Chapter 1 Energy

Energy in action

Energy makes it possible for work to be done, whether this is moving a boulder, evaporating water, growing a leaf or creating a volcano. Energy can appear in many different forms. It may be radiation energy as transmitted from the sun to the Earth; it may be chemical energy stored in plants and the food we eat; it may be electrical energy which enables lamps to glow or electric motors to operate; or it may be kinetic energy - the energy of motion such as that of a moving ball. Energy may be stored in water or in the air. This is due to the motion energy of the molecules of which the water and the air are made, and this is often referred to as heat: the hotter a body, the greater is the internal energy of the molecules, the more energy is stored.

Energy is constantly being transformed from one form to another. A rock at the top of a mountain is said to have gravitational potential energy due to its position; when it falls some of this energy turns to kinetic energy and when it hits the ground the energy is given to the surroundings, the molecules move faster and thus the surroundings become hotter. Energy from the sun is radiated into space as waves and some of this is intercepted by our planet as it orbits around the sun. This energy is absorbed by plants and stored as chemical energy, and animals and human beings absorb their energy as food, which enables us to do jobs of work. Some of the energy absorbed by the Earth millions of years ago has been stored in the coal and oil reserves within the Earth and which are now being used up at an ever increasing rate. It is important to realise that apart from the energy released when the nuclei of atoms, such as uranium, are broken up, all our energy comes originally from the sun.

The transfer of energy on Earth is governed by two fundamental laws:

- ☞ Energy can neither be created nor destroyed, it is merely transferred from one form to another.
- ☞ Although the total energy in any transfer is always conserved (in other words, there is as much energy at the end of the transfer as there was at the beginning), it often happens that some of the energy finishes in a 'useless' form. For example, when fossil fuel (coal or oil) is burnt in a power station, the stored energy is transferred to become electrical energy. But in the process some energy is inevitably lost to the surroundings which become hotter. In this form the energy is so spread out that it is virtually useless and cannot do further work. It is the role of the engineers to try to keep this 'lost' energy to a minimum.

Energy transfers have a profound influence on the environment, of which the following are examples.

- ☞ As the Earth moves in its orbit around the sun, it rotates on its own axis once a day. Owing to the inclination of the axis, different parts of the Earth get varying amounts of energy from the sun in the course of the year. This accounts for the different climatic changes in the north and south hemispheres.
- ☞ These differences in the amount of energy absorbed in different parts of the atmosphere lead to different temperatures and different pressures. In turn these lead to **convection** currents both in the atmosphere and in the oceans of the world.
- ☞ The water cycle is powered by the energy received from the sun. Water in the sea absorbs some of the radiated energy. The molecules move faster and some escape, and **evaporation** has occurred. Convection currents cause the water vapour to rise, in due course **condensation** may occur and the water falls as rain, forming streams and rivers, eventually returning to the oceans to complete the cycle.
- ☞ The radiated energy from the sun powers ecological systems. Green plants absorb

some of the energy in the process known as **photosynthesis**, enabling carbohydrates to be produced from carbon dioxide and water with oxygen being released as an additional product.

☞ Some of the energy in plants is stored in the seeds. For example, a bean seed (or pulse) contains a protein-sugar mix which powers germination. If the bean (or other plant material) is eaten by an animal, it provides energy through the breakdown of sugars in the presence of oxygen and releases carbon dioxide in the process.

It is important to appreciate that in almost every energy transfer some energy is lost to the surroundings. The engineer does his or her best to keep this heat loss to a minimum. In the case of an animal eating a plant or a person eating food, this 'lost' energy serves the very useful purpose of keeping the body warm.

The sun radiates energy in the form of waves. Because the sun is very hot, many of these waves have very short wavelengths. Radiation of short wavelength can penetrate glass. All objects radiate some energy, but objects which are much cooler than the sun give out waves with a longer wavelength and these do not penetrate glass but are absorbed or reflected by it. Thus in a greenhouse, the sun's radiation passes easily through the glass and warms the plants inside. As the plants are very much cooler than the sun, they radiate waves which do not pass back through the glass. The greenhouse thereby traps the energy inside and it becomes warmer.

A similar **'greenhouse effect'** occurs around the Earth. The carbon dioxide and other gases in the atmosphere allow short wavelength radiation from the sun to reach the Earth but trap longer wavelength energy which the Earth radiates out. So if there is an increase in these gases, due, for example, to the burning of fossil fuels, it is inevitable that the Earth will become hotter. The resulting climatic changes will affect both natural ecosystems and agricultural crops as well as causing a rise in sea level. This 'global warming' has led to considerable concern amongst scientists, politicians and lay-people alike.

A further factor involves the destruction of forests which absorb atmospheric carbon dioxide. Deforestation will therefore contribute to the greenhouse effect through decomposition and burning, which release carbon dioxide, and also because carbon dioxide which would have been used by the forest plants is now being left in the atmosphere.

Energy

Basic concepts and issues

Energy sources

Photosynthesis

Energy storage

Convection

Condensation

Evaporation

Energy conservation

The greenhouse effect

Activities

1.1 Do-it-yourself greenhouse

1.2 Energy from the sun

1.3 Maintaining the balance

1.4 Energy transporter

1.5 Puddle-o-meter

1.6 Power plants

1.7 Photosynthesis game

1.8 Energy from water power

1.9 Energy from wind power

1.10 Time pieces

1.1 Do-it-yourself greenhouse

Concept

The sun radiates short wavelength waves to the Earth which pass easily through the atmospheric gases. Objects on the Earth are much cooler than the sun and so radiate waves with much longer wavelength and this radiation cannot pass through the atmospheric gases, so that the energy is trapped as happens in a greenhouse.

Context

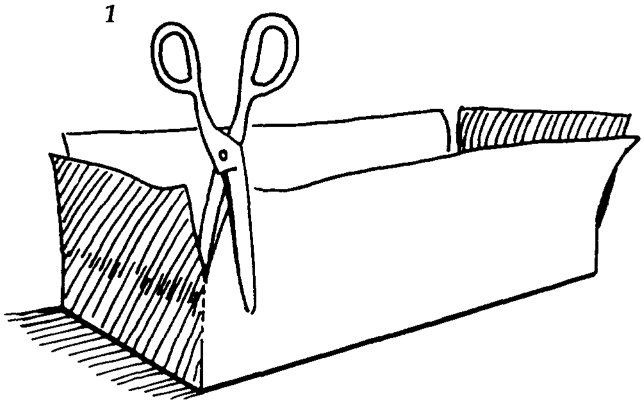
A way to investigate the natural greenhouse effect by constructing a simple greenhouse made from waste materials.

Equipment

Sticky tape - cardboard box - scissors or craft knife - polythene bags - cans or plastic cartons - paint - soil - water - thermometer

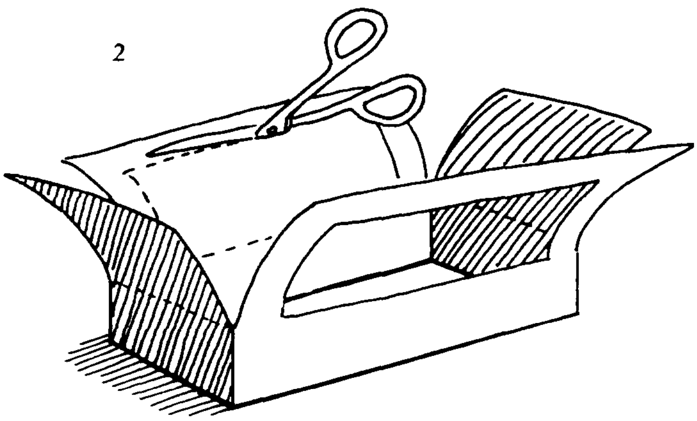
Making it

1



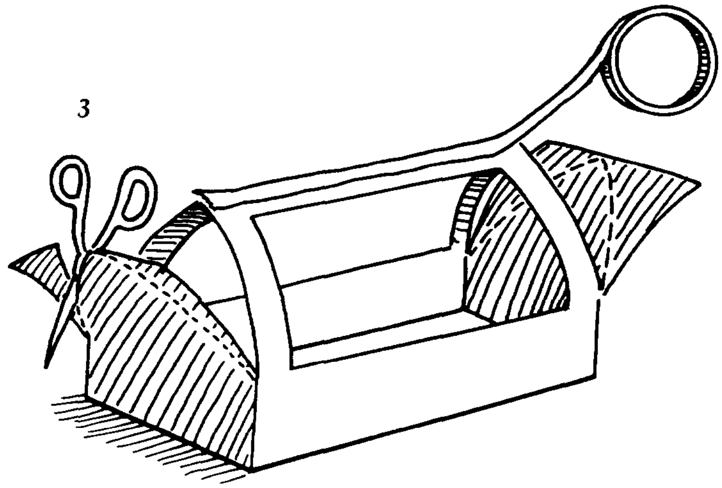
Cut down the corners of the box to form flaps. Leave about 4cm from the base to help maintain rigidity.

2



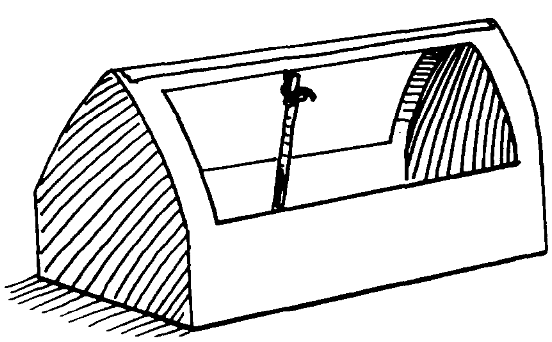
Fold the flaps outward and on the two longest sides cut out a rectangle leaving a 2cm 'frame'.

3



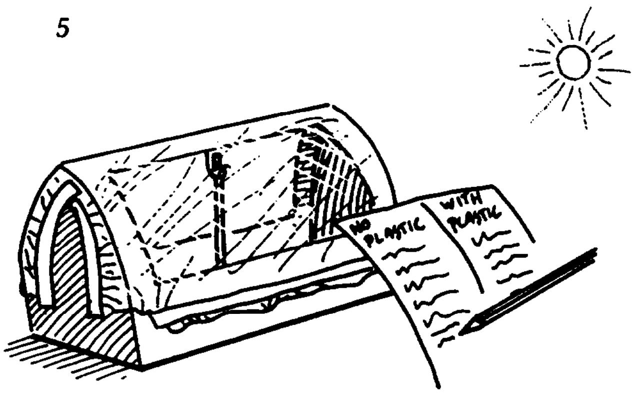
Join the two frames together along the top. Now trim the end flaps and tape them in place.

4



Place the 'greenhouse' in the sun. Suspend a thermometer from the apex of the greenhouse frame and record the temperature.

5



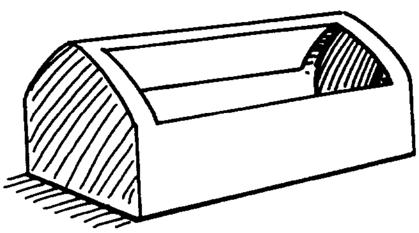
Tape clear plastic over the window frames, place the 'greenhouse' back in the sun and then take new thermometer readings.

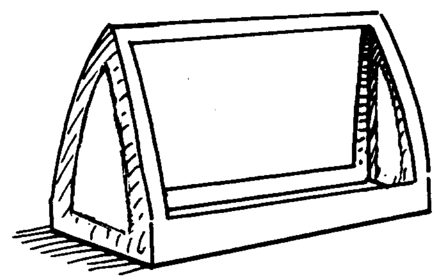
How do the thermometer readings taken after taping the plastic over compare with the earlier ones?

Make sure you place the box in the same position as it was when you took the first temperature readings and ensure that there are no unwanted air currents.

Using it

Try altering the pattern to create different shapes which will in turn vary the angle of the windows.





See if this has any effect on the temperature inside (and therefore on the amount of energy "caught").

From this simple investigation you can then explore other factors affecting how a greenhouse holds its heat.

Variations

Take another box and create a greenhouse with a window on each side but none at the ends. Line the base of the greenhouse with plastic and, before sealing it together, make a door in one end for easy access. You can now experiment with various other factors to see if they change the greenhouse effect:

a. Try painting different colours on the inside of the box and then monitoring the temperature.

b. Place tins containing 'nothing' (air), or stones, or gravel or water inside the greenhouse. (These can act as radiators storing heat over time).

c. Try insulating the greenhouse with different materials. (Relate the results to energy loss from homes and the value of insulating them).

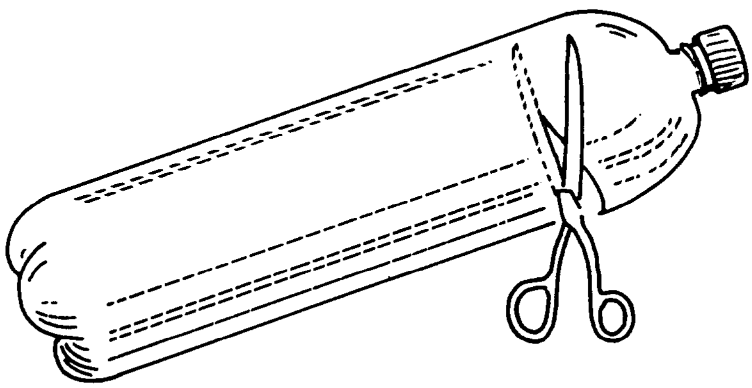
d. Try 'double glazing' the windows (do this by using two layers of plastic separated by a small air space) to see if this makes any difference.

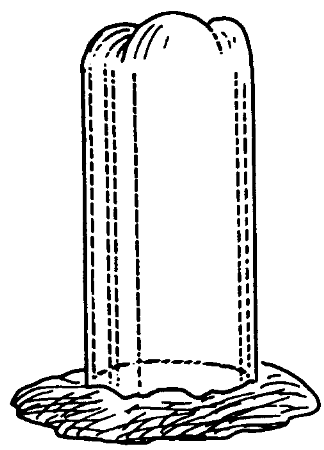
e. The greenhouse can also be used for growing and germinating experiments.

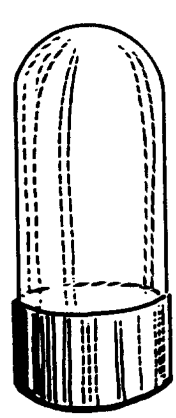
An alternative greenhouse

Alternative greenhouse designs can be developed using plastic bottles. Cut the funnel shape off the bottle. In crinkle bottomed bottles you can invert the bottle to make the greenhouse. A seal can be created by placing a ring of plasticine or clay around the edge. Where the bottles have a rigid base, remove the 'black cup' from the bottom of the bottle. The body of the bottle can be placed into the cup.

If no thermometer is available, the efficiency of the greenhouse can be tested by investigating its evaporation abilities. Time how long it takes for a standard amount of water (eg. 1 ml) to evaporate or weigh a plastic cup or jar of water before and after leaving it for some time in the greenhouse.







1.2 Energy from the sun

Concept

As the Earth moves in its orbit around the sun, it is also rotating once a day about a North-South axis through the Earth. This rotation accounts for night and day. However, the inclination of this axis is such that different parts of the Earth get varying amounts of energy at the different seasons of the year.

Context

An activity starting in the classroom which then moves outside to show why the amount of the sun's energy hitting the Earth's surface varies.

Equipment

*1. **Paper planets:** a balloon - old newspaper - bucket - water - torch - sticks - plasticine or clay*

*2. **Sundial:** card - sticks or straws*

Making paper planets

1. Shred the newspaper into strips.

2. Make up a bucket full of water and flour mix. This should be the consistency of runny paste. The amount of flour varies with size of bucket and water.

3. Soak your strips of newspaper overnight in the paste.

4. Cover the partly inflated balloon in a criss-cross pattern with the soaked paper to make a papier maché globe. Remember not to fill the balloon to its full size if you want a sphere.

5. When the balloon has gone down (or bursts) it leaves a paper globe. This can be mounted on a desk using plasticine and a stick. The stick is simply pushed into the plasticine (or clay) and the globe lowered over it.

6. The continents may be painted on the globe or different sized 'planets' created.

Using it

1. Place the globe in the middle of a darkened room and shine a torch onto it. Look at the area of the globe covered by the light. (It may be helpful if you restrict the torch's beam by covering it with silver foil from sweet wrappers to leave only a small hole for light to escape).

2. You can fix the torch in a bench clamp or vice and then experiment with different angles or rotate your globe around. Is there an area that always receives light? What parts of the globe receive least sunlight energy? What happens as the angle of tilt increases?

3. You can follow this activity with an outdoor one. By making a simple sun dial it is possible to monitor the sun's path during the day and over several months.

Making sundials

A sundial is easily made using a straight stick (such as a lolly stick) and a piece of card. Place the card on the ground and carefully make a hole in the middle. Push the stick through the hole into the ground. Make sure you do not site the sundial in the shade.

Adapting it

Try measuring the shadows during the day. Mark the times when the shadow is longest and shortest on the card and record the time and position of the shadows.

Compare shadow length at different times of the year. How might this be connected with the weather conditions?

Try different sized globes and look at the effect of different shapes.

A variation on using the papier maché approach is to use an old cloth (muslin for example) which is soaked in runny plaster or wet clay.

1.3 Maintaining the balance

Concept

All living things breathe in oxygen to make energy available for a variety of activities through the process of respiration. This process, like the burning of fossil fuels, produces carbon dioxide and water as by-products, some energy being lost as heat. Plants also photosynthesise, using the energy of the sun to build up food from carbon dioxide and water, and in the process produce oxygen. Maintaining the balance of these atmospheric gases is extremely important.

Context

These activities demonstrate an invisible balance between the two gases - carbon dioxide and oxygen. Obviously both gases are vital for the maintenance of life but carbon dioxide is currently being produced faster than it can be absorbed by plants. The increasing levels of carbon dioxide (one of the 'greenhouse gases') is one of the factors contributing to global warming. You can investigate the production of carbon dioxide by burning candles and varying the volume of atmospheric oxygen available.

Equipment

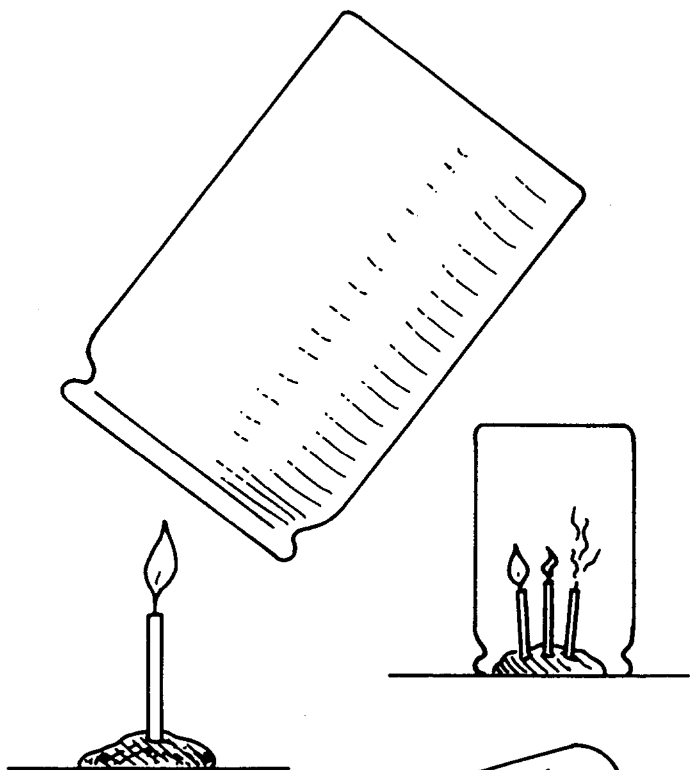
Glass jar - candle - plasticine or clay

Making it

1. Fix the candle in place on a bench using the plasticine or clay.

2. Light the candle and cover it with the glass jar.

3. How much time passes before the flame goes out?



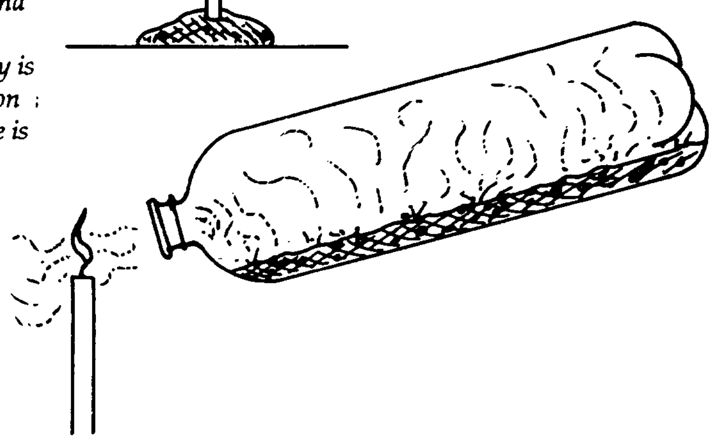
Using it

1. Get your group to compare the effects of burning more 'fuel' by increasing the number of candles.

2. Try varying the size of the jar. (The volume of air can be measured in each jar using a measuring jug. Fill the jars you are using with water; empty the water into the measuring jug and read off the volume of water which will equal the volume of air).

Adapting it

Mimic the action of breathing out (exhalation) using a plastic bottle. Put some vinegar into the bottle and then add some bicarbonate of soda. These react together creating a brown bubbling 'fizz' as energy is released and the chemicals combine (gaseous carbon dioxide causes the fizzing). If the neck of the bottle is held near to a lighted candle and gently tilted the escaping gas can put out the flame.



1.4 Energy transporter

Concept

Energy from the sun is absorbed by the surfaces it hits and the nature of the surface will determine how much is absorbed or reflected. This energy can also be absorbed by water. If the water receives sufficient energy it will then change state to a gas (evaporation). This gas floats upwards on warm air currents. This hot air cools, and the water vapour cools, releasing energy as it condenses.

Context

This activity involves making 'solar panels' to absorb the energy of the sun and using this to heat up water.

Equipment

Black plastic bin liner or bag - clean tin can - cardboard box - assorted glues and sticky tape - cutting implements - clear plastic (such as old bags or rolls of cling film) - thermometer

Making it

1. Divide the participants into groups of 3 or 4.

2. Give each group the same sized plastic bag, (preferably black), a tin can full of water and a cardboard box.

3. Let the groups have as much clear plastic as they require and easy access to the tools, glue and tape.

4. Ask them to create a device which will heat the water in the can to the highest possible temperature using the sun's energy.

5. After an allotted time ask the groups to place their 'solar panels' somewhere outside in the sun. If the sun is a problem electric lamps can be used instead.

Using it

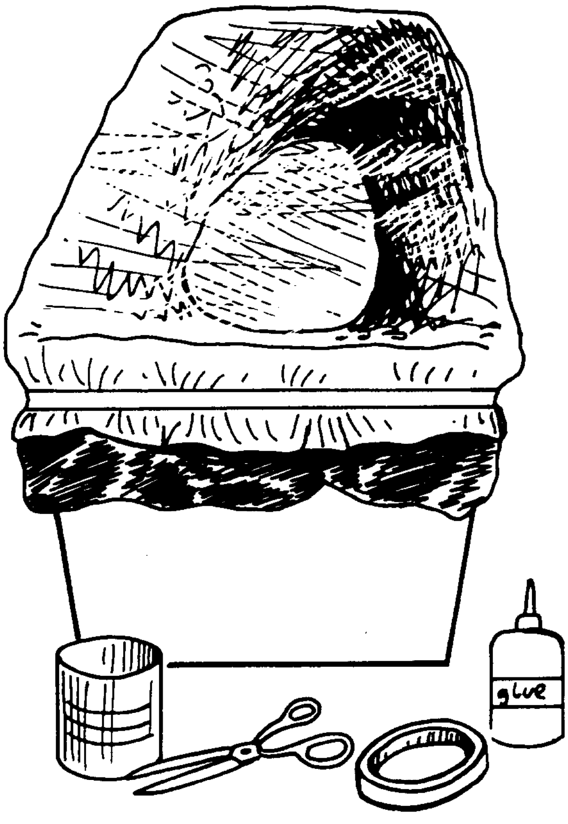
1. The black bin liner will absorb the sun's energy efficiently and help to warm up the water better if it is in direct contact with the water (ie. tip the water out of the can into the bag). You may find it necessary to lead the group with suggestions in this early stage.

2. This is an open-ended exercise but it can lead into other energy transporter activities showing convection and condensation.

3. You may wish to demonstrate cloud formation by boiling a kettle. The formation of steam, as droplets of water condense from vapour, is the same as the cooling of rising water vapour in the atmosphere. You can also demonstrate the rising of hot air as it is replaced by cooler air by dropping a feather over the top of a heat source such as a radiator. The feather should 'float' on the hot air.

Adapting it

You can vary the types and colours of the materials used to heat the water. This can show the effect of different land surfaces on the absorption of energy from the sun.



1.5 Puddle-o-meter

Concept

As a liquid absorbs energy - for example from the sun or by being heated on a stove - the molecules move faster and some will have sufficient energy to break away from the liquid and become a gas. This process is known as evaporation.

Context

The sun's energy will evaporate water from oceans, reservoirs, ponds and other water bodies. This can easily be monitored using the puddles formed after a rain storm.

Equipment

Chalk or thick marker pen - puddle - impermeable surface

Making it

1. Choose a puddle formed on tarmac, concrete or polythene.

2. Mark out its perimeter using chalk or the marker pen.

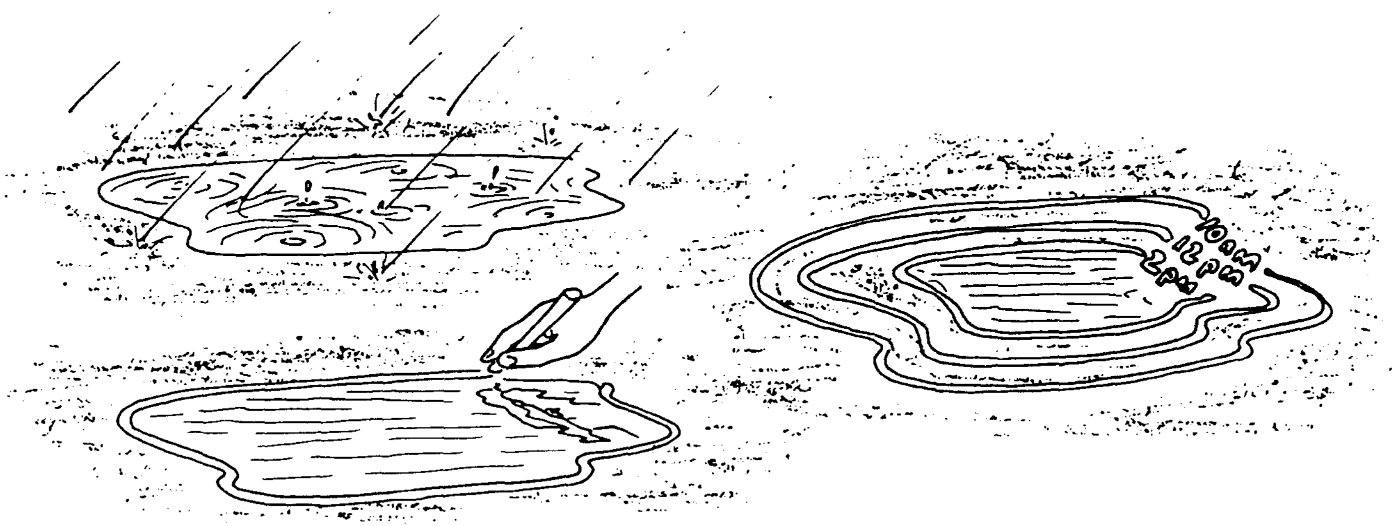
Using it

Measure the puddle's diameter and draw new perimeters round it through the day. Remember to record the time that you do this so that comparisons can be made between different puddles in different situations and you have an idea of how long it takes for puddles of any one size to evaporate. How is the rate of evaporation affected by the depth of the puddle? (You may wish to refill the puddle up to the perimeter marks to discover the volume of water that has evaporated over the time the recordings were taken).

Adapting it

Try comparing the rates of evaporation of different surfaces such as tarmac and concrete.

Also try the experiment on different days and under different conditions (linking it to the 'Weather station' ideas in the section on Air).



1.6 Power plants

Concept

During the process of germination, plants grown from seed use up their stored energy reserves.

Context

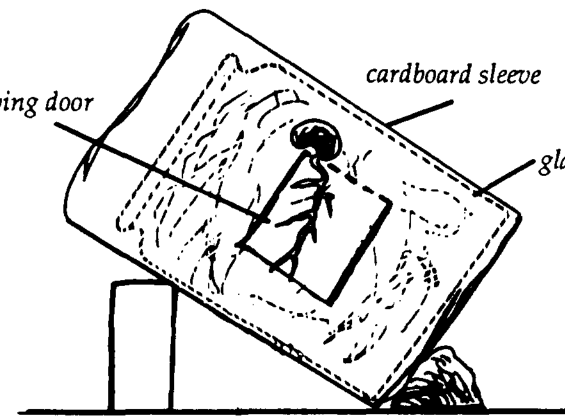
This activity observes the process of germination and investigates some of the factors affecting the growth of young seedlings.

Equipment

Glass jars - tissue paper - bean seeds or radish seeds - cardboard - growth medium (sand - soil - compost) - fertilisers

Making it

1. Seed germination can be studied easily by filling a jar with tissue paper. Place a bean seed between the paper and the side of the jar. Cover the jar in a cardboard sleeve to prevent light reaching the seed. Keeping the paper moist, you can monitor seed germination. You have made a 'root viewer'!



Using it

1. Place the root viewer at an angle by propping it up as shown. As roots respond to gravity they will grow downwards and you will then be able to monitor growth by observations through the door.

Variations

The effect of light can be tested by covering the viewer in a cardboard box, big enough to let seedlings grow, with a slit at one end. Ensure the joints of the box are sealed so that the only light source is through the slit. Remember that most plants can germinate with little or no light as food stores in the seeds provide energy. Also remember that light is needed after germination for photosynthesis so leave the experiment to run for a long period. The seedlings should grow towards the light.

Factors affecting nutrition and the energy required by a plant to grow can be monitored in your root viewer. This is done using the same method as before except this time the jar is filled with a growth medium. The cardboard sleeve should also have a door made in it. Sow your seeds in the jar and let them grow. Take care not to over water as there is no drainage.

1.7 Photosynthesis game

Concept

Photosynthesis is a sun-powered reaction enabling plant leaves (or other green parts of the plant which contain chlorophyll) to make food by combining carbon dioxide gas and water to produce sugars (releasing oxygen in the process). Photosynthesis is the basis of all our food chains since plants create the necessary fuels for cell growth and in turn provide nutritional energy for animals when eaten.

Context

This process is difficult to demonstrate but a 'play' approach often helps to put over some of the fundamental concepts.

Equipment

Card - string - pencils - torch or candle

Making it

1. You will need to make some labels. Pieces of cardboard attached to a string necklace can be made easily. Before threading the string it is best to strengthen the hole in the card with tape. Also tying the string as shown makes the cards last longer. One label is needed for every member of the group.

2. On half of your labels write (or invent a symbol to represent) carbon dioxide. On the other half write (or use a symbol for) water.

3. Now make a number of green coloured cards to represent chlorophyll in the leaf. (They need to be big enough for two people to stand on). The cards should then be scattered on the floor.

4. Darken the room and place in one corner the light source which will represent the sun.

Using it

1. As participants enter the room give them a card, which they should put on with the words or symbol towards their chest.

2. Explain to them that the room is the inside of a leaf which is a 'food factory'. When the sun comes out the 'factory' is able to combine water and carbon dioxide to form sugar (a food), oxygen being produced as a by-product.

3. The participants turn their labels around to see whether they are carbon dioxide or water. They then have to find a partner and stand on a green chlorophyll card that captures sunlight and powers the reaction. Only one couple can stand on a green chlorophyll at a time and everything stops when the sun goes down.

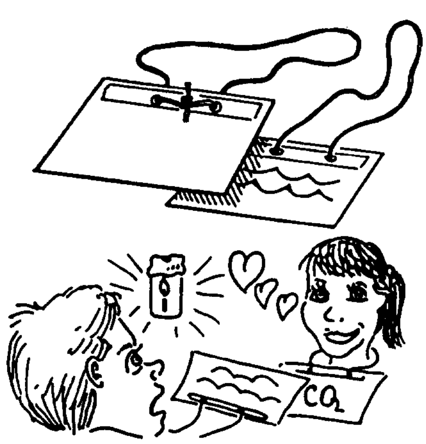
4. When the 'sun' comes up again the combined molecules can report to an 'exit' (a corner of the room you have designated prior to the game starting).

Adapting it

1. You can make cards where the reverse of the carbon dioxide gas label has ***sugar*** *written on it and the water label has* ***oxygen*** *on it. The oxygens exit to an 'atmosphere' sign and the sugars go to the* ***phloem*** *corner for distribution (phloem is the system of tubes in plant tissues which help to distribute food).*

2. Oxygen cards when exiting can be swapped for 'caterpillar' cards and 'pesticide' cards. The 'sugars' and 'pesticides' labels are kept hidden from the 'caterpillars'. When the the light comes on caterpillars get energy by eating (which they do by collecting sugar cards). If however a caterpillar finds it has collected two pesticide cards, the caterpillar 'dies'!

3. A simple candle lantern (the 'sun') can be made using a coffee jar with a candle in the base. An old silver foil sweet wrapper can be made into a vented lid. A cardboard sleeve can be lifted or dropped to represent 'sunrise' and 'sunset'.



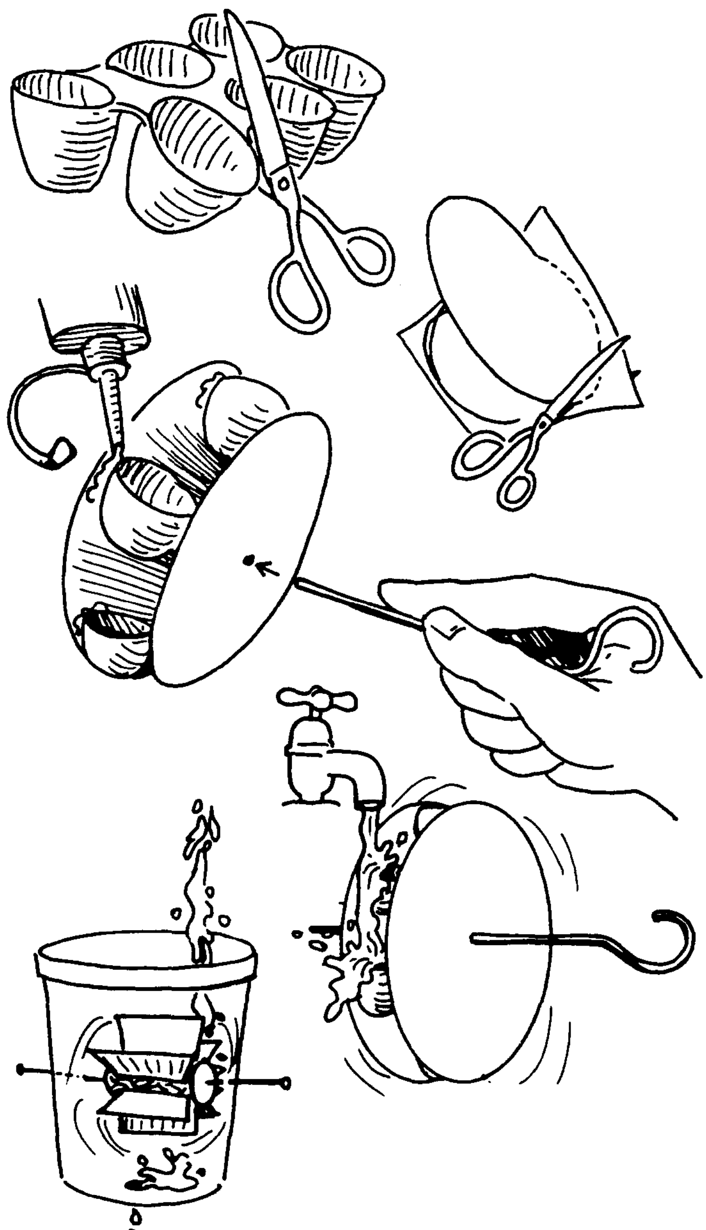
1.8 Energy from water power

Concept
The power of water can be harnessed as a useful alternative energy source.

Context
The principles of water power can be easily demonstrated. This is often best done by a group working together to design and make a simple working model of a water wheel. If this is successful more complex models may be developed.

Equipment
Plastic egg cartons or small plastic cups - waxed card containers - staples or waterproof glue - compass - scissors - paper clips (assorted sizes) - wire (coat hangers etc)

Making it
1. *Cut the cups from the egg cartons (or use small plastic cups).*
2. *Cut out two circles (the same size) from the waxed card.*
3. *Staple or glue the cups onto the waxy side of the card to make a water wheel.*
4. *Place a wire through the centre of the wheel, and bend the ends to make the wheel stand free.*
5. *Place the wheel under a small stream of water (eg. a tap or a tin of water with a small hole near the bottom) so that one cup begins to fill. As it overbalances the next cup should fill up.*



Using it
1. *From this basic design you can experiment with the number of cups and their position.*
2. *Try to design a pivot, axle and stand that can lift a small weight.*

Variations
Another simple water wheel can be made using a cork and large plastic carton.

Start by cutting down the carton lengthways to produce strips of plastic. These 'plastic fins' can then be fitted into slits made along the length of the cork. Push a pin through each side of the carton into the cork to complete your water wheel. Try using a plastic cup with the base removed so that water falling onto the water wheel can drain away.

1.9 Energy from wind power

Concept

The power of the wind can be harnessed as an alternative energy source.

Context

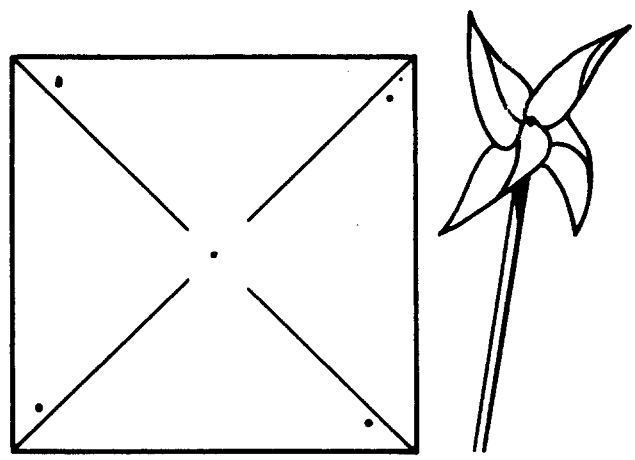
Wind energy has long been used to pump water and is now being harnessed to power generators. The following experiments investigate how the wind moves a windmill.

Equipment

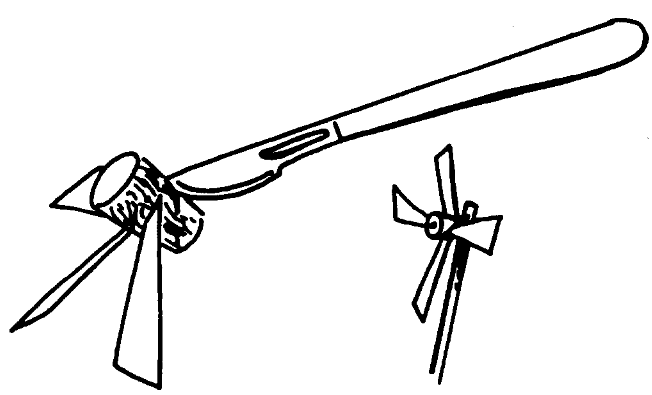
10cm card squares - corks - plastic cartons - wire - pins - wood scraps

Making it

1. A paper windmill can be made from 10cm squares of thin card. Draw diagonals as shown and mark the 5 holes with a pin. Cut along the diagonals almost to the centre. Bring the corners of the windmill to the centre and drive a pin through the holes into the wood.



2. A different design can be made using a cork and pieces of plastic. Cut slits into the cork and insert plastic blades cut from lengths of the plastic containers. Try different lengths and shapes of plastic. Also try different angles of blade (some straight, others slightly angled to the wind).



1.10 Time pieces

Concept
Energy exchange, absorption and transformation are often monitored over time. It is possible to create simple time-keeping devices that can be built and set up alongside those experiments which involve time-keeping.

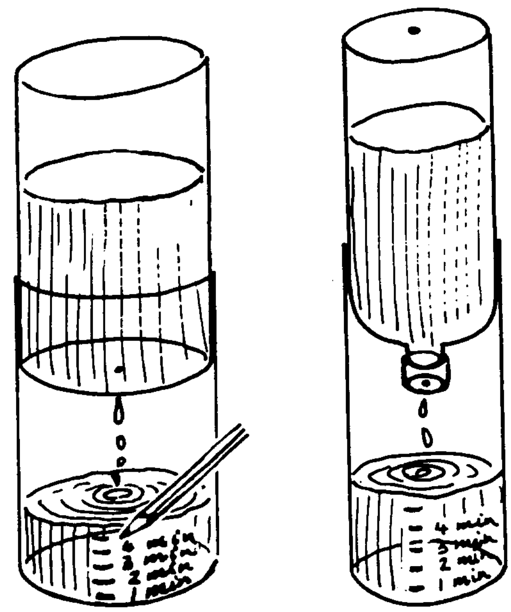
Context
Design and investigation often require clocks or stop watches and these simple home-made devices can be used as alternatives.

Equipment
Plastic bottles - marker pen - screw top jars - the loan of a watch or clock with a second-hand to calibrate your home-made timers

Making it - Water clock 1
1.Cut the funnel end (top section) off two plastic bottles (keep the funnels - they might prove useful for other experiments!).

2. Make a small hole in the base of one bottle and put it into the top of the other bottle.

3. Fill the top one with water and then mark time intervals on the side of the bottom one as it fills up.



Making it - Water clock 2
1. Remove the funnel end from a plastic bottle

2. Make a hole in the cap and base of a second plastic bottle.

3. Fill the second bottle with water (keep your finger over the hole in the base!) and invert into the first bottle as shown in the diagram.

4. Again mark time intervals as for water clock 1.

Making it - Sand clock
1. Take the lids of two identical jam jars.

2. Glue lids together (back-to-back) so that the jam jars can still be screwed into each end.

3. When the glue is dry make a small hole in the centre which passes through both lids.

4. Fill one bottle with sand. Screw the 'double' lid on then screw the other jar in. Invert the timer so that the sand falls into the empty jar. How long does it take for all the sand to move from one jar to the other?