbed on hair or glass rubbed with silk) close to the paper.

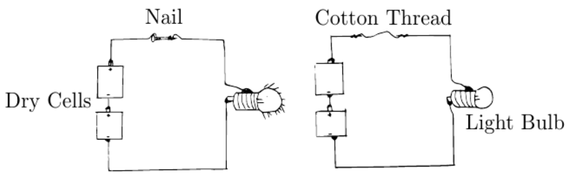
Questions: Which way does the paper move for different charged objects?

Theory: The paper will deflect when a charged object is brought near due to induction. Any charge on the paper can be detected based on whether it is attracted to the object (same charge) or repelled (opposite charge).

2.2 Current Electricity

Simple Electric Circuits

2.2.1 Conductors and Insulators



Materials: Dry cells, light bulb, speaker wire, cardboard, various materials (nail, pen cap, aluminum foil, string, balloon, toothpick, bottle cap, pencil, etc.)

Setup: Connect the dry cells and light bulb using speaker wire and leave two ends of the wire free.

Procedure: Have students predict which materials will cause the bulb to light. Then try them one by one by placing across the free wire ends.

Observations: Metal objects such as nails, aluminum foil, bottle caps, etc. turn on the light, while others do not.

Theory: Conductors are materials which allow electric current to pass through them easily, while insulators do not. Placing conducting materials (e.g. many metals) across the wires closes the circuit and allows electrons to flow through bulb and produce light.

2.2.2 Creating a Light Bulb

Materials: Glass jar with lid, glue, wires, power source, thin iron wire, nail

Setup: Use the nail to poke two holes in the jar lid. Pass a wire through each hole half way into the jar. Connect the wires inside the jar with the iron wire. Seal the sires into the lid with glue and close the lid on the jar.

Procedure: Connect the wires outside the jar to the power source.

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

Theory: Electricity can be used to generate light as a result of resistance in a wire.

Questions: Why do bulbs eventually stop working? What other materials produce light when heated?

Notes: You may need to try different types of wire for the bulb. It should be very thin and have a high resistance.

Ohm's Law

2.2.3 Verifying Ohm's Law

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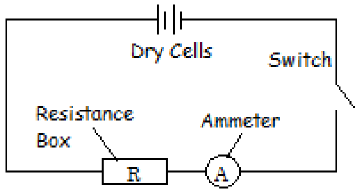


Materials: Dry cells, speaker wire, resistance box/rheostat, ammeter/galvanometer

Setup: Connect the circuit as shown.

Procedure: Adjust the resistance box/rheostat to give 1 Ω. Read the current I on the ammeter. Repeat for different resistances (2 Ω, 3 Ω, 4 Ω, 5 Ω).

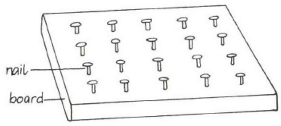
Questions: Tabulate values of R and I. Plot a graph of resistance, R (vertical) against $\frac{1}{I}$ (horizontal). Find the slope of the graph.

Observations: As the resistance increases, the current decreases.

Theory: Ohm's Law tells us that potential difference in a circuit is directly proportional to the current passing through it ($V = IR$). Solving this equation for R gives $R = \frac{V}{I}$, so the slope of the graph represents the voltage V.

Electrical Components

2.2.4 Circuit Boards

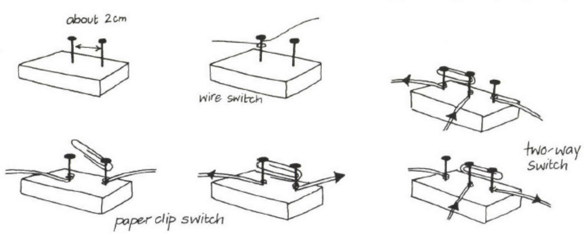


Materials: Wood board, nails

Setup: Make a grid of nails in the board as shown.

Procedure: Use the nails to connect different circuit components. Gaps between nails can serve as a switch.

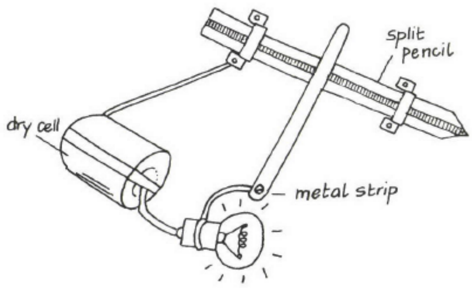
2.2.5 Switches



Materials: Nails, small wooden blocks, paper clips, speaker wire

Procedure: Assemble the various switches shown and use them to connect circuit components.

2.2.6 Rheostat



Materials: Dry cell, metal strip, pencil, wire, bulb

Procedure: Cut a pencil in half so that its graphite center is showing. Connect a dry cell, bulb and metal strip as shown. Move the metal strip along the graphite in the pencil.

Observations: When the metal strip is moved to the left along the graphite of the pencil, the bulb burns more brightly.

Theory: The graphite acts as a resistor. Its resistance depends on its length, so when a shorter distance is used in the circuit, there is less resistance and the bulb burns more brightly.

2.2.7 Finding Circuit Components

Materials: Old or broken electronics (radio, car stereo, computer, phone charger, disc drive, etc.), pliers, screw driver, soldering iron (optional), empty matchboxes

Setup: Ask local community members/fundis/repair shops for old or broken electronics.

Procedure: Identify common components inside the devices and place them in separate containers (matchboxes). Pliers or a soldering iron may be necessary to remove some components.

Hazards: If using a soldering iron, do not touch the tip as it can quickly cause second degree burns. NEVER open a component which is connected to a power source!

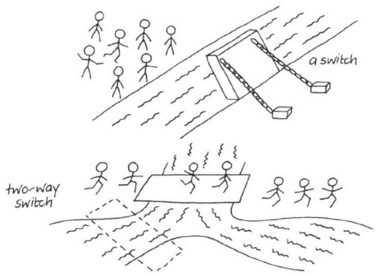
Observations: You should be able to find a variety of resistors, capacitors, wires, motors, rheostats, switches, diodes, transistors, transformers, speakers, inductors, bulbs, etc.

Notes: Have this be an ongoing activity for your school. Keep looking for more things to take apart.

Water Analogies

Switches

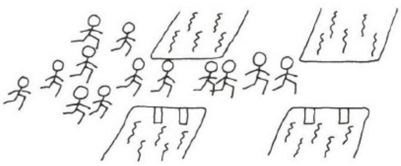
The drawbridge acts as a switch.



The plank can only be in one of two positions. It is analogous to a two-way switch.

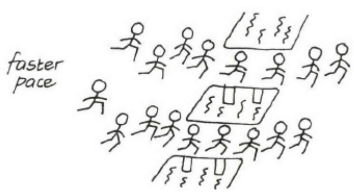
Circuits in Series

If the bridge breaks, the flow stops, i.e. if one component breaks, the circuit is incomplete and electricity cannot flow.



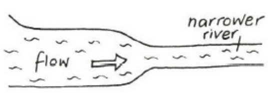
Circuits in Parallel

If one bridge breaks the race can go on, i.e. if one component fails there is still an alternative route for the electricity to flow.



Electricity

The river (electricity) flows through the narrow and the wide part of the river. However, where the river is narrow the amount of water flowing (the current) is smaller, but the resistance or power is greater, while the voltage stays the same.

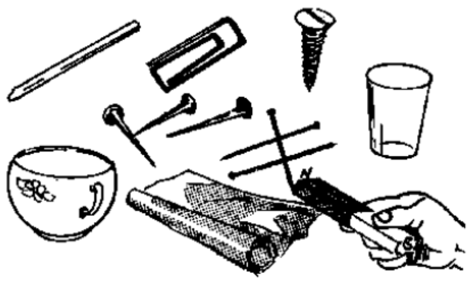


A dam acts like a switch. Unless the dam is opened no water can flow.

2.3 Magnetism

Concept of Magnetism

2.3.1 Magnetic and Non-magnetic Materials



Materials: Magnets*, various local objects e.g. nails, plastic, wood, cloth, copper, iron, aluminum, etc.

Procedure: Bring a magnet close to each of the materials listed above.

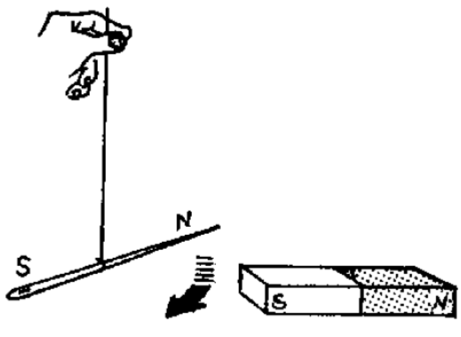
Questions: What happens to each material?

Observations: Some materials such as nails and paper clips are attracted to the magnet, while others like toothpicks and plastic are not.

Theory: Materials that are attracted by magnets are called *magnetic materials*, while those that are not attracted to magnets are called *non-magnetic materials*.

Properties of Magnets

2.3.2 Interaction Between Magnets



Materials: 2 magnets or magnetised needles

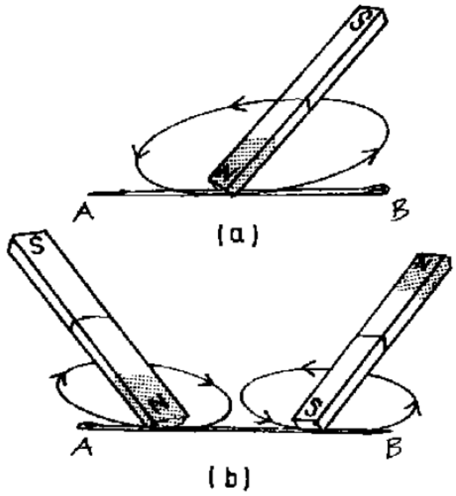
Procedure: Suspend one magnet or magnetised needle and bring the other close to it. First try N-pole to N-pole, then N-pole to S-pole, and so on.

Observations: When two N-pols or two S-poles are placed near each other, the pin deflects away from the magnet, but when an N-pole and S-pole are near together, they attract.

Theory: Like poles repel, unlike poles attract.

Magnetisation

2.3.3 Stroking Method



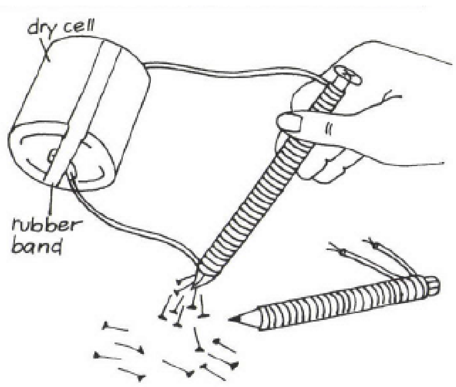
Materials: Magnet*, needle

Procedure: Move one pole of a bar magnet many times along the needle as shown in (a). Now take another needle and move the magnet as shown in (b), starting from the middle.

Observations: The needle in (a) has a N-pole at A and S-pole at B, while the needle in (b) has a S-pole at A and a N-pole at B.

Theory: The first needle is magnetised by the single touch method, and the second is magnetised by the double touch method.

2.3.4 Electromagnet



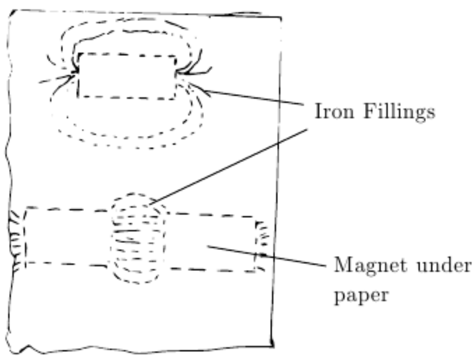
Materials: Dry cell, nail, insulated copper wire, pins

Procedure: Make about 50 turns of wire around the nail. Connect the wire to the dry cell. Pick up the pins with the magnetised nail.

Theory: The nail is magnetised by the electrical method. The moving electric charge in the wire solenoid creates a magnetic field in the nail. The stronger the current and the greater the number of turns of wire, the stronger the magnet.

Magnetic Fields

2.3.5 Magnetic Filings



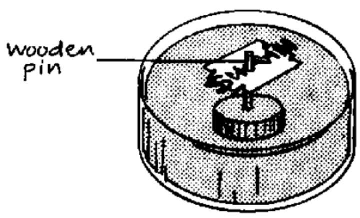
Materials: Bar magnets, paper, steel wool

Procedure: Place one or two bar magnets under a sheet of paper. Sprinkle iron filings over the top to reveal the lines of the magnetic field.

Observations: The iron filings reveal the magnetic lines of force.

Theory: Filings gather around the poles, where the magnetic force is strongest. Lines of repulsion are seen for like poles, and there is a *neutral point* in the center through which no lines pass. Lines of attraction are shown for unlike poles.

2.3.6 Simple Compass



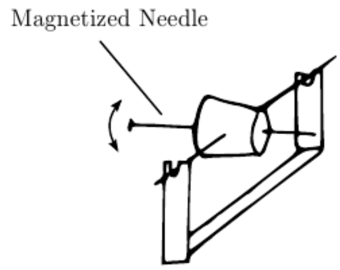
Materials: Bowl filled with water, wooden pin, magnetised razor blade

Procedure: Fix a wooden pin vertically in a bowl of water. Slip a magnetised razor blade along the pin and carefully place it on the surface of the water so that it can rotate. Gently rotate the bowl and then the razor blade and observe what happens.

Observations: When the bowl is rotated, the razor blade continues to lie in the N-S direction. When rotated itself, it returns to this orientation.

Theory: The magnetised razor blade aligns itself with earth's magnetic field in a N-S direction. As long as it remains magnetised, it will keep this orientation.

2.3.7 Magnetic Dip Gauge



Materials: Magnet, needle, cork/foam, two pins, paper, pen, cardboard or metal strip

Setup: Push the two pins into the ends of the cork to create an axle. Push the needle through the cork perpendicular to the axle. Magnetise the needle by stroking with a magnet. Balance the pins on a U-shaped stand made of cardboard or metal strip. Cut out a semicircular piece of paper and label it for 0 to 90 degrees; glue to the stand.

Procedure: Set the gauge so that the needle is free to rotate vertically. Measure the angle of the needle relative to the ground.

Observations: Before magnetising the needle, it balances horizontally in equilibrium. When magnetised however, it will dip down to show the direction of earth's magnetic field.

Theory: Like a compass, the needle naturally moves to show the direction of the earth's magnetic field. The gauge only works if facing N-S.

2.4 Forces in Equilibrium

Effect of Turning Forces

2.4.1 Ruler Balance

Materials: 2 rulers, bottle caps, toilet paper tube, tape, cardboard

Setup: Make a knife edge by fixing a ruler vertically in a piece of cardboard. Fold a piece of tape around the center so that the adhesive faces outwards. Cut a toilet paper tube in half and cover one side of each with tape. Label the tube tube containers A and B and tape them to either side of the second ruler.

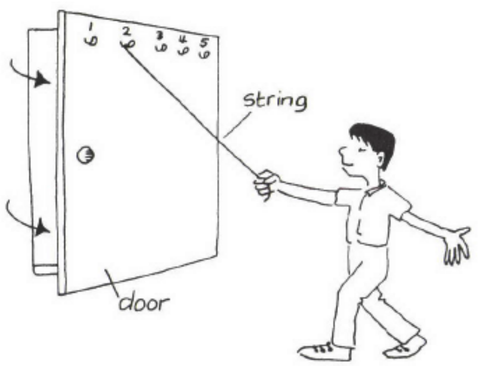
Procedure: Place the ruler/tube assembly on the knife edge so that it balances (15 cm mark). Place 3 bottle caps in A and then add caps to B until it balances again. Record the result. Repeat with the ruler beginning at the 17 cm and 13 cm marks.

Questions: How many bottle caps were required to balance the ruler each time?

Observations: When the ruler is placed at the 15 cm mark, an equal number of caps on either side causes the ruler to balance. At the 17 cm mark, more caps must be placed in B to balance, and at the 13 cm mark, fewer caps are required to balance.

Theory: Moment = Force × Lever arm. In order to balance the moments on either side of the pivot must be equal. When the lever arm of A is larger, a greater force (more bottle caps) must be placed in B to counter. When A has a shorter lever arm, a small force (few bottle caps) is sufficient to tip the balance for B.

2.4.2 Moment of a Door



Materials: Hooks/nails, string, door

Procedure: Place the hooks in the door 10-15 cm apart. Attach a string to the hooks, one at a time and try to pull the door open.

Questions: Which hook makes it easiest to open the door?

Observations: The door is easier to open for hooks which are farther from the hinge.

Theory: Increasing the lever arm (distance from hinge) requires a smaller force to generate the moment needed to open the door. A short lever arm requires a larger force to achieve the same moment.

2.4.3 Door Tug-of-War

Procedure: Get two students. One pushes against a door near the hinge and the other pushes in the opposite direction near the handle of the door.

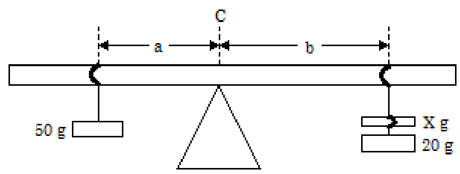
Observations: The student pushing near the handle of the door will find it much easier to push the door her way.

Theory: Moment of a force depends on both the *magnitude of the force* and *length of the lever arm*. The student that pushes farther from the axis of rotation can exert less force, while still producing a greater moment.

Principle of Moments

2.4.4 Determining an Unknown Mass

NECTA PRACTICAL



Materials: Metre rule, triangular wooden block, string, dry cell, * (20 g and 50 g)

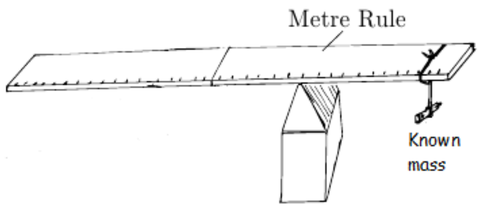
Procedure: Balance the metre rule on the wooden block (should be near 50 cm mark). Hang a 50 g mass a distance $a = 5$ cm from the pivot point on one side. Balance the opposite side using a 20 g mass together with the dry cell. Record the length b required to balance the ruler. Repeat for $a = 10$ cm, 15 cm, 20 cm and 25 cm.

Questions: Plot a graph of a against b. Calculate the slope and use it to find the mass of the dry cell, X.

Theory: From the principle of moments, $(50g)(a) = (20 + Xg)(b)$. Canceling g we find that $\frac{a}{b} = \frac{20+X}{50}$ = slope, so the value of X can be determined.

2.4.5 Mass of a Ruler

NECTA PRACTICAL



Materials: Metre rule, triangular wooden block, *

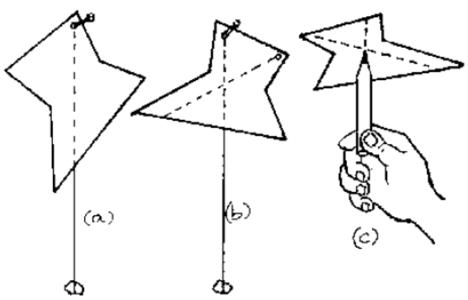
Procedure: Place a known mass on one end of a metre rule. Adjust the position of the ruler until it balances on the knife edge.

Questions: Determine the mass of the metre rule.

Theory: Using the known mass and measured distances on either side of the pivot, the unknown mass of the ruler can be found.

Centre of Gravity

2.4.6 Finding the CoG



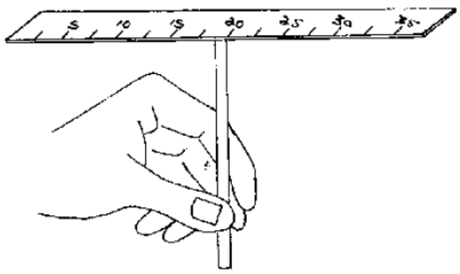
Materials: Manila paper, pen, nail, sting, stone

Procedure: Cut a piece of manila paper into an odd shape. Suspend it from a nail and attach a string with a stone. Mark the position of the string at two points and then connect with a straight line using a ruler and pencil, as shown in (a). Repeat by fixing the nail in another point on the shape (b). Balance the shape at the point where the two lines meet.

Observations: The shape balances at the intersection of the lines.

Theory: The intersection of the two lines locates the *centre of gravity* of the object, and so it balances.

2.4.7 CoG of a Ruler



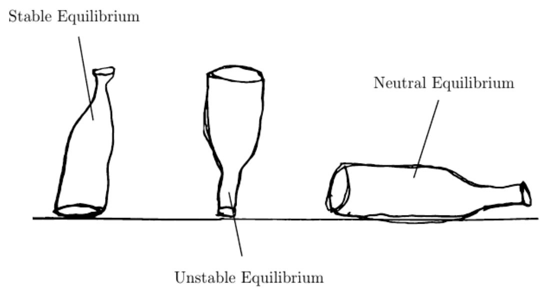
Materials: Ruler, pencil/pen

Procedure: Find the centre of gravity of a ruler by balancing it on the tip of a pencil.

Observations: The ruler balances at its center point.

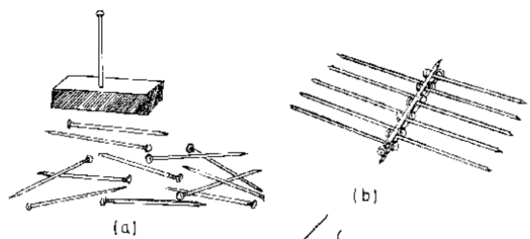
Theory: The ruler's mass is evenly distributed. Thus, its centre of gravity acts at its geometrical centre.

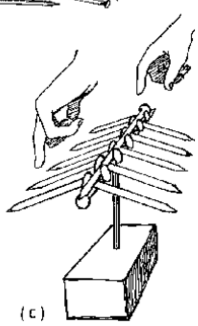
Types of Equilibrium



A body is in *stable equilibrium* if a small movement would rise its CoG, *unstable equilibrium* if a small movement would lower its CoG, and *neutral equilibrium* if a small movement would keep its CoG at the same level.

2.4.8 Balancing Nails





Materials: Nails, piece of wood

Procedure: Stand one nail vertically in a piece of wood. Give students 10-12 nails and tell them to balance them all on top of this one nail.

Observations: Arranging the nails according to figure (b), they can all be balanced.

Theory: The CoG is lower than the supporting head of the first nail, so the entire assembly is in *stable equilibrium* and thus does not fall over.

2.4.9 Balancing Forks

Materials: 2 forks, 2 coins, jar/can

Procedure: Take 2 coins and attach two forks as shown in the figure. Balance the arrangement on the edge of a jar or can.

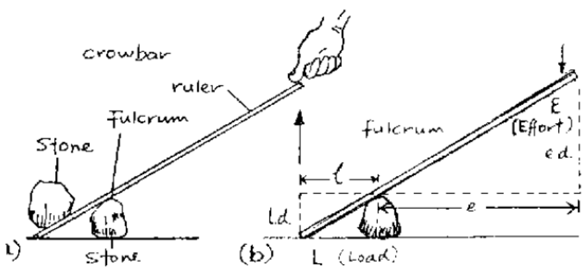
Theory: The CoG of the system is over the balancing surface, so it is in stable equilibrium.

2.5 Simple Machines

Mechanical Advantage (M.A.) = Load ÷ Effort
Velocity Ratio (V.R.) = effort distance ÷ load distance
Efficiency (e) = work output ÷ work input × 100% = M.A. ÷ V.R. × 100%

Levers

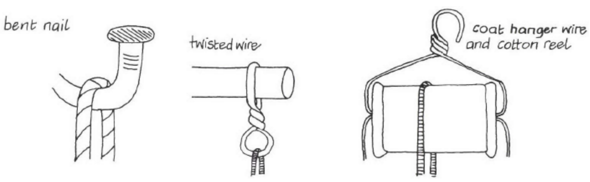
2.5.1 Ruler Lever



Materials: Ruler, stones
Procedure: Make a lever using a ruler and a stone. Use it to lift a heavy stone or brick.
Theory: The mechanical advantage is greater than one, i.e. the effort is less than the load; but the velocity ratio is greater than one, i.e. the effort distance is greater than the load distance.
Applications: Seesaw, pliers, wheelbarrow, bottle opener, forearm, etc.
Notes: Now slide the ruler down so that the fulcrum is near the center and try to lift the stone. Is it easier or more difficult?

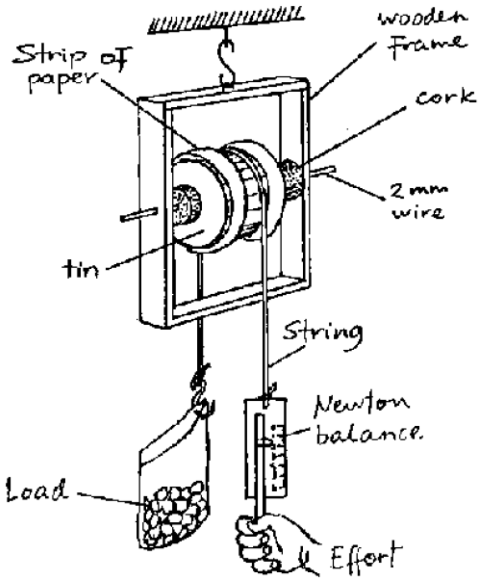
Pulleys

2.5.2 Simple Pulleys



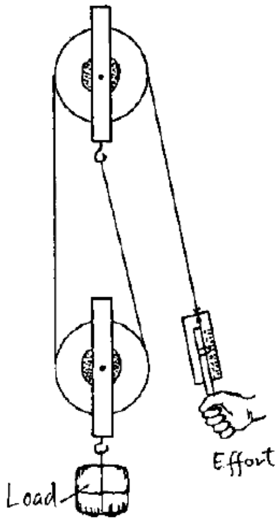
Materials: Nails, wire, coat hanger, water bottle, cotton reel
Procedure: Construct pulleys using any of the methods shown above. Alternatively, cut off the tops of water bottles just below the lip where the cap rests.
Applications: Flagpole, well buckets, construction of tall buildings, etc.

2.5.3 Single Pulley



Materials: *, bag of stones, string, stiff wire, thin wood, tin, cork, paper
Setup: Use one of the pulleys above, or construct one by poking holes on either end of a tin and placing a wire as an axle. Fix the axle into a wooden frame as shown.
Procedure: Attach a string to a load much heavier than the pulley (e.g. bag of stones). First measure the weight of the load using a spring balance. Then run the string across the pulley and record the effort required to lift the load.
Observations: The weight of the load and the effort force required to raise it are equal.
Theory: A pulley has a M.A. of 1, meaning the load and effort are the same. The advantage of a single pulley is that it *changes the direction* of the load. It is much easier to lift a heavy load by pulling downwards (with the help of your own weight) than by pulling upwards.

2.5.4 Block and Tackle System



Materials: 2 pulleys*, string, *, load (bag of stones)

Setup: Connect two single pulleys as shown in the figure, using any of the designs described above.

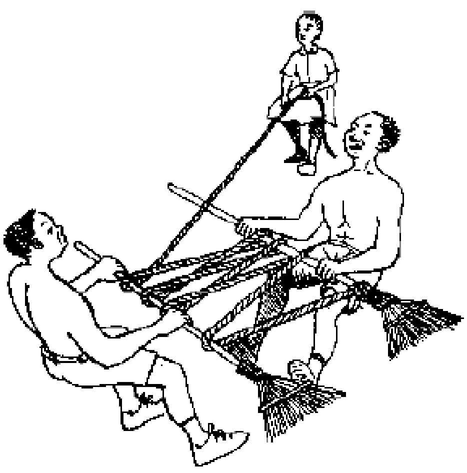
Procedure: Use this system to lift the same load as in the previous activity. Measure the effort using a spring balance.

Observations: It is easier to lift the load this time, i.e. the effort is smaller.

Theory: Neglecting friction and the weight of the pulley, the M.A. will be 2, i.e. the load is twice the effort. The V.R. is equal to the number of pulleys in the system, in this case 2.

Notes: Try with more pulleys and see how it affects the M.A.

2.5.5 Strength vs. Science



Materials: 2 broomsticks/jembe sticks, rope

Procedure: Fix one end of a rope to one stick and wind it back and forth around the two sticks as shown. Have 2 strong students pull on the sticks and one small student pull the other end of the rope.

Observations: The small student wins.

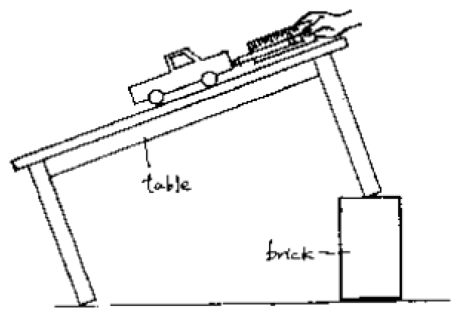
Theory: This is an arrangement of “broomstick pulleys.” The small student requires much less effort to pull the heavy loads of the two strong students. However, the small student will have to move farther than the others.

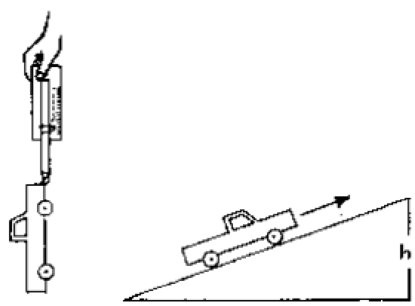
Applications:

Notes:

Inclined Plane

2.5.6 The Ramp





Materials: Table, brick/books, *, small weights/toy car

Procedure: Tilt a table by placing a brick or stack of books underneath its legs on one side. Weigh a small object (i.e. toy car) using a spring balance. Now pull the object up the tilted table and measure the effort with the spring balance.

Observations: The effort is smaller than the load (weight of the object).

Theory: The effort distance is the distance moved along the table, whereas the load distance is the *vertical* distance that the object moves. Thus, both the M.A. and V.R. depend on the angle of inclination of the plane.

Applications: Hills, ramps, screws, Egyptian pyramids

Wheel and Axle

2.5.7 Bottle Cap Gearworks

Materials: Soda bottle caps, nails, small piece of wood

Procedure: Find the exact center of each bottle cap and poke a hole through it for the nail. Nail the caps into the wood at even intervals so that they can freely rotate and in turn cause others to rotate. Make different configurations and note the direction of rotation from one gear to another.

Observations: Adjacent gears turn in opposite directions.

Theory: Gears allow for the direction of rotation of a force to be changed. If the gears are of different sizes, then the rates of rotation will also vary.

Hydraulic Press

See activities in the Form I topic of Pressure.

2.6 Motion in a Straight Line

2.6.1 Object Toss

Procedure: Take any object lying around the classroom and repeatedly toss it vertically into the air while walking around the classroom.

Theory: When the object is first thrown upward, it has an initial velocity. As it continues up, the velocity gets smaller, until reaching zero at the top of its trajectory. It then gains a downward velocity which increases in magnitude. The horizontal motion matches your motion, showing that horizontal velocity is constant.

Measuring Motion

2.6.2 Making the Vehicle

Materials: Matchboxes/block of wood, bottle caps, sand/stones, nails

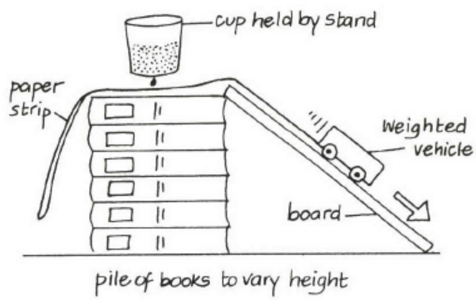
Procedure: Attach bottle cap wheels to a base made from matchboxes or wood. Fill the base with sand or some other small weight.

2.6.3 Making the Timing Cup

Materials: Plastic cup/tin, dilute ink/food colour, pin, string, stopwatch

Procedure: Pierce a small hole in the bottom of the cup and seal with a pin attached to a string. Fill the cup with ink or food colour. When the pin is pulled out the ink will fall in regular drops. Use a stopwatch to measure the average time between drops.

2.6.4 Ticker Timer



Materials: Long, thin strips of paper, pile of books, board, ruler

Procedure: Pile the books to make slopes of different heights. Attach the ticker tape (paper) to the weighted vehicle. When the vehicle is released, pull out the string in the timer cup. Repeat for a variety of heights and angles of the slope and for different weights in the vehicle.

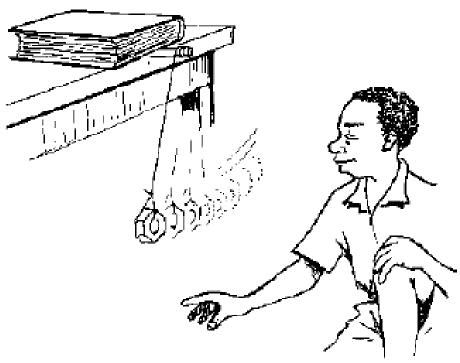
Questions: Calculate the velocity and acceleration of the vehicle using the distances between dots on the ticker timer and the average time between drops for the timing cup.

Observations: When the car is moving at constant speed, the dots are in regular intervals. When the car is accelerating, the distance between consecutive dots increases.

Theory: Velocity = distance ÷ time. Acceleration = velocity ÷ time. By measuring the distance between two dots over a set interval of time, both velocity and acceleration may be calculated.

2.6.5 Determining Acceleration Due to Gravity

NECTA PRACTICAL



Materials: String, stone, stopwatch, metre rule

Procedure: Tie the string around a stone and hang from a table. Pull the pendulum to one side and release while starting the stopwatch. Record the time taken to complete 10 full oscillations (back and forth). Record the result. Adjust the string length and repeat.

Questions: Calculate the acceleration due to gravity.

Theory: The period T of a pendulum is given by $T = 2\pi\sqrt{\frac{l}{g}}$, where l is the length of the pendulum and g the acceleration due to gravity. Solving for g, we see that $g = \dfrac{4\pi^2 l}{T^2}$. Thus, we can calculate the acceleration due to gravity by measuring the string length and *average* period (divide total time by number of periods, in this case 10).

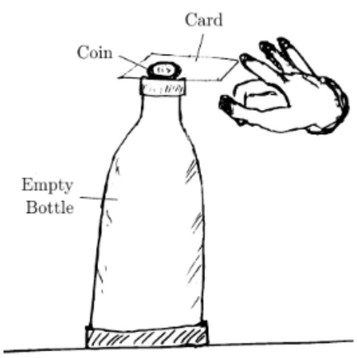
Notes: The mass of the pendulum has no effect on its period.

2.7 Newton's Laws of Motion

Newton's First Law and Inertia

Newton's First Law: *An object at rest will remain at rest and an object in motion will remain in motion at a constant speed in a straight line unless acted upon by an external force.*

2.7.1 Card Flick



Materials: Card, bottle/cup, coin

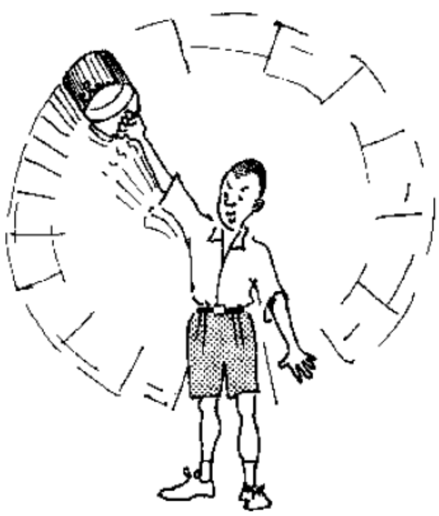
Procedure: Place the coin on a card so that it rests above the opening of a bottle or cup. Flick the card horizontally.

Observations: The card goes flying off but the coin drops straight down into the bottle.

Theory: The inertia of the heavy coin is large compared to the friction between the card and coin. Thus it remains in place while the lightweight card flies away.

Notes: The trick works best with a heavy coin and by making sure the card is flicked as horizontally as possible.

2.7.2 Bucket Swing



Materials: Bucket, rope, water

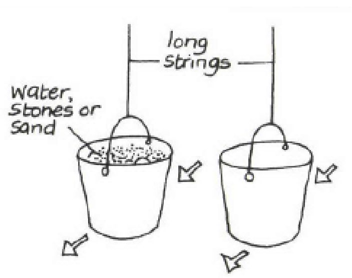
Procedure: Fill a bucket about half way with water and attach a rope to the handle. Swing the rope in a vertical circle so that the bucket is facing downwards at the top of its arc.

Hazards: Don't try to stop the bucket at the top of its swing.

Observations: The water remains in the bucket, even when turned upside-down. You can feel the bucket pulling outwards as you spin it.

Theory: The water and bucket are being pulled outwards by a force known as *centripetal force*. This is essentially a result of the inertia of the items, as they want to continue their motion in a straight line path at any given point throughout the swing. You must constantly exert a force on the rope to cause the bucket to change its direction of motion.

2.7.3 Bucket Pendulums

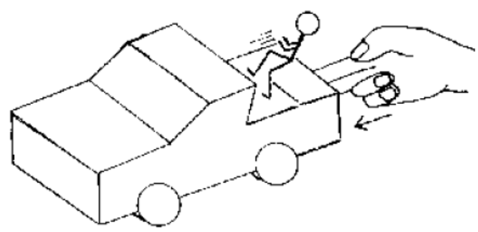


Materials: 2 buckets, sand/water/stones, rope

Procedure: Hang two buckets from a support using rope. Fill one with sand, water or some other weight. Try to push each bucket.

Theory: Inertia must be overcome to start a bucket in motion. The heavier bucket has more inertia and hence requires a greater force to begin swinging.

2.7.4 Standing Passenger



Materials: Toy car, block of wood

Procedure: Make a toy car out of matchboxes and bottle caps so that there is an open space like the bed of a truck. Stand a tall, thin object such as a block of wood or cardboard passenger in the car. Push the car forward suddenly, make it turn a corner and stop it suddenly.

Observations: The passenger falls backward when the car moves forward suddenly; falls to the right when the car turns to the left; and falls forward when the car stops suddenly.

Theory: The passenger's inertia wants to keep the passenger at rest or moving in a straight line at constant speed. When the car accelerates, the passenger falls over.

Applications: Standing on a bus

2.7.5 Spinning Eggs

Materials: 1 fresh egg, 1 boiled egg

Procedure: Place the two eggs on a table. Spin the first egg. Stop it briefly with your hand and then release it. Repeat for the second egg and note any differences you observe.

Questions: Which egg is fresh and which is boiled?

Observations: The fresh egg continues spinning after briefly stopping it, while the boiled egg stops completely.

Theory: The fresh egg contains liquid inside, which continues spinning independent of the egg being stopped, due to its inertia. The boiled egg is solid inside, so it spins as a single unit and stops when the egg is stopped briefly by your hand.

Newton's Second Law and Momentum

Newton's Second Law: *The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts.*

Force = mass × acceleration

Momentum = mass × velocity

2.7.6 Atwood's Machine

Materials: Simple Pulleys*, string, *, stopwatch, metre rule

Setup: Attach a 1.5 m string to 2 known masses (e.g. 100 g and 90 g). Run the string across the pulley and support the larger mass so that the smaller mass rests on the table. Measure the height h of elevation of the large mass.

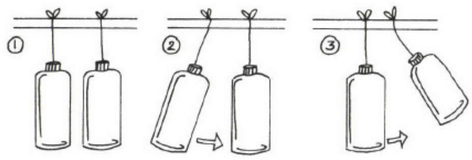
Procedure: Release the large mass and use a stopwatch to measure the time taken to reach the table t. Repeat 3 or 4 times and take an average reading for time taken. Repeat for different masses.

Questions: Determine the acceleration of the system using the equation of motion $s = v_0 t + \frac{1}{2}at^2$, where $s = h$ and $v_0 = 0$.

Theory: Newton's Second Law tells us that $F = ma$. Here, F is the net force of gravity acting on the system, and is given by $(m_1 - m_2)g$, where g is the gravitational constant. The combined mass of the system is $(m_1 + m_2)$, so the acceleration can be given as $a = \dfrac{(m_1 - m_2)g}{(m_1 + m_2)}$. Calculate the theoretical value of a using this formula, then compare to the experimental value obtained above.

Notes: Use similar masses to get more accurate results.

2.7.7 Bumping Bottles



Materials: 2 bottles, string, horizontal support

Procedure: Hang 2 bottles side by side along a horizontal support. Lift one and release it, noting the effect on the other bottle. Then try varying the masses of the bottles by filling them with different amounts of water and try again.

Observations: When the bottles are empty, the first one comes to rest after hitting the second, and the second bottle reaches a height similar to the original release height of the first.

Theory: When the bottles touch, momentum is transferred from one to the other. The relative velocities of the bottles, v_1 and v_2, depend on their relative masses, m_1 and m_2, according to $m_1 v_1 = m_2 v_2$. Momentum is conserved.

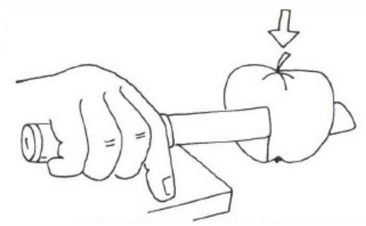
2.7.8 Pile of Coins

Materials: Pile of coins and books

Procedure: Try to remove the bottom book without upsetting the pile. Impossible? To remove the bottom coin from a pile, flick another coin at it.

Theory: The momentum of the flicked coin is transferred to the bottom of the pile. The momentum overcomes inertia.

2.7.9 Dropping Fruit



Materials: Knife, fruit

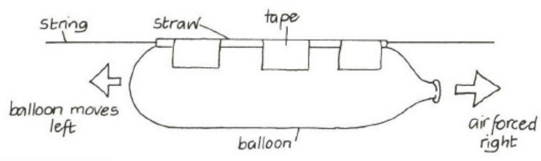
Procedure: Drop a fruit onto a sharp knife from different heights.

Theory: The farther the fall, the greater the momentum and the deeper the cut.

Newton's Third Law

Newton's Third Law: *For every action there is an equal and opposite reaction.*

2.7.10 Balloon Rocket

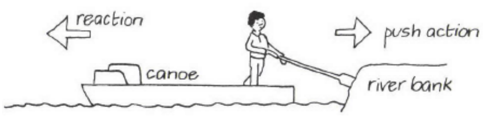


Materials: Balloon, string, straw, tape

Procedure: Run a zip line using string between two tables or chairs. Thread a straw and tape it to the balloon so that it can slide across the line. Blow up the balloon and release it to fly across the string.

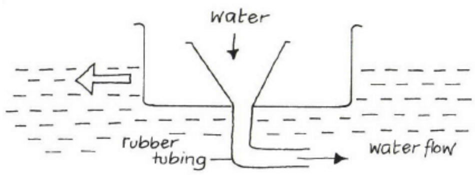
Theory: As the air is forced out the opening in the balloon, there is an equal and opposite force applied to the balloon which propels it across the line. This is an application of Newton's Third Law.

2.7.11 Pushing a Canoe



Applications: Jet airliners and canoes employ Newton's Third Law. Hot gases are forced out of an airliners engines in one direction (action) - this is known as thrust. The plane moves in the opposite direction (reaction). The canoe also moves away from the push action.

2.7.12 Boat Thrust



Materials: Plastic container, rubber tubing, funnel

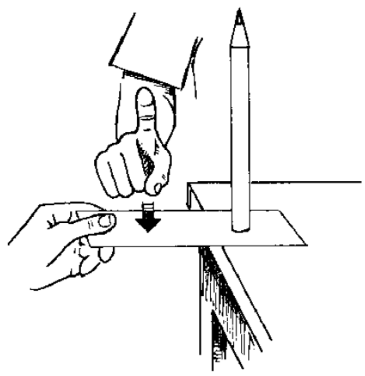
Setup: Make the tug boat as shown.

Observations: As water is poured into the funnel, the boat moves forward.

Theory: Water is forced out the rear tube by gravity (action), which propels the boat forward (reaction).

Applications: Turn the activity into a competition for students by allowing them to use different materials for the boat and seeing which one travels the fastest.

2.7.13 Pencil Launch



Materials: Pencil, card

Procedure: Stand a pencil upright on a card at the edge of a table. At once hit the card with your finger so that it leaves the table.

Observations: Pushing the card downwards (action) causes the pencil to fly upwards (reaction).

2.7.14 Bottle Rocket

Materials: 500 mL bottle, nail, rubber stopper, pin, ball/bicycle pump, tape, pen tube, rigid straight wire (bicycle spoke), water

Setup: Heat a nail and poke a hole in the bottle lid. Cut a round rubber stopper to fit this hole. Pierce the stopper with the needle of the bicycle pump. Insert the stopper into the hole in the bottle top. Cut a hollow pen tube into two 3 cm pieces and tape to the side of the bottle in a straight line.

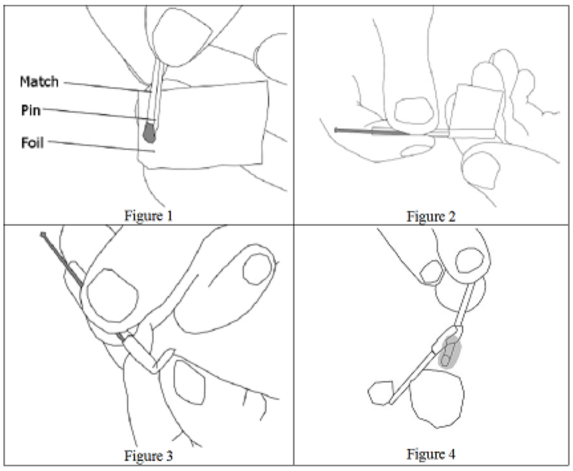
Procedure: Insert the rigid wire into the ground outside. Fill the bottle half way with water and tighten the lid. Mount the pen tube supports on the rigid wire. Insert the bicycle pump needle through the stopper in the lid and pump until the stopper is pushed out completely.

Hazards: Make sure no one is standing in the way of the rocket. Launch in a large open space.

Observations: When the stopper is forced out of the bottle the rocket flies into the air. It should be possible to reach a height of 10 metres or more.

Theory: When the stopper leaves the bottle, pressurized air forces water out of the bottom of the bottle at a high speed. This results in a forward reaction force on the rocket.

2.7.15 Matchstick Rocket



Materials: Matches, aluminum foil, pin/syringe needle

Setup: Rip a small piece of foil about 2 cm $\times$ 3 cm. Hold the pin next to a match so that the tip touches the head of the match. Hold them together and wrap the foil tightly around the head of the match (with pin) so that about 1 cm of foil extends beyond the tip of the match. Fold down the extra foil. Remove the pin by sliding it out the bottom, leaving a thin tunnel.

Procedure: Support the match rocket at a 45° angle on a stone. Light another match and hold it under the foil of the rocket.

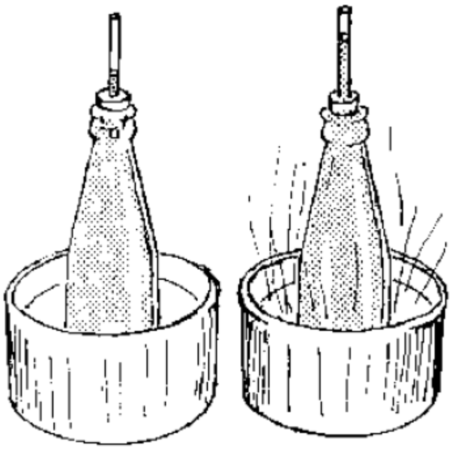
Hazards: When igniting, keep your face away from the rocket.

Observations: After a few seconds, the rocket is propelled forward.

Theory: The rocket launches when the match head inside the foil ignites due to the heat of the surrounding foil. The gases are expelled backwards through the thin tunnel (action), and the rocket is driven forward (reaction) by an equal and opposite force.

2.8 Temperature

2.8.1 Principle of a Thermometer



Materials: Bottle, pen tube, stopper/cork/rubber cylinder, food colouring, hot water bath

Procedure: Fill a bottle (about 500 mL) with coloured water up to the rim. Tightly fix a stopper carrying a narrow pen tube into the mouth of the bottle. The liquid level should be just visible above the stopper. Now place the bottle into hot water and heat it for a short time.

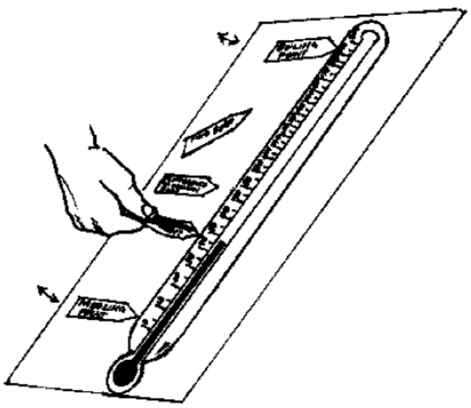
Observations: The liquid level rises after heating.

Theory: When liquids are heated, they expand. A thermometer can be made by calibrating the change in volume according to temperature change for a given liquid.

Applications: Clinical thermometers use mercury, while many outdoor thermometers use alcohol. The expansion of alcohol is six times greater than that of mercury. Mercury has a higher boiling point, so it is used to measure higher temperatures.

Questions: Why is water typically not used in thermometers?

2.8.2 Fixed Points of a Thermometer



Materials: Cardboard/manila paper, tape, marker pens

Procedure: Draw a large diagram or display chart of a thermometer on manila paper. Use coloured arrows to indicate the characteristic fixed points for water and other substances. Make separate charts for the Fahrenheit, Centigrade and Kelvin scales.

Physics Activities for Form III

Physics Activities for Form IV

Local Materials List

In order to gain a thorough understanding of science, students must be able to make a connection between classroom learning and the outside world. The following is a list of locally available materials which may be used to substitute conventional materials and apparatus for various activities. These materials have the following advantages:

- They are readily available in the village or a nearby town;
- They are cheaper than conventional materials;
- They may safely substitute the conventional materials without fear of losing accuracy or understanding;
- They help students to draw a connection between science education and the world around them.

Imagination and innovativeness is encouraged on the part of the student and teacher to find other suitable local substitutions.

Throughout this book you will see materials that have been marked with an asterisk (*). These are items which may be made or purchased using locally available substitutes. The guide for using and making these local materials is found in this section.

Alligator Clips

Use: Connecting electrical components
Materials: Clothespins, aluminum foil, glue
Procedure: Glue aluminum foil around the clamping tips of a clothespin.

Balance

See the Form I activity on Construction of a Beam Balance.

Beakers

Use: To hold liquids, to heat liquids
Materials: Water bottles, jam jars, metal cans, knife/razor
Procedure: Take empty plastic bottles of different sizes. Cut them in half. The base can be used as a beaker. Jam jars made of glass or cut off metal cans may be used when heating.

Bunsen Burner

See .

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. Capacitors tend to state their capacitance in microFarads on their bodies.

Delivery Tube

Use: For the movement and collection of gases, capillary tubes, hydraulic press
Materials: Straws, pen tubes, IV tubing (giving sets) from a pharmacy, bicycle tubing, or pawpaw petioles

Drawing Board

Use: Reflection, refraction of light
Materials: Thick cardboard

Droppers

Use: To transfer small amounts of liquid
Materials: 2 mL syringes
Procedure: Take a syringe. Remove the needle to use as a dropper.

Eureka Can

Use: To measure volume of an irregular object, Archimedes' Principle, Law of Flotation
Materials: Plastic bottle, knife, Optional: super glue, straw, nail, candle
Procedure: Cut the top off of a 500 mL plastic bottle. Then cut a small strip at the top (1 cm wide by 3 cm long) and fold down to make a spout. Alternatively, heat a nail using a candle and poke a hole near the top of a cut off bottle. Super glue a straw so that it fits securely in the hole without leaking.

Funnel

Use: To guide liquid or powder into a small opening
Materials: Empty water bottles, knife
Procedure: Take an empty water bottle and remove the cap. Cut it in half. The upper part of the bottle can be used as a funnel.

Glass Blocks

Use: Refraction of light
Materials: 8 mm - 15 mm slabs of glass
Procedure: Have a craftsman make rectangular pieces of glass with beveled edges, so students do not cut themselves. Glass blocks from a lab supply company are generally 15 mm thick. 8 mm and 10 mm glass is relatively common in towns. 12 mm and thicker glass exists though is even more difficult to find. Stack several pieces of thinner glass together and turn them on their edge.

Heat Source

Use: Heating substances
Materials: Candles, kerosene stoves, charcoal burners, Motopoa (alcohol infused heavy oil), metal can, bottle caps, butane lighter
Procedure: Cut a metal can in half or use a bottle cap and add a small amount of Motopoa.

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.

Light Bulbs

Use: Electrical circuits, diodes
Materials: Broken phone chargers, flashlights, other electronic devices
Procedure: Look for LEDs from broken items at hardware stores, local technicians, or small shops.

Masses

Use: Calibrating and using beam balance and spring balance, Hooke's Law
Materials: Known masses, beam balance, empty bottles, plastic syringe, water, plastic bags, sand, stones, thread, paper, tape, pen
Procedure: Use a beam balance and known masses at a market 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.

If using water, use a beam balance from a nearby school to measure the exact mass of an empty water bottle. Add a volume of water in mL equal to the mass in g needed to reach a desired total 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.) This can be done precisely by using a plastic syringe. Label the bottle with tape and a pen.

Measuring Cylinder

See the Form I activity on Construction of a Measuring Cylinder.

Metre Rule

Use: Measuring length, Principle of Moments, drawing graphs
Materials: Slabs of wood, ceiling board, permanent pen
Procedure: Buy one, take it and a permanent pen to a carpenter, and leave with twenty. Measure each new one to the original rule to prevent compounding errors. See also the Form I activity on Construction of a Metre Rule.

Nichrome Wire / Resistance Wire

See .

Optical Pins

Use: Compass needles, making holes, flying wire
Materials: Office pins, sewing needles, needles from syringes

Plane Mirror

Use: Laws of Reflection, periscope, water prism, super glue, small wooden blocks
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. Super glue to small wooden blocks to stand upright.

Resistors

Use: Electrical components
Materials: Old radios, circuit boards, soldering iron
Procedure: Remove resistors from old radios and circuit boards by melting the solder with a soldering iron or a stiff wire heated by a charcoal stove. If you need to know the ohms, the resistors tell you. Each has four strips (five if there is a quality band) and should be read with the silver or gold strip for tolerance on the right. Each color corresponds to a number:

black = 0	yellow = 4	violet = 7
brown = 1	green = 5	gray = 8
red = 2	blue = 6	white = 9
orange = 3		

and additionally for the third stripe: gold = -1 and silver = -2.

The first two numbers should be taken as a two digit number, so green-violet would be 57, red-black 20, etc. The third number should be taken as the power of ten (a 10^n term), so red-orange-yellow would be $23 \times 10^4 = 230000$, red-brown-black would be $21 \times 10^0 = 21$ and blue-gray-silver would be $68 \times 10^{-2} = 0.68$. The unit is always ohms. The fourth and possibly fifth bands may be ignored.

Retort Stand

Use: To hold pendulums, to elevate springs or other objects
Materials: Filled 1.5 L water bottle, straight bamboo stick, tape, marker
Procedure: Tape the bamboo stick across the top of the water bottle so that it reaches out 20 cm to one side. Attach a small clamp if required or hang object directly from bamboo stick.

Scale Pan

Use: Beam balance, Hooke's Law
Materials: Plastic bottle, cardboard box, string
Procedure: Cut off the bottom of a plastic bottle or cardboard box. Poke 3 or more holes near the top and tie string through each hole. Join strings and tie at the top to hang from a single point.

Spring Balance

Use: To measure force applied on an object
Materials: Strip of cardboard, rubber band, 2 paper clips, staple pin, pen
Procedure: Cut a rubber band and fix one end to the top of a cardboard strip using a staple pin. (A stronger rubber band allows for a greater range of forces to measure.) Attach one paper clip near the top as a pointer. Attach the other paper clip as a hook at the bottom of the rubber band. Calibrate the spring balance using known masses. Write the equivalent force in Newtons on the cardboard. (A 1 g mass has a weight of 0.01 N, 100 g has a weight of 1 N, etc.)

Springs

Use: Hooke's Law, potential energy, work, spring balance
Materials: Springs from hardware stores, bike stores, junk merchants in markets, window blinds, rubber bands, strips of elastic
Procedure: Remove plastic covering if necessary and cut to a desired length (5 cm). Alternatively use rubber bands or elastic from a local tailor - these can also be used to calculate a constant of elasticity.

Stopper

Use: To cover the mouth of a bottle, hold a capillary tube
Materials: Rubber from old tires or sandals, cork, plastic bottle cap, pen tube, super glue
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. Alternatively, super glue a pen tube to a plastic bottle cap and connect to rubber tubing.

Stopwatches

Use: Simple pendulum, velocity, acceleration
Materials: Athletic and laboratory stopwatches from markets, digital wristwatches

Test Tubes

Use: To heat materials without a direct flame, to combine solutions
Materials: 10 mL syringes, matches
Procedure: Remove the needle and plunger from 10 mL syringes. Heat the end of the shell with a match until it melts. Press the molten end against a flat surface (like the end of the plunger) to fuse it

closed. If the tube leaks, fuse it again. Test tubes made this way may be heated in a water bath up to boiling, hot enough for most experiments.

Test Tube Holder / Tongs

Use: To handle test tubes
Materials: Wooden clothespins, stiff wire, strip of paper or cloth
Procedure: Use clothespins or stiff wire for prolonged heating, or strips of paper or cloth for short-term heating.

Test Tube Racks

Use: To hold test tubes vertically in place
Materials: Wire grid from local gardening store, styrofoam block, plastic bottle, knife
Procedure: Fold a sheet of wire grid to make a table; punch holes in a piece of styrofoam; cut a plastic bottle in half and fill it with sand to increase stability. Or cut a plastic bottle along its vertical axis and rest the two cut edges on a flat surface. Cut holes into it for the test tubes.

Tripod Stands

Use: For supporting containers above heat sources, for elevating items
Materials: Stiff wire, metal rods
Procedure: Bring a sample to a welder or metal worker in town; make sure the stand is not too short or too tall. You can also make your own from stiff wire.

Water Bath

Use: To heat substances without using a direct flame
Materials: , water, cooking pot
Procedure: Bring water to a boil in a small aluminum pot, then place the test tubes in the water to heat the substance inside the test tube. Prevent test tubes from falling over by clamping with clothespins or placing parallel wires across the container.

Wire

All-purpose wire

Use: Connecting circuit components, current electricity
Materials: Speaker wire, knife
Procedure: Speaker wire can be found at any hardware store or taken from old appliances - the pairs of colored wires brained together. Strip using a knife, your teeth, or a wire stripper.

Specific gauge wire

Use: Electrical components, motors, transformers, simple generators
Materials: Copper wire without plastic covering (transformer wire), knife/scissors, matches
Procedure: Scrape or burn off the insulating varnish at any points you wish to make electrical contact. These wires come in a variety of diameters (gauges). A useful chart for converting diameter to gauge may be found here. If the wire is sold by weight, you can find the length if you know the diameter - the density of copper metal at room temperature is 8.94 g/cm^3. For example, with 0.375 mm wire, 250 g is about 63 meters.