CHAPTER XII

Experiments and materials for the study of sound
Children will find fundamental principles and elementary experiments in this chapter on sound interesting and closely related to everyday experiences.

A. HOW SOUND IS PRODUCED AND TRANSMITTED

1 Different sounds

Exercise on naming different sounds from experiments, if possible, such as crash (dish falls and breaks), thud (falling weight), clang (beating sheet of iron with hammer), clatter (falling tin cans), crackle (damp wood on fire), tick (clock), crunch (stepping on gravel), splash (stone falls into water), pop (toy gun), boom (drum), bang (door), patter (rain drops on pavement), tramp (feet), rustle (leaves), rattle (thunder, snake), rumble (far-off thunder; thunder rattles, crashes and rumbles) buzz (bee), tinkle (hitting spoon against drinking glass), neigh (horse), bleat (sheep), cackle or cluck (hen), low (cattle), chirp (bird), hiss (airplane), whistle, moan, etc.

Children will have fun imitating these sounds. Help them to find the exact definitions in dictionaries.

2 Vibrating bodies produce sound

Tie a loop of stout string in a hole near one end of a ruler. Hold the loop with the fingers. Swing the ruler in a vertical circle. Whirl it faster. What sound is produced? Repeat the same experiment with different sizes of rulers and loops. To make it easier, use another ruler or a wood rod instead of your fingers.

3 Say ‘Ah’. Prolong it and feel your wind- pipe. What causes the vibrations? Again feel it when you are speaking, singing and whistling.

4 Place a ruler on a table so that about three-quarters of it juts out from the table edge. Now hold down the end on the table with your hand. Bend the other end and let go quickly. The ruler vibrates up and down. Note what sound you hear. Again place the ruler so that half juts out from the table edge. Repeat the experiment. Note the sound you hear again. Is it different from the last one? Repeat the experiment with different lengths of the ruler jutting out from the table edge.

From these experiences one may conclude that sound is produced by vibrations. The vibrating bodies set up vibrations in the air which strike your ear, and you hear a sound.

5 Meaning of a vibrating object

Secure a small, heavy object, such as a piece of lead or iron or a small ink bottle. Tie the object with one end of a string about 1-m in length. Now set up a pendulum by hanging the object from the top of a doorway with the other end of the string. Let the object swing freely like a pendulum. How many swings will it make in one minute? Take many more counts with shorter lengths of string. You will note that shortening the string makes the object swing faster.

Also observe the vibration of a children’s swing.

Secure a pendulum clock and a metronome, or a musician’s time-piece. Make a study of rates of vibrations with these instruments. Imagine that an object vibrates faster and faster; beyond 16 times per second the surrounding air will be set into vibration, and a very low note will be heard. Higher notes are produced from faster vibrations, up to about 20,000 times per second, which is the highest note man can hear.

Also see Chapter XI, experiments B 3-5.

6 Run a toy car with a siren. The faster it runs, the higher the note it produces.

7 Blow across the mouth of an empty bottle. Try the same experiment with different-sized bottles.

8 Now replace the vibrating human lips in the last experiment by the wing top of a burner. Air blown through the wing top will pass the opening with great speed and spread out flat lile a broad flame. The resonating sounds produced depend on the vibrating air columns in bottles or tubes. Adjust the position of the wing top so that the air stream produces the loudest sound. You will hear the lowest note from a fairly big bottle or a paper mailing tube, up to the highest audible note from the end hole of a very small key.

9 Sympathetic bottles

Have a pupil hold the mouth of one bottle close to his ear without obstructing the opening. Now blow strongly across the mouth of another similar bottle until you produce a strong, clear note. Every time you do this, resonant vibrations are set up in the second bottle. These produce a weaker, though similar, note which your pupil can hear distinctly.

10 Secure a tuning fork and a used petroleum tin can, a violin or any wood box as a sound box. Set the fork into vibration by hitting it against a block of wood. Then press its handle against the sound box. You will hear a very loud humming sound from the box. Repeat the experiment with a dinner fork.

11 Air carries sound

Let one person whistle; other persons in the same room will hear the sound distinctly. Now send the first person into another room, and let him whistle again; it will no longer be possible to hear him distinctly.

12 Sound cannot travel through a vacuum

Make a vacuum pump and receiver (Chapter VII, experiment I 3).

Tie two small bells inside the vacuum receiver. Start the experiment by shaking the receiver with air inside; you will hear the bells ringing. Then screw in the cap tightly, suck the air out of the receiver with the pump. Shake the receiver again; you will not hear the ringing of the bells as clearly as before. What does this mean?

Repeat the experiment, but create the vacuum by burning pieces of paper in the receiver.

13 Take a long garden hose, open at both ends. Use it as a telephone line for talking and listening to another person. Air inside the hose is the carrier of sound. The principle is still applied within a ship for speaking from one quarter to another.

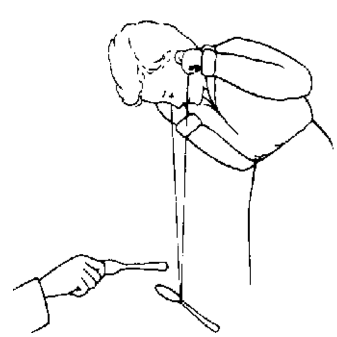
14 Solids carry sound

Secure two used tin cans with lids neatly cut out. Now punch a small hole in the centre of the bottom of each tin can. Thread several metres of a thin cotton string through the holes. Attach a matchstick at each end of the string so that the matchsticks cannot go through the holes. Now use the cans as telephones: get the string taut and talk and listen to your pupil. Sound travels through the string and through the air inside the tin cans. The bottom part of the tin acts as a diaphragm.

This experiment can also be performed with two empty matchboxes, one side of each being covered tightly with thin pieces of transparent cigarette wrapper paper. The holes may be punched in the paper.

15 Church bell from a spoon

Cut one metre of a cotton cord. With both ends together, balance a teaspoon in the loop. Now hold each end with your fingertips. Press both ends to your ears and bend down so that the string and spoon hang freely. Let someone hit the spoon lightly with a nail or another spoon. You will hear a chime like that of a church bell. Again sound travels right up the string, ending in your ears.



16 Tapping codes through water pipes

Send a code message made up by a pupil and yourself through a water pipe that goes from one room to another on the same floor or on different floors. By striking the water pipe with a piece of iron in one room the sound reaches your pupil in the other. Then interchange messages. Sound travels through the water pipe this time.

17 Hear through your teeth

Set a fork or a tuning fork into vibration. Wait until you cannot hear any sound from the fork, then place the handle between your teeth. The sound will still be heard. Repeat the experiment by placing the handle on the bone at the back of your ear.

18 Liquids carry sound

Place your head under a pool of water so that your ears are immersed. (It may be in a swimming pool, the sea, a river or even a bath tub.) Let somebody else strike a gong or a bell under the water away from you, while your ears are still under water. You will hear the sound coming through the water clearly. It is a fact that sound travels about four times as fast under water as through air.

19 Gas balloon acts as a sound lens

Fill a rubber balloon with air by blowing into it with your mouth until it expands to normal size. Hold the balloon with your fingers. Now the balloon is partly filled with carbon dioxide gas. Hold the balloon between your ear and a watch. You will hear the sound of ticking more clearly than without the balloon. This is because sound waves travel more slowly through heavy carbon dioxide gas than they do through air. The balloon acts as a con- verging lens to sound waves. Repeat the experiment with a balloon full of hydrogen gas.

20 How waves travel

The way in which energy is carried by waves can be studied by observing how they travel along the surface of water. They can often be seen in lakes, ponds and harbours, and the patterns produced help to explain many of the phenomena of light and radio, as well as of sound.

A more detailed examination of this behaviour can be made in the laboratory by producing ripples on the surface of a shallow dish of water. One way of making the patterns more visible is to place a source of light underneath a shallow tank with a glass bottom. Ripples produced in such a tank behave as cylindrical lenses, and shadows are seen on the ceiling or a screen placed above.

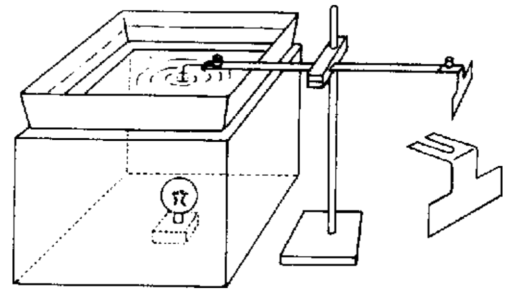
21 Making a ripple tank

Cut a rectangular aperture in the bottom of a photographic developing dish of full plate size, leaving a rim about 2.5 cm wide all round. Fit a sheet of clear glass to the tank and stick it down to the rim using a waterproof glue. Set it aside to dry. Obtain a cardboard box about 30 x 30 x 45 cm in size. Cut a circular hole L5 cm in diameter in the middle of one of the smaller faces, and make a small door in the middle of one of the rectangular sides. Paint the inside of this box a dull black. As a point source of light fit a car bulb and holder to a cube of wood of 7.5 cm side.

Stand the tank over the circular aperture in the box, and pour in water to a depth of about 1 cm. Darken the room and switch on the bulb. Observe the circular pattern produced on the ceiling when a drop of water falls into the water from a pen filler or pipette. If the pattern is distorted by the action of waves reflected from the sides of the tank, fit sloping beaches of picture frame moulding in the water all round the edges. Should there be patterns parallel to the sides caused by vibration of the tank as a whole, stand it on strips of 'sorbo' robber or felt.

Continuous trains of waver can be produced by a vibrator with one end dipping into the water. Clamp a 30 cm hacksaw blade in the middle and attach a single piece of stout copper wire to one end, using an electrical terminal or a small bolt. Bend the wire at right angles to the plane of the blade and cut it off about 2.5 cm long. Support the blade in a firm retort stand so that the end of the copper wire dips into the water in the tank. Pluck the free end of the blade, and notice the generation of continuous waves.

Cut a T-shaped piece of tin to form a dipper for plane waves and attach it to the free end of the blade as before. Stick a piece of plasticine to the blade near the copper wire so that both ends of the blade carry the same load; in this way the vibration will be maintained for a considerable time.



22 To study reflection of waves

Cut strips of tin slightly wider than the depth of the water in the tank and about 8 cm long. Bend the end of one of them at right angles and stand it in the water near one end of the tank. Adjust the position of the vibrator so that circular waves are reflected from this obstacle. Use both single pulses and continuous waves. Notice that the reflected waves appear to diverge from a spot as far behind the 'mirror' as the vibrating wire is in front. Now replace the point dipper by the fiat piece of tin which generates 'plane' waves. Observe the form of the reflected waves when the obstacle makes different angles with the incoming waves. Clearer patterns are obtained with plane waves if the lamp is turned on its side and so placed that the filament is parallel to the dipper. Repeat these experiments using a curved strip of tin which represents a convex or concave reflector when different sides face the waves.

As ripples have a lower velocity in shallow water than in deep water, it is possible to study the transmission of waves as they pass into an apparently 'different' medium. To study, for instance, the action of the 'sound lens' of experiment 19 above, use a circular disc of glass or Perspex to form a circular 'shallow' in the tank. Place such a slab in the middle of the tank and use a pipette to adjust the level of the water so that the slab is just covered. Allow a train of plane waves to pass over it and notice that the waves passing over the diameter of the slab are held back and there is a resultant focusing effect. Slabs of different shape can be used to study refraction at a single surface, and the action of prisms and lenses.

B. SOUND AND MUSIC

1 Vibrating box

Cut a hole in the bottom of a used tin can. Put a stout string or a fishing line through it with its end tied tightly to a pencil inside the can. Rub resin on the string. Hold the can with one hand and keep the string taut with two fingers. Now draw your fingers along the line. Sound will come from the can. Repeat the experiment of drawing your fingers along the line at different speeds. Note the different pitches of sound. Can you make music out of the can? Try again with different sizes of tin cans and candy boxes. Will wood boxes give similar sounds?

2 Rubber band harpsichord

Stretch several rubber bands about a cake tin, cigar box, photographic developing dish or wash basin. Arrange them to different tensions with correspondingly different keynotes. Now play on them as on a harpsichord. The principle of this instrument is vibrating strings and a sound box. Repeat the experiment with various sizes of rubber bands on the same box.

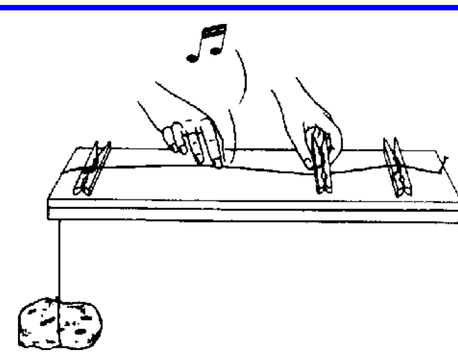
3 One-string guitar

Secure a steel wire about 1 m long, a nail, three clothes pegs, a sound box made of thin plywood or of some other material (size about 60 x 15 x 3 cm) and a weight to hold the wire taut. Assemble these parts as shown in the diagram. Can you get music out of this home-made guitar? Repeat the experiment with more strings.

4 Music box with pins

Arrange several pins in a row on the sound box used in the above experiment or on a cigar box. Play music on this music box by plucking the pins with a letter opener. You will get lower notes out of longer pins and higher notes out of shorter ones.

Make another observation using a hair comb having different lengths of teeth.



5 Drinking straw orchestra

Secure 10 drinking straws for five players and a pair of scissors. Flatten one end of a straw and cut both corners of this hat end. Now this flat end acts as the reed of a wind instrument. Blow into it and adjust the reed until you get the best vibrations.

Next, set up an orchestra by making similar reeds out of other drinking straws. Cut off the other ends of the straws bit by bit to tune with different musical notes until you get a complete scale. Each of the five players is responsible for two notes, holding a straw in each hand. To begin with, try to play your National Anthem.

The principle is that the air column inside the straw vibrates because of the vibrating reed.

6 Bottle and glass tube trombone

Secure a glass or metal tube about 1 cm in diameter and 20 cm in length, and a bottle nearly full of water. Hold the bottle in one hand and the glass tube in the other, with the end of the tube dipping in the water. Now blow across the other end of the tube for a note. Next, as you blow, move the bottle up and down. You will hear various notes as you change the length of the column of air vibrating in the tube.

7 Musical bottles

Prepare a set of musical bottles so that each contains an air column tuned to one of the notes of the scale. Select eight similar bottles. Let the first one be empty. If water is added to the others to the proper heights, when they are tapped with a ruler or chopstick they will sound out a complete musical scale. You can do the same experiment with tall drinking glasses. The air columns inside the bottles or glasses take up vibrations from the outsides.

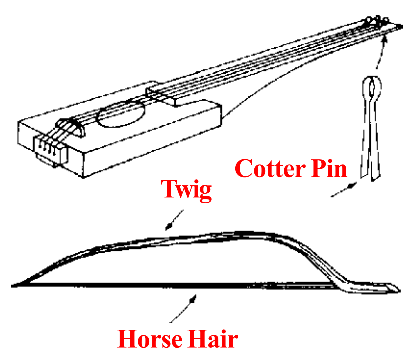
It is fun also, if you happen to possess china vases or bells of many sizes. Pick out those which are tuned to notes of the scale. Arrange them in a row. Hold a chopstick or a fork in each hand and carefully beat out a tune on them.

8 A set of dinner chimes

Secure a straight steel pipe about 3 cm in diameter and about 3.5 m in length. Cut it into four parts, 100 cm, 90 cm, 80 cm and 70 cm. Drill holes through both sides of each pipe near one end, and suspend them. Let them hang freely. Strike each pipe in turn with a rubber hammer and compose a sort of signature chime for your class.

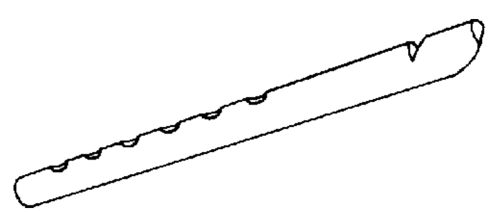
9 Cigar box violin

Procure a cigar box or any similar box, regular strings from a music supply store, bits of wood, a piece of resin and cotter pins. Try to assemble these parts yourself so as to make the cigar box violin shown in the figure. The bow may be made from horsehair and a twig about 70 cm in length.

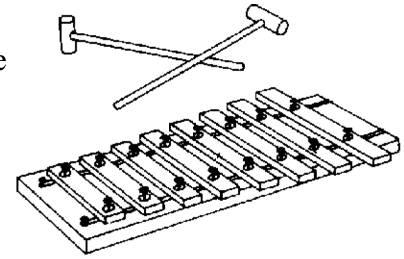


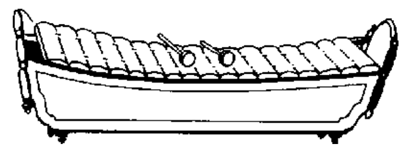
10 Shepherd's pipe

A section of bamboo is suitable for the pipe. Secure a straight bamboo about 1.5 cm in diameter and 30 cm in length, open at both ends and all through its length. Dry it by roasting on a small fire until its skin turns a yellowish brown all over. When it cools, make the mouthpiece and row of holes as shown in the figure. The pipe is similar to a tin whistle but the sound obtained is sweeter. The air column vibrated is measured from the exit hole in the mouthpiece to the first uncovered hole.



11 Xylophone and marimba





What you need here are strips of hard wood, bamboo, or iron, and a board; 8, 12 or 16 of these strips, cut to the proper lengths to sound out the scale when tapped, are required. For pieces of hardwood 2.5 cm wide and 1 cm thick, lengths of 20.0, 22.8, 24.2, 25.8, 27.2, 28.3, 29.5, 30.5 cm will give the diatonic scale. For the fiat board of the xylophone, drill a hole about 2 mm in diameter near the end of each strip. Lay strips of felt on the board and drive small nails through each hole to hold the strips loosely. The strips will vibrate when tapped with a rubber hammer. This can be made from a pencil and a piece of eraser.

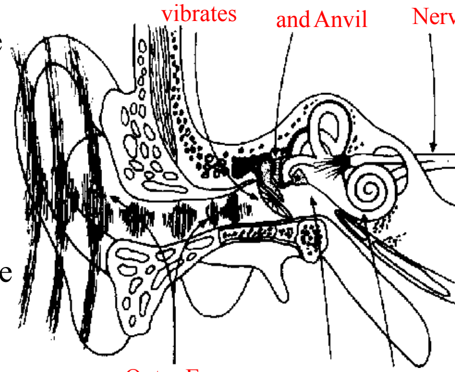
For the marimba, pieces of wood are shaped, as shown in the figure, to form the base and act as a sound box. Drill two holes near the end of each strip. Put a stout string through aid the holes as shown and suspend the strips over the box.

Now procure two rubber hammers with rather long handles. Tap the strips lightly to obtain music.

Other simple musical instruments can be constructed, e.g., a variety of drums, scale of small gongs, flutes and many string instruments. Try to devise them yourself.

C. RECORDING AND REPRODUCING SOUND

1 How the ear works



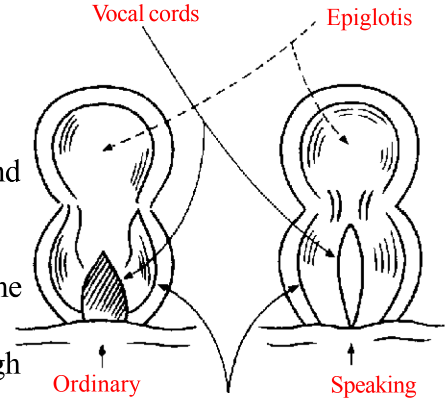
Air vibrations enter the ear by the auditory passage formed at the base of the ear by the ear-drum membrane. They set the ear-drum in motion and, in doing so, set in motion the system of three little bones attached to it; by this means they reach a cavity in the bone called the inner ear.

One part of the ear is shaped like a snail shell. Here is found the organ which receives the sound vibrations and is connected with the brain by the auditory nerve. Another part of the inner ear which includes three small semicircular canals and serves to maintain equilibrium plays no part in hearing.

Sound vibrations are normally transmitted to the snail-shell-shaped cochlea by the ear- drum and the small bones (this gives rise to a nerve message which is carried to the brain); but they can also be transmitted by the bones of the skull, and we hear a sound if the waves reach the cochlea by either route.

When a sound reaches our two ears, we can distinguish the direction from which it comes; if it comes from straight ahead, the vibrations reach both ears at the same time and with the same strength; but if the source of the sound is on one side of us, one of our ears is farther away from it and receives the waves less strongly and with a slight delay.

2 How the voice is produced

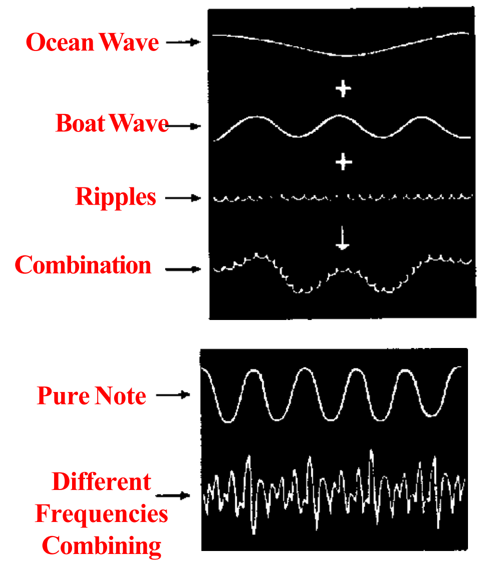


Mouth, teeth, tongue, throat and lungs are all used in the production of the voice. The sound is produced by vibrations of two thin sheets of membrane called the vocal cords, which are stretched across the sound chamber called the larynx. The larynx is the upper end of the windpipe and is located well back, at the base of the tongue. Here a trap door of cartilage called the epiglottis automatically drops down over the larynx when you swallow, so that no food will go through the windpipe. When the cords are stretched by the contraction of certain muscles in the throat, a narrow slit tends to form between them. It is when the air is forced through this narrow slit that the cords are forced to vibrate. This sets the air vibrating in the windpipe, lungs, mouth and nasal cavities.

3 Sound wave patterns

The number of complete vibrations in one second is the frequency of a particular vibration. The way in which different sound frequencies combine is analogous to water waves. Ocean waves are longest, i.e. of low frequency. Let a small motor-boat pass over these waves. The boat sends out its own waves, which have a shorter frequency than ocean waves. Next, if there is a breeze, it will send tiny ripples across the surface of the motor- boat waves. The ripples usually have an even shorter frequency than the other two. Now these three vibrations combine to form a pattern shown in the figure.

In a similar way, sound waves of different frequencies from various instruments combine and form sound wave patterns.

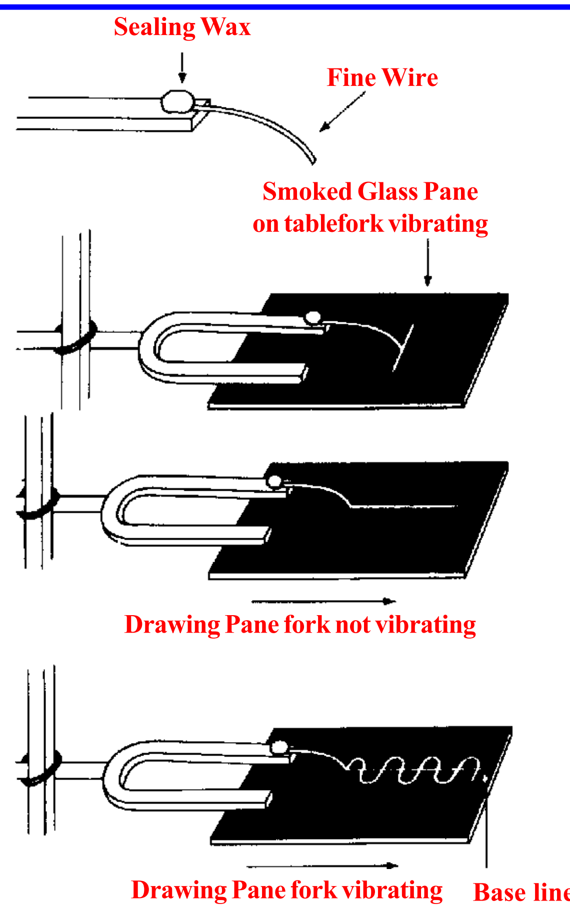


4 Wave pattern of a tuning fork

With a few drops of hot sealing wax attach a piece of fine wire to the prong of a tuning fork. The fork is held rigidly by the handle and placed horizontally just above the table top. Smoke a small pane of glass from the flame of an oil lamp or a candle. Now lay the smoked glass pane under the prong with the fine wire which is bent to touch the glass pane. Start the vibrations with the finger and draw the pane along the table fast enough to make a wavy line on the pane.

Repeat this experiment drawing the pane away at different speeds and using different tuning forks.

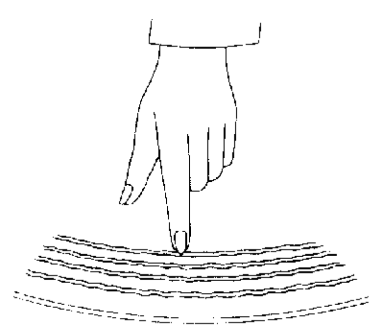
The higher the top of the wave from the base line the louder the sound.



5 A gramophone reproduces sound

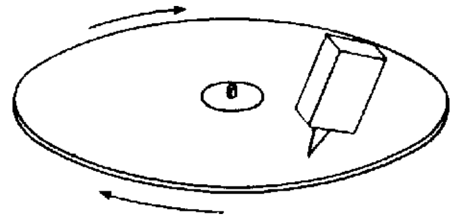
Secure a 78 r.p.m. gramophone record and a hand magnifier. Through the magnifier you will notice a great number of wavy lines on the record. If possible, compare the wavy lines of records of different speeds.

Next, set the record turning at its usual speed of rotation. Place the edge of your finger-nail in the groove and listen carefully. Do you hear music coming from your nail? Do you feel your nail vibrate? It is clear that your nail is forced to vibrate as it follows the grooves, and produce the recorded sounds.



6 A simple reproducer

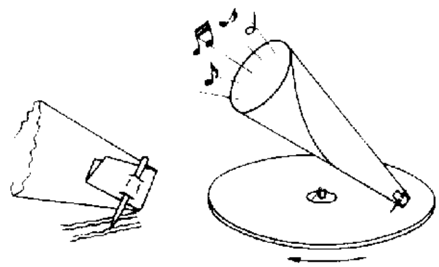
Thrust a record needle through the corner of a card or an empty matchbox. Now repeat the last experiment. Let the needle replace your fingernail. Has the sound been amplified ?



7 Another simple reproducer

For a more effective home-made reproducer you can copy the early phonographs by using a horn. Substitute for the card or the match- box a horn made out of a square sheet of heavy wrapping paper, about 40 x 40 cm.

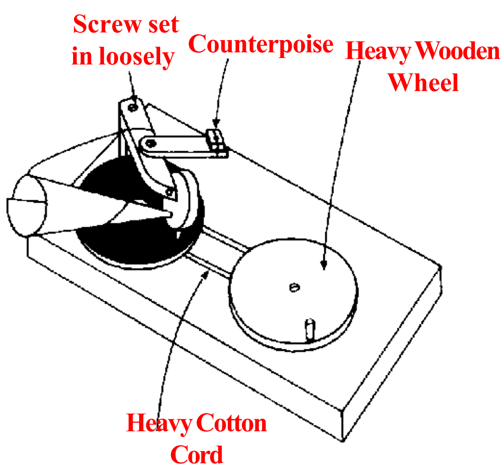
Shape the paper into a cone and fold the small end. Force a needle into all thicknesses as indicated in the diagram. Hold the horn so that the needle will rest lightly in the groove as the record rotates. Now, everybody in the room should hear the music from your simple reproducer.

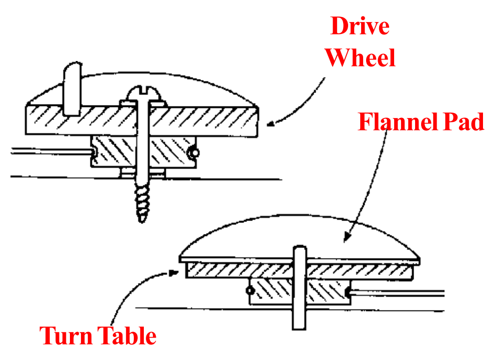


8 A gramophone for everyone

What you need are two circular pieces of wood about 2.5 cm thick, and 30 cm in diameter, a base board about 80 x 40 x 2.5 cm, a sheet of flannel, 30 cm in diameter, as base, a piece of mica sheet 10 x 10 cm, a tube of Duco cement, gramophone needles, pins, a metal flange as frame of the reproducer, and an adaptor for the needle.

Your gramophone will look roughly like the first figure. Mount the two circular pieces of wood on the base board as illustrated, with the drive wheel and turn-table connected by a suitable length of heavy cotton cord. The flannel or felt pad is glued to the turn-table as the base for the record.



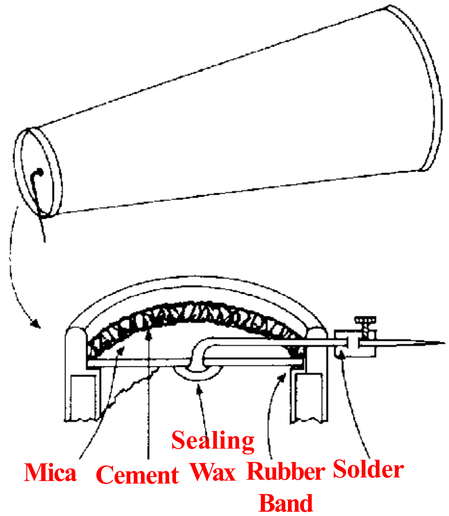


The important part of the machine, i.e., the reproducer and horn, may be made in one of two ways. The paper milk container method is the simpler one. Follow the illustration.

(a) Cement a rubber band neatly around the edge of the metal flange upon which the cap normally rests.

(b) Cut a disk from the mica sheet to fit the milk container opening.

(c) Drill a small hole at the centre and, after bending an oversize pin sharply near the head, insert it into the hole and then through another hole in the metal flange.



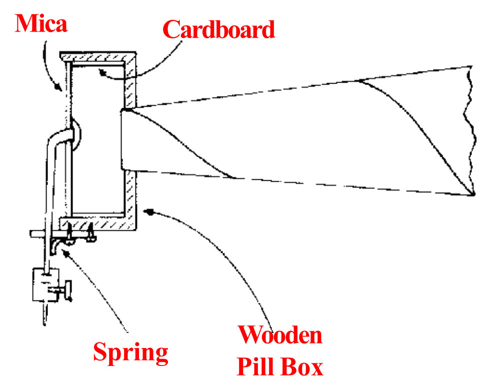
(d) Cement the diaphragm in place with Duco or a quick-drying cement.

(e) For the adaptor, cut a 6 mm length of small brass rod, drill a small hole all the way through and solder it to the cut-off end of the pin; secure a little set screw and drill a hole in the side a bit smaller than the threaded part of the screw and then force the screw in by turning it strongly so that it is well secured.

(f) Instead of making the adaptor in (e) you can use a brass electric wire fixer in any old lamp socket as the adaptor. (g) For the horn, remove the bottom of a wax paper ice-cream cup or a paper milk container, and fix it in the hole of the metal flange.

(h) Attach the whole unit to the carrier arm with adhesive tape, and the rest will be up to you.

The second way of making the reproducer is illustrated above. This will give you an instrument more on the lines of a regular gramophone.

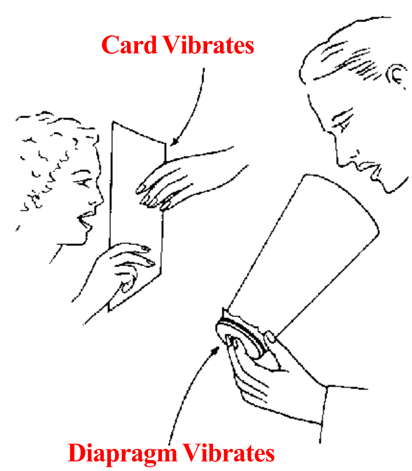


9 Recording of sound by gramophone

Recording is just the reverse process of reproducing. We have learnt that the voice or any other sound can be used to cause an object to vibrate and to form wavy lines on a smoked glass pane in motion.

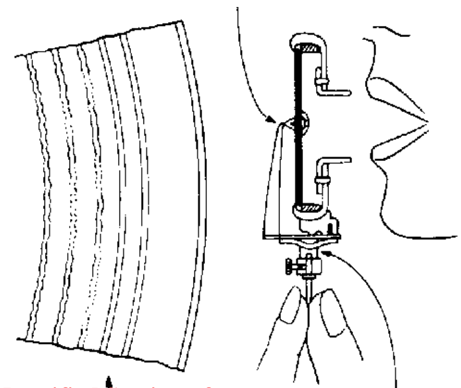
Hold a card in front of your mouth and utter sounds against it. Feel the vibrations with your finger tips.

Remove the bottom of an ice-cream cup or a paper milk container and bind a diaphragm of thin paper or rubber over the small end. Hum into it and feel the vibrations again.

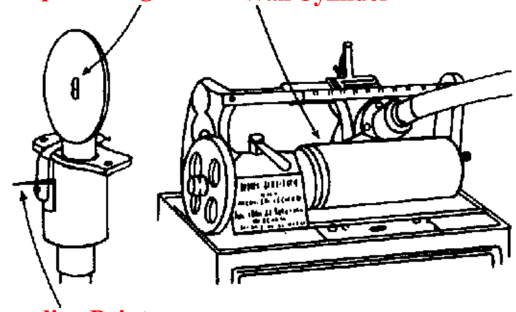


Detach the reproducer you made in the last experiment. Speak into the opening and, while doing so, feel the tip of the needle vibrating.

Now replace the reproducer and put a smoked glass disk of about the same diameter as the usual record on the turn-table. Speak into the horn and at the same time rotate the turn-table. The vibrating needle point will draw wavy lines, a record of your voice. A hard-wax circular sheet might be used in place of a smoked glass disk.



Thomas A. Edison devised the first talking machine, which was a recorder as well as a reproducer. He first recorded the sounds and then played them back. If you are able to visit a science museum, have a look at the old-fashioned type of dictaphone. The parts are shown more clearly than in the newer types.



"BE A GOOD SCIENTIST. FOLLOW INSTRUCTIONS EXTREMELY CAREFULLY. WEAR PROTECTIVE CLOTHING WHEN WORKING ON ANY EXPERIMENTS THAT INVOLVE FIRE OR EXPLOSIONS."

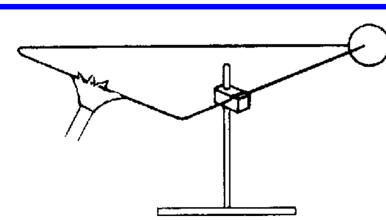
CHAPTER XIII

Experiments and materials for the study of heat

A. THE EXPANSION EFFECT OF HEAT

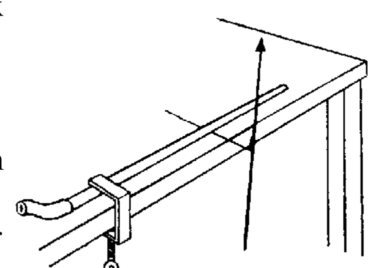
1 Triangle to show expansion on heating

Bend a piece of stiff metal wire into a triangle. Support it in a horizontal plane and suspend a coin between the two free ends forming one corner. Heat the opposite side of the triangle and the coin will fall out.



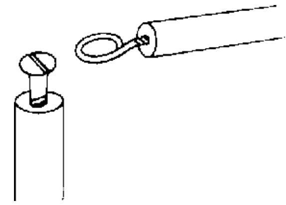
2 To show the expansion of a solid when heated

Get a piece of stout copper tubing about 2 m long. Lay it on a table and fix one end by a clamp. Underneath the other end put a piece of bent knitting needle or bicycle spoke to act as a roller. A thin strip of balsa wood about 1 m long fixed to the roller by sealing wax will show any movement of the rod resting on it. Blow steadily down the tube at the fixed end, and the expansion of the tube caused by the hot breath will be detected by this arrangement. Now pass steam through, and the pointer will make a complete revolution or more, depending on the diameter of the roller. Repeat the experiment after the roller and pointer have been moved nearer to the loose end of the rod. Compare the results.



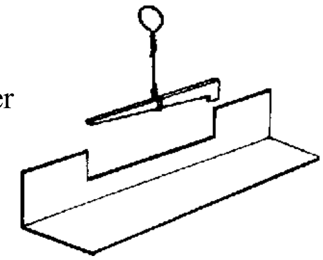
3 The ring and plug experiment

Secure a large wood screw and a screw eye; the head of the screw must just go through the screw eye. Screw each one into the end of a stick, letting at least 2.5 cm of metal protrude. Heat the head of the screw in a flame for a while and then try to put it through the screw eye. Keep the screw hot and heat the screw eye in the flame at the same time. Now try to put the screw head through the screw eye. Keep the screw head in the dame. Cool the screw eye in cold water. Again try to put them together. Next cool the screw head and try again.



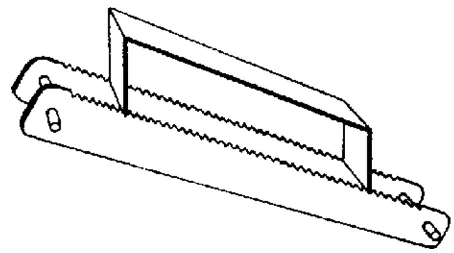
4 A bar and gauge

To construct this traditional apparatus use a cut nail as the bar and a piece of tin as the gauge. Cut the gap in the tin with shears and bend it into an angle girder so that it will stand on the bench with the gap upwards. Wind a piece of iron wire round the nail to serve as a handle.



5 Thermal creeper

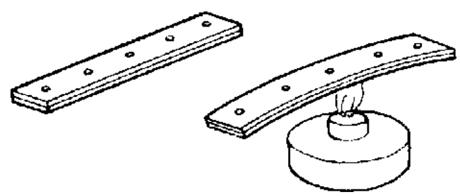
This model illustrates the creeping of lead roofs etc., under the action of heat. Push a cork onto each end of a knitting needle. Stick two pins through each cork so that the apparatus has four legs. These legs are slanting so that the front pair slide forward as the needle expands, but stick in the ground and drag the back 'legs' after them as it contracts. A bridge of brass set on a pair of hacksaw blades will behave in the same way and will, in fact, climb uphill.



6 A bimetallic strip

A pair of iron and brass strips, riveted together, will bend when heated because of the difference of expansion. Make the holes with a nail and use small tacks as rivets.

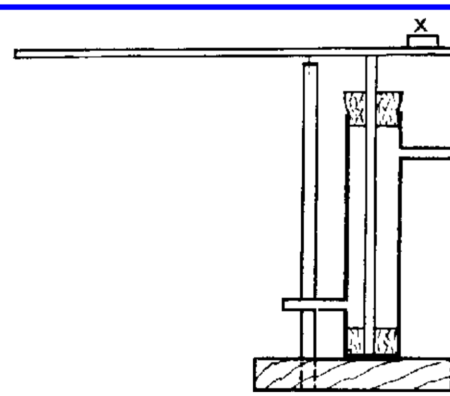
Another way of fastening the strips together is to cut them with projections at equal intervals and bend them over to interlock.



7 A device to measure the rate of expansion

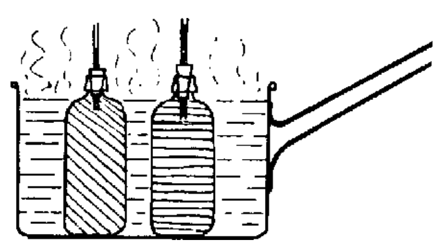
The Liebig's condenser described on page 36 is used as a steam jacket for this experiment. The expansion of the test rod is magnified by a wooden lath acting as a lever. A piece of dowelling rod with a razor blade stuck into the top makes a satisfactory pivot, and X is a counterweight.

First cold water and then steam should be passed through the outer tube. The expansion of the rod is calculated from the dimensions of the lever and the movement of the free end.

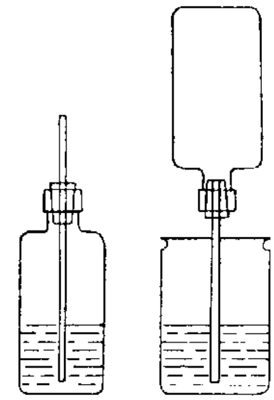


8 Expansion of liquids

Fit two or three similar medicine bottles with corks and tubes. Fill them with different liquids and immerse them in a pan of hot water. The rise inside the tubes will indicate the difference in expansion rates. If the diameter of the tubes and the capacity of the bottles are known it is possible to calculate the apparent coefficients of expansion.



9 Expansion of gases



The medicine bottles can also show the expansion of air or other gases. Push the glass tube through the cork and trap some air. A hand placed on the bottle drives liquid up the tube.

A simple form of air thermometer can be made arranging the tube as shown on the right in the diagram. Also refer to experiment B2 below.

Warming the bottle causes air to be expelled. This reduces pressure inside. When the bottle cools liquid is forced up the tube.

10 Expansion of gases—soap bubble

A soap bubble stretched over the neck of a medicine bottle will grow larger if warm hands are placed on the bottle.

11 Another way to show the expansion of gases

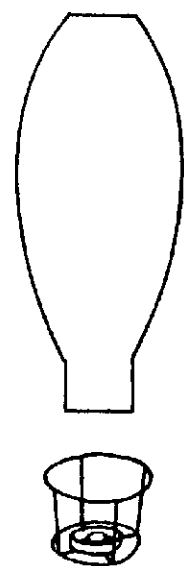
Stretch a rubber balloon over the neck of a flask which has been made from a used electric bulb. Heat the flask gently with a candle or an alcohol flame.

See also Chapter VIIT, experiment B 2.

12 An expansion experiment with a balloon

Partially inflate a balloon or a basket ball. Hold the balloon or ball over a hot plate or place it in the warm sun for a while and observe the results.

13 Fire balloon



Make a simple fire balloon from a large paper bag similar to those used by milliners.

Open out the mouth with a ring of florist's iron wire having a stay across the diameter. Fix the ring to the bag with strips of gummed paper. Tie a small piece of sponge or cotton wool to the middle of the stay and dip it in methylated spirit. Light the spirit and hold the bag by the ring. There is danger of setting fire to the paper bag in this experiment, which is best performed in the open air.

This paper bag balloon is not very stable in flight. A better one can be made as follows:

Place on a table six sheets of tissue paper, one on top of the other. Cut them in the shape shown in the figure and stick them together at the edges to form a balloon. A circular disk will be needed as cap to close the top. Fix a ring to the neck as before. Such a balloon will rise to great heights and can be flown from a piece of string like a kite. Solid methylated spirit, as employed in some spirit lamps, is easier to use if it can be obtained: it can be placed on a small tin lid attached to the wire ring at the mouth of the balloon.

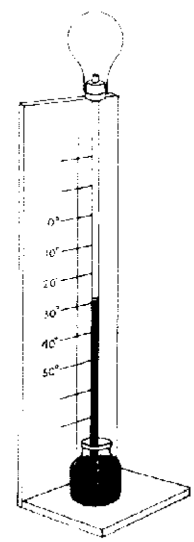
B. TEMPERATURE

1 Is your temperature sense reliable?

Fill three pans with water. Have one at the highest temperature you can bear your hand in. Fill a second one with ice-cold water. The third should be lukewarm. Put both hands in the lukewarm water and hold them there for about half a minute. Does the water seem to be the same temperature for both hands? Does it feel hot, cold or neither?

Next place your left hand in the hot water and your right hand in the icy water for a minute. Quickly dry your hands and plunge both into the lukewarm water again. How does the right hand feel? How does the left hand feel? Do they feel the same as when in the lukewarm water before? What do you think about your temperature sense?

2 Making an air thermometer



Fit a flask made from a used electric bulb (or a thin-walled bottle or test tube) with a one-hole rubber stopper which has a 60 cm length of glass tubing in it. The stopper must be an air-tight fit in the bulb. You can seal the stopper in by dropping some wax from a candle around the joint. Build a support for your thermometer from wood as shown in the diagram. Paste a strip of paper for a scale behind the tube. Place the lower end of the tube in a small bottle of cold water, coloured with ink. Heat the bulb of the thermometer gently to drive out some of the air. Drive out just enough air so that when the bulb cools to room temperature the coloured water will rise about half way up the tube.

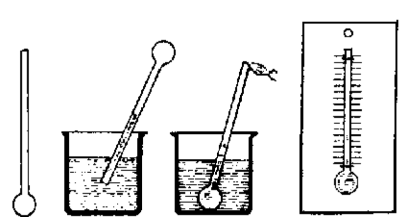
To make your scale, let the thermometer stand in a room for several hours. Have another thermometer near the bulb. Make a line on the paper at the level of the water and mark the reading of the thermometer at this point. Next move your thermometer to a warm place to stand for an hour with the other thermometer near the bulb. Mark the water level and the temperature. Move again to a cool place and again mark the water level and temperature. Divide the space between these marks into equal divisions and mark off the corresponding temperatures.

3 How a thermometer works

Fill a flask made from a used electric light bulb with water that has been coloured with ink. Insert a one-hole stopper carrying a 30 cm length of glass tubing until the water rises in the tube a distance of 5 or 6 cm. Place the flask on a tripod over an alcohol burner and observe the water level as you heat it. The water expands more rapidly than the glass and rises up the tube. Some keen observers in the class may notice that just at the moment heating is begun, the water level drops and then begins to rise. This is because the glass bulb starts to expand before the water inside reaches the temperature of the glass.

4 Making a spirit thermometer

To make a simple alcohol thermometer, accurate enough for indicating variations of temperature, use 20-30 cm of glass tubing of about 5 mm external diameter with about 1 mm bore. A bulb of about 1.5 cm external diameter is first blown in one end of the tubing; coloured industrial alcohol is allowed to enter by means of a rubber tube and a thistle funnel till the thermometer is filled and without bubbles. The thermometer is then placed in water at 600 C, which is slightly below the boiling point of alcohol, allowing the excess alcohol to ooze out. Then the open end is sealed off. With water at different temperatures the thermometer is tested and the scales are drawn.



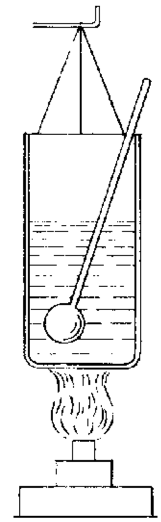
5 Testing a thermometer

Thermometer scales are marked at two fixed points, steam temperature and the temperature of melting ice. Secure a thermometer and place it in steam immediately above the surface of water boiling in a flask. Leave it there for several minutes and notice how closely it registers 100^0 C, or 212^0 F.

Note. If you live at a high altitude the temperature of steam may be well below 100^0 C or 212^0 F because of the reduced pressure. The thermometer will register exactly only at sea level or where the barometer reading is 760 mm of mercury.

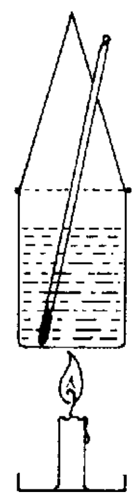
Remove the thermometer from the steam, allow to cool for a few moments and then place it in a jar of melting ice. Observe how nearly it reads 0^0 C, or 32^0 F.

6 Heat and temperature—the idea of a calorie



Suspend a tin containing 50 cc of water and a thermometer over a small Bunsen flame or a candle. Heat it for two minutes, constantly stirring, and record the final temperature. Empty out the water and repeat the experiment with 100, 150, 200 cc of water, using the same flame. It is sufficiently accurate to count 1 cc of water as 1 g. Find the product of mass of water multiplied by rise in temperature in each case. As the same heat is given out by the flame to each mass of water, the result suggests that a convenient unit of heat would be that absorbed by 1 g of water rising in temperature by 10 C. This unit is called a gram calorie.

7 Calorific value for fuel



As fuels vary greatly in their heating effect, it is useful to have some way of indicating their relative effectiveness. A suitable index is the number of calories given out when one gram of the substance burns completely away: this is called the calorific value.

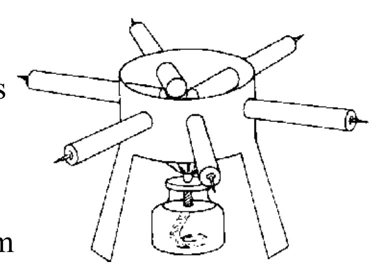
Hang a small can from a stand by means of fine wires. Pour 100 cc of cold water into it, and take the temperature. Place a small piece of candle on a tin lid and weigh it. Now place it under the can of water and light the wick. Stir the water with the thermometer and when the temperature reaches 60^0 C blow out the flame and weigh the tin lid and candle again. The mass of water (in cc) multiplied by the rise in temperature (in C^O) gives the calories produced, and the mass of candle used can be found from the weighings. The calorific value can be calculated from these two quantities. Solid methylated spirit or a methylated spirit lamp can also be used in this experiment.

C. THE TRANSFER OF HEAT

1 Conduction in a metal bar

Secure a bar of copper, brass or aluminium at least 30 cm long. Attach tacks or nails to the bar with melted paraffin at intervals of 3 cm. Set the bar above a table top and heat one end with an alcohol or other flame. Observe the evidence that heat moves along the bar by conduction.

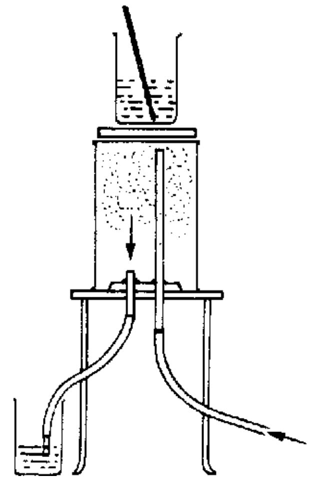
2 Metals conduct heat at different rates



Obtain 15 cm lengths of several metals. The bars should be of approximately the same diameter. Punch holes in the side of a tripod that has been made from a tin can. Insert the metal bars so that they touch at the centre of the can. Attach a tack or nail to the outside end of each bar with some paraffin. Place an alcohol dame under the tripod so that it touches the inner edge of each bar equally. Observe the order in which the tacks fall from the outer end of the bars. Most of the simple experiments on this topic are confusing because they involve specific heat as well as conduction.

3 Measurement of the heat conducted through different substances

The steam can described in Chapter II, C 5, will serve as a hot plate for experiments in conductivity if it is placed upside down on a tripod. Steam is introduced through the long pipe and condensed in cold water. Place a slab of cardboard on the hot plate and on it a small tin containing 100 cc of water and a thermometer. Measure the rise in temperature after 5 minutes and calculate the heat transmitted. Repeat the experiment using slabs of equal thickness of metal, cloth, cork, etc.



4 Metals are good conductors of heat

Hold a piece of paper above a candle flame: it will char if brought near. Place a metal coin on the paper and repeat the experiment: the metal will conduct away the heat and leave a pattern on the paper.

5 Conductivity of metal and wood

A piece of metal tube with a wooden rod fitted into it shows the same effect: if the wooden rod is held over a flame, it will not burn. A penholder with a metal band at one end can be used for this experiment. The same principle is involved in a simple experiment with a cigarette, a metal coin and a handkerchief. Wrap the coin in the hand- kerchief, stretching the fabric tightly over it between finger and thumb. Press the red hot ember of the cigarette on this part of the handkerchief; it does not burn.

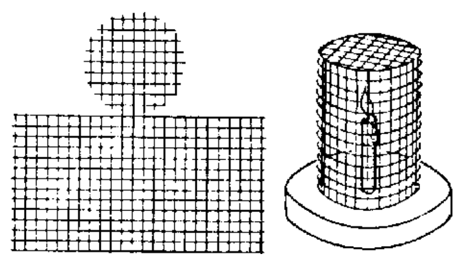
6 Conduction with a metal game

Hold a piece of metal gauze in an alcohol or gas flame. Observe that the flame does not come through the screen as the heat is conducted away from the flame by the wires. If you have gas in your room place a burner under a tripod and cover it with a wire screen. Turn on the gas and light it above the screen. You will observe that the gas burns only above the screen as the heat is conducted away by the screen and keeps the gas below the screen from reaching its kindling temperature. This observation gave Sir Humphrey Davy his idea for making the miners' safety lamp which prevented the explosion of gases in the coal mines.

7 A model Davy lamp

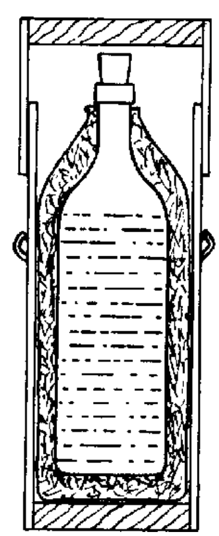
The traditional experiments on the conductivity of wire gauze can be followed by an improvised Davy lamp. A Christmas candle enclosed in a cylinder of wire gauze does not light a jet of gas played on it from a rubber tube.

A block of wood or plasticine is used as a base.



8 Haybox thermos flask

Make a cloth bag to fit loosely round a bottle, and stuff it with kapok and cotton waste. Enclose this in a cardboard or bamboo cylinder fitted with carrying string. Although no vacuum is used, drinks are kept hot or cold for several hours.



9 Water is a poor conductor of heat

Hold the bottom end of a test tube of cold water in the hand. Heat the top in a Bunsen flame until it boils. The fact that you can still hold the bottom shows how bad a conductor water is.

10 Heat is transferred by convection in liquids

Secure a large glass jar that can be heated. The bottom part of a glass coffee-maker can be used. Fill the jar with water. Put some grated blotting paper particles or sawdust in the water and give them time to settle to the bottom. Now place the jar over an alcohol lamp and begin to heat it. Observe the paths taken by the particles of paper. The paper particles follow the convection currents set up in the water.

11 What causes convection currents in water ?

Fill a large jar with cold water and weigh it accurately on a balance. Fill the jar with exactly the same amount of hot water and weigh. You will observe that the jar of warm water weighs less. Volume for volume cold water is heavier than warm water; so when water is heated convection currents are set up, the warm water being lifted, because of buoyancy, by the cold surrounding water. In other words hot water is less dense than cold, and this is the cause of convection currents in a liquid.

12 Effect of temperature on the density of water

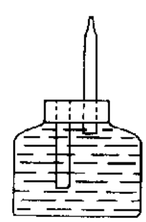
The sensitive balance described on earlier can be used to demonstrate changes of up thrust when a body is suspended in cold and then warm water. Replace one of the pans of the balance by a key or other suitable metal object hung from the beam. Counterpoise this in a can of water. Now blow steam into the water to raise its temperature and notice that the key apparently becomes heavier owing to reduced up thrust on it. As metals expand much less than liquids the effect is easily seen. If absolute measurements are required, a correction for the expansion of the metal may be made, or an inexpansible alloy such as Invar should be used in place of the key.

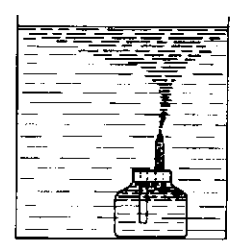
13 At what temperature does water attain its maximum density?

Put a piece of ice into a glass of water. Arrange two thermometers so that one measures the temperature near the surface, and the other the temperature near the bottom. It will be noticed that the water cooled by the ice falls to the bottom; this continues until the water at the bottom of the glass reaches a temperature of about 4^0 C. It will stay at this temperature for a long time, the colder water remaining higher up near the ice. From this it can be deduced that the water at 4^0 C is denser than the water at 0^0 C. This curious behaviour of water is of great practical significance in nature, and explains why a pond freezes from the surface downwards while the bottom surface seldom falls below 4^0C.

14 Another way to show convection currents in water

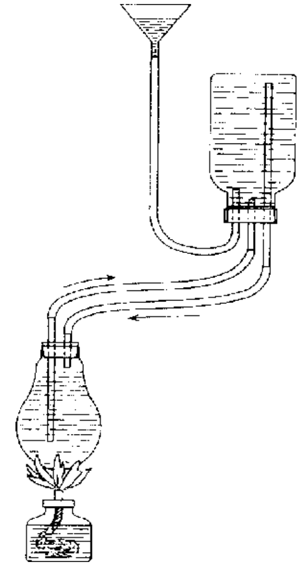
Fit an ink bottle or paste jar with a cork carrying two pieces of glass tubing as shown in the diagram. One piece of tubing should be drawn out to a jet like the end of a medicine dropper. This tube should be put just through the cork and should extend about two inches above. The other tube should be just level with the cork and extend nearly to the bottom of the bottle. Fill the bottle with very hot water that has been coloured deeply with ink.





Now fill a large glass jar such as a battery jar or cookie jar with very cold water. Rinse off the ink bottle and quickly place it on the bottom of the large jar. Observe what happens. Can you explain this?

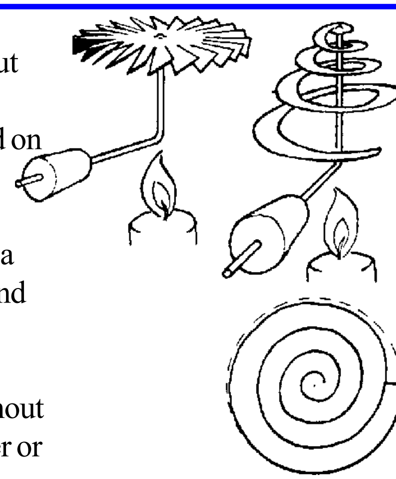
15 How to make a model hot water heating system



Make a flask from a large electric bulb. Secure a wide-mouthed bottle and a funnel. Fit the bottle with a cork carrying three glass tubes arranged as shown in the diagram.

Fit the flask with a two-hole cork carrying two glass tubes, one going just through the cork and the other extending nearly to the bottom. Attach the funnel as shown. This serves as the expansion tank. Fill the system with water and heat. Observe which part of the radiator gets hot first. Can you explain how the water circulates by convection currents?

16 Convection currents in air



Obtain a circular disk of thin tin as used to close tobacco containers. Cut teeth in the circumference and pivot it on a bent knitting needle. Hold it above a candle flame, and it will revolve rapidly. A paper spiral supported on a knitting needle will revolve in a similar way.

Bring a piece of red-hot iron into contact with 'solid methylated spirit' (Meta fuel). The vapour immediately recrystallizes and tills the room with a highly diverting snow- storm. The crystals are set in motion by draughts and convection currents already in the room.

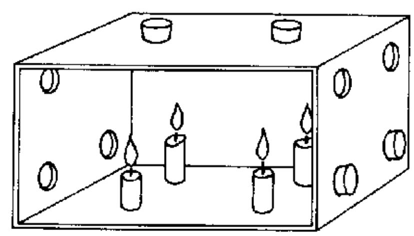
Another way of showing these air currents is by making use of the difference in refractive index of warm and cold air. A 12 volt car bulb without reflector will cast 'shadows' of convection currents from an electric heater or even from an ordinary electric lamp bulb.

See also Chapter VIII, experiment B 6.

17 How convection currents cause winds

See Chapter VIII, experiment B 6.

18 Convection currents and ventilation



Use the box which you used for a study of winds in Chapter VIII, experiment B 5, page 97. Bore four holes in each end, two above and two below. Put solid corks in all the openings including the two on the top where the lamp chimneys were placed for the other experiment. The holes in the opposite ends represent windows which may be opened or closed at the top and at the bottom. Put four candles in the box and light them. You are now ready to study the best conditions for ventilation. Close all the windows and observe the candles for a little while. Now try different combinations of openings. One window open at top and bottom. One open at the top, the other at the bottom. Both open at the top. One only open at the bottom. Both open at the bottom. One only open at the top. What window openings provide the best ventilation ?

19 Heat is transferred by radiation

In the previous experiments you have seen that heat can be transferred by material sub- stances, by solids, liquids and gases. Heat can also be transferred by wave motion, even across a vacuum. This is called radiation. Heat travels by radiation almost instantaneously. This experiment will demonstrate some interesting things about radiation. Hold your hand under an unlighted electric bulb, palm upward. Turn on the electricity. Can you feel the heat almost as soon as you turn on the bulb? The heat could not have reached your hand by conduction because air is a very poor conductor of heat. Neither could it have reached your hand by convection because this would have carried the heat upward away from your hand. It actually came to your hand carried by very short waves. Radiation carries heat in every direction from the source.

20 Radiant heat waves can be focused

Hold a reading glass lens in the sun and focus the rays to a point on a wad of tissue paper. You will observe that the tissue paper catches fire from the focused heat rays. Try the effect of using tissue paper blackened with Indian ink or soot. Does it catch alight more readily ?

21 Radiant heat waves can be reflected

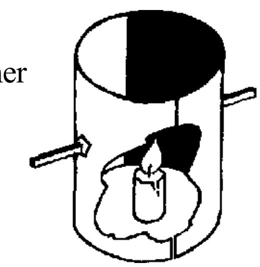
In the above experiment note the distance from the reading glass to the tissue paper. Place a tilted mirror about half this distance from the lens. Feel about with your hand above the mirror until you find the point where the heat waves are focused. Hold a bit of crumpled tissue paper at this point and see if it will catch alight.

22 Different kinds of surfaces affect radiation

Secure three tin cans of the same size. Paint one white, inside and out, and another one black; leave the third one shiny. Fill the three cans with warm water at the same temperature. Record the temperature. Place cardboard covers on each can, set them on a tray, and then put them in a cool place. Record the temperature of the water in each can at five- minute intervals. Was there a difference in the rate of cooling? Which surface was the best radiator of heat? Which the poorest?

Next fill the cans with very cold water, record the temperature, cover each can and place them in a warm place or in the sun. Record the temperature of the water at five- minute intervals. Which surface was the best absorber of heat? Which the poorest?

23 Another way to show how surfaces affect radiation



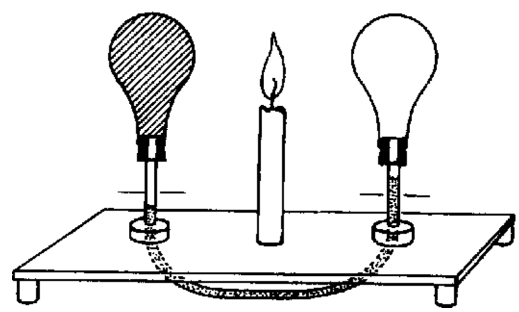
Cut two vertical slits opposite each other on the side of a cylindrical tin, so that the surface of the tin is divided into two parts. Blacken the inside of one half leaving the other half shiny. Put a lighted candle inside the tin, in the exact centre of the base.

A difference in temperature of the two outside surfaces can be detected with the fingers.

Matchsticks fastened to the outside with wax can also be used as indicators, and the one behind the black surface will fall off first.

An alternative experiment is to use a coiled cylinder of fine wire gauze wrapped round the top of the tube of a Bunsen burner as emitter and blackened thermometers as detectors of radiation.

24 A simple thermoscope



Flasks, or cut-off light bulbs, can be used to construct this apparatus. Besides the experiment illustrated with the candle, it works well for other experiments, e.g., the Leslie Cube.

Fit both bulbs with corks and tubes about 15 cm in length. Pass the lower ends of the tubes through flat corks and, having made holes about 22 cm apart in a suitable base- board, glue the tubes in a vertical position and connect the open ends by rubber tubing. Remove one bulb and blacken the other in a candle dame. Pour liquid into the U tube so formed until the level is about 7.5 cm above the baseboard. Replace the clear bulb and slide the tube in or out a little so that the liquid remains level. Place a candle equidistant between the bulbs and wait for results.

25 How heat losses can be reduced

Secure four large tin cans of the same size and four smaller tin cans of the same size. Put three of the small cans inside three of the larger ones and pack insulating material under and around each of the smaller cans. Pack one with shredded newspaper, the second with sawdust and the third with ground cork (other more convenient insulating materials may be substituted). Inside the fourth large can place the small can resting on two corks. Fit paste board covers to each can. Have a hole in each cover for a thermometer. Now fill each small can to the same depth with water that is nearly boiling. Record the temperature of the water in each can. Take the temperature of the water in each can at five-minute intervals and notice which is the best insulator as indicated by the slowest rate of cooling.

D. MELTING AND BOILING

1 Observing a boiling liquid

Secure a very large Pyrex beaker or a large tin can. Fill the vessel nearly full of cold water and place it over a flame. Leave it there until it boils. You will first observe air bubbles coming out of solution in the water and rising to the surface. When the water is near the boiling point, steam bubbles will form and collapse almost at once. As the boiling point is reached, the bubbles will form at the bottom and rise to the surface before bursting.

2 How to boil water in paper

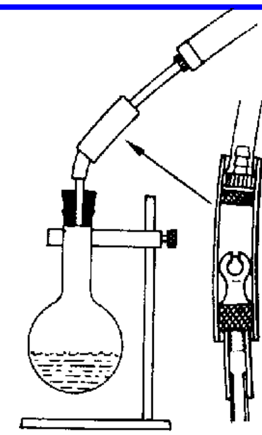
Secure some smooth paper: either wrapping paper or writing paper will do. Make a box about 25 cm square by folding the corners up and pinning them. Fill the box about half full of water and place it on a burner. You can boil the water without burning the paper. The paper conducts heat from the flame to the water and does not catch fire because its kindling temperature is above the boiling point of water (100^0C or 212^0 F)

3 Boiling water by cooling it

Fit a flask with a tight solid stopper. Remove the stopper and fill the flask a little more than half full of warm water. Bring the water to the boiling point over a flame. Put the stopper tightly in the flask and invert it over a pan or sink. Pour cold water over the flask: the water starts boiling again. Put a piece of ice on the flask. Cooling condenses the water vapour above the water and reduces the pressure on the water. When the pressure is reduced, water boils at a lower temperature, This explains why it takes so long to cook things at high altitudes.

4 Boiling ether by reducing the pressure

Obtain a glass bottle or flask, with cork and tube. Pour ether into it to a depth of about 2.5 cm, and add a little powdered glass or sand. Replace the cork and with narrow rubber tubing attach to the glass tube a non- return valve such as the one used in a football pump adaptor. Push over this a length of Bunsen tubing, and attach the connector of a cycle pump which has previously had the washer reversed. Clamp the flask in a stand so that the liquid can easily be observed. After a few sharp strokes of the pump, the ether will boil vigorously.



5 When liquids evaporate, they absorb heat

Set up an air thermometer like the one in experiment B 2. Put some rubbing alcohol on the bulb of the thermometer. What do you observe? Where did the heat come from to evaporate the alcohol? Try carbon tetrachloride; try ether.

6 Freezing by rapid evaporation of ether

With a knife cut a depression in a softwood board or block. Place a glass tube in the rubber connector of a bicycle pump. Pour a little water in the depression you have made in the wood block and place a tin can in the water. Pour a little ether in the tin can and force air through it with the pump. As the ether evaporates it absorbs heat from the water and the can will soon be frozen to the wood by a film of ice.

7 The cooling effect of a dry wind

Obtain two similar thermometers and wrap the bulb of one of them in a small piece of wet cloth. Shield them from draughts and wait until they read the same temperature. Now place them on a window sill in a current of air. It will be seen that the thermometer with the wet bulb shows a much lower temperature. This is because the evaporating water takes heat from the bulb. The current of air assists evaporation by bringing dry air to the thermometer. This phenomenon is common in everyday life: the evaporation of sweat from the body on hot and windy days is very refreshing.

8 How heat changes solids to liquids

Place samples of such things as lead, solder, ice, sealing wax, paraffin wax in separate containers that may be heated. Small tin cans or lids will be useful. Experiment with these and see if you can get some information on the relative amount of heat needed to melt each sample.

9 Freezing water with ice and salt

Crack some ice into small lumps and place a layer in the bottom of a large can; cover this with kitchen salt and then add other layers of ice and salt. Put some water in a smaller tin can, and place this tin inside the large can. Then add more layers of ice and salt until the large can is full. Record the time taken to freeze the water in the small tin. Compare this with the time required to freeze the same amount of water if only ice is used in the large can.

10 Water expands when it freezes

Secure a small metal can which has a screw top. Fill it to overflowing with water and then screw the top on so that there is no air space. Bury the can of water in a mixture of ice and salt and leave it for some time until the water freezes. You should obtain some interesting results.

11 Heat is absorbed when solids melt

Secure a small container of chopped ice and find its temperature with a thermometer. Place the container over a flame and observe the temperature until all the ice is melted. When did the temperature begin to rise? Why did it not rise for some time? What became of this heat energy?

12 Melting by pressure and refreezing

When you apply pressure to ice you lower the freezing point. This is why skates move so easily over ice. Hold an ice cube or a piece of broken ice in each hand. Press them together over a piece of paper. Can you make water come from the ice with pressure? Push two ice cubes together forcibly and then release the pressure. Try to separate the ice cubes. The water refreezes when you release the pressure, holding the ice cubes solid.

13 Latent heat of steam found by using a tin

The rate of heat supply of a flame to 100 g of water in a tin may be found by taking the temperature at intervals and plotting a time- temperature graph.

When the water begins to boil there is no further rise in temperature but the rate of heat supply is the same. If one disregards the water lost by evaporation in bringing it to the boil, the heat required to boil 100 g of water completely away (that is until the bottom of the tin is dry), can be found from the time required for this to happen.

14 Latent heat found by using a hollow solid

An alternative way of determining the latent heat of steam is to use a heavy hollow metal solid as a condenser. A teapot can be used for a rough estimate.

The mass of water condensed in the teapot when steam from a kettle is passed into it depends on the heat capacity of the teapot.

If a brass axle cap is used, it should be fitted with a bung having inlet and exit tubes. When steam is passed into the apparatus, some time elapses before any comes out of the exit tube, because it is being condensed by the cold metal. After steam has issued for a few minutes, and the metal is therefore at 100^0 C, the steam supply should be stopped. The mass of steam condensed is found by taking its volume with a measuring cylinder. Given the specific heat, mass and initial temperature of the metal, the heat absorbed by it in condensing the steam is calculated.

15 Latent heat of ice

A rough value of the latent heat of ice can be obtained by measuring how much ice is melted when a heated solid is buried in ice shavings.

Weigh the solid of known specific heat and raise its temperature to 100^0 C by suspending it in water from a piece of cotton. Quickly transfer it to a funnel of powdered ice, and collect the resulting water in a test tube or measuring cylinder.

Calculate the heat given up by the metal in cooling to 0^0 C.

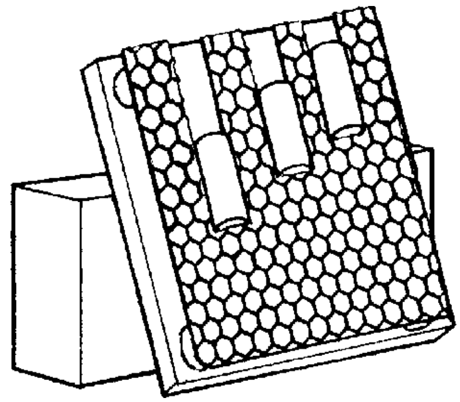
This apparatus can also be used to demonstrate the difference in specific heat of different materials. The volume of water obtained in each case provides a comparison of the specific heats.

16 Specific heat using a teapot

Pour boiling water into a weighed teapot at room temperature. The temperature will remain steady at about 96^0C. Measure the mass of hot water used when it has cooled a Little, using a measuring cylinder. Assuming there is no loss of heat to the surroundings, the specific heat of the material can be calculated.

This experiment forms an introduction to the subject of specific heat, or might be used as part of an investigation of the qualities of different materials used in teapots.

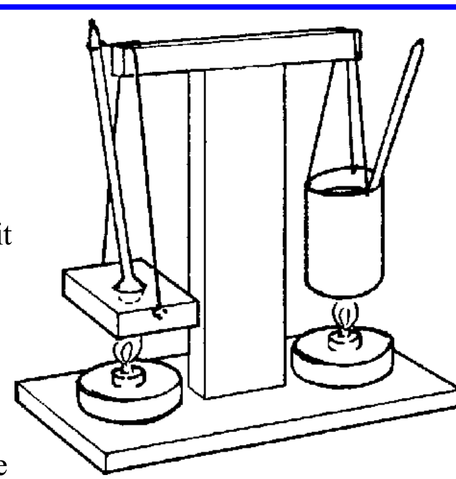
17 Specific heat comparison



To compare the specific heats of different metals, prepare cylinders of each of them of the same mass. Bring them to the temperature of boiling water and transfer them to a nearly vertical inclined plane, made from a piece of wood, and having a sheet of beeswax cell-former fastened to the front, but held away from the board by corks.

The cylinders will slide down the incline, melting tracks through the wax whose length will depend on the specific heat of the metal used.

18 Measurement of specific heat



Procure a piece of metal (say, 100 g of iron), and a tin containing 100 g of water. Suspend both above similar spirit lamps as in the diagram (a small Bunsen flame will do).

The iron weight needs a hole to be drilled in it to fit the bulb of a thermometer loosely; the tin of water also requires a thermometer in it which can be used as a stirrer.

It is assumed that the lamps are supplying heat at the same rate. They are applied to these bodies for the same length of time.

Both lamps should be removed when the thermometer in the iron reaches 80 degrees, as it will probably then overshoot the mark to 100 degrees. The surprising difference in temperature emphasizes the effect of specific heat. Since 1 g of water absorbs 1 calorie for a temperature rise of 1^0 C, the heat supplied to both iron and water is (100 x rise in temperature of the water). The heat supplied to the iron is (100 x S x rise in temperature of iron). So the specific heat

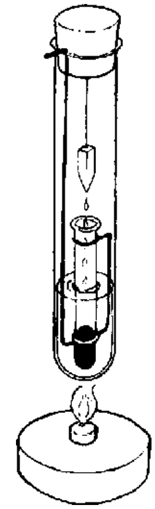
$$S = \frac{\text{rise in temperature of water}}{\text{rise in temperature of iron}}$$

19 Specific heat-hollow solids

An experiment somewhat similar to the teapot determination can be carried out using a hollow solid such as a brass axle cap or a short connector for iron tubing. Heat losses can be minimized by using a cloth to cover these vessels. The procedure is the same as before. Boiling water is poured in. The final steady temperature recorded will be much lower than that in the case of the teapots.

If a brass object weighs 1 kg the final temperature may be in the region of 60^0 C.

20 Simple latent heat calorimeter



In this apparatus the vapour of tetrachlor- ethyline, which has a small latent heat, is allowed to condense on a solid (e.g. copper or aluminium) which is suspended in it. The liquid formed is collected in a small graduated test tube. When no more condensation takes place, i.e. when the metal has assumed the temperature of the vapour the liquid collected is measured.

The large test tube is about 20 cm by 4 cm in diameter; the graduated tube is a small aspirin or pill bottle, and is carried in a wire cradle. The solid is pointed, at least at the bottom, so that the liquid streams off it readily.

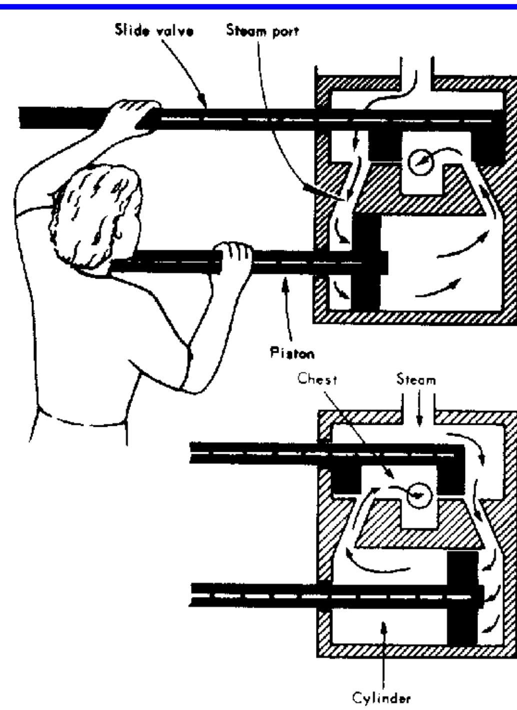
E. HEAT ENGINES

1 Pressure exerted by steam

Secure a small metal can with a friction top. Do not use a can with a screw top. Place a little water in the bottom of the can, press the lid on tightly, place over a dame and step back. In a little while you will see the expansive force of steam.

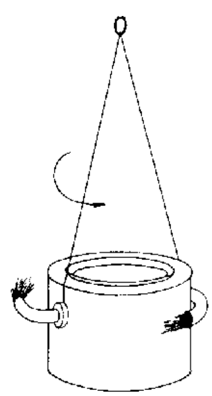
2 How a steam engine works

Make a drawing on a blackboard like that shown below. Make the drawing about 60 cm square. Cut from stiff cardboard a piston and a slide valve as shown. You can have pupils move these on the drawing to show the position of the piston and slide valve when the engine is running.

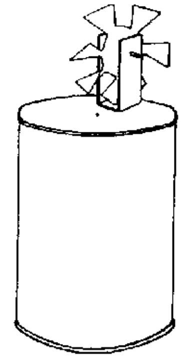


3 How to make a historic steam toy

Hero, scientist of ancient Alexandria in Egypt, made a steam toy which he called the Ball of the Winds. This is how to make a model of the toy. Secure a tin can with a friction top which holds about a pint or half litre. Pierce two holes in the can on opposite sides, large enough to carry small one- hole stoppers. Bend two glass tubes as shown in the diagram. The tubes should be drawn to jets at the end. Insert the tubes in the stoppers so that the jets point in opposite directions. Fasten cord to the stoppers and suspend by a swivel or chain. Pour water in the can to a depth of about 3 cm, put the cover on tightly and place over a flame.



4 How to make a model steam turbine

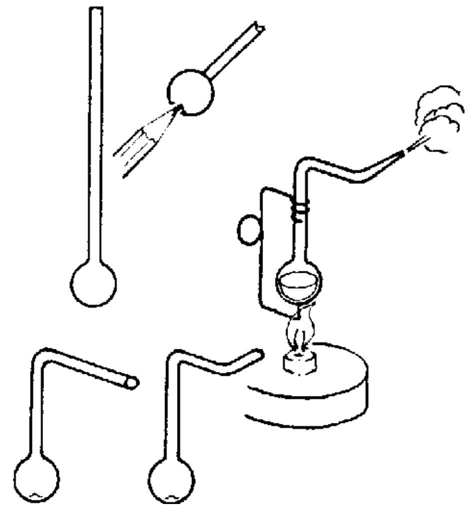


A turbine model can be made from a tin fitted with a vane wheel. The vanes are made by cutting radial slots from a circular piece of tin, and twisting the blades which remain.

The axle is a piece of knitting needle, and the axle support is made from a strip of tin bent into a U piece and soldered to the top of the can.

A hole for a steam jet should be made opposite the vanes.

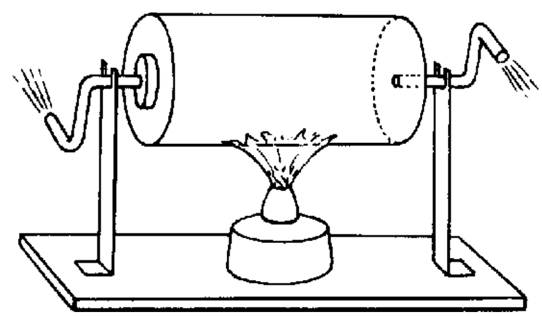
5 How to make a model turbine from glass



Very little glass blowing experience is needed to make this model. Seal one end of an ordinary piece of glass tubing in a flame and blow a bulb about 1.5 cm in diameter.

Soften the bottom of the bulb and press a pencil into it. This will make a depression to serve as a lower bearing for the turbine. Bend the top of the tube over at 90 degrees and draw it out to a jet bent at right angles again. Half fill the bulb with water by heating it and then immersing the open end under the surface of a beaker of water. Make a wire frame to act as a support as shown in the drawing.

6 Heat engine from an old metal polish tin



The tin is supported horizontally on two copper pipes which serve as exit tubes. They are soldered through the centre of the bottom and the cap respectively. The tin is partially filled with water and rests on two iron brackets screwed to a wooden base.

7 To show the force of exploding gas

8 How petrol vapour is exploded in an engine

9 How to make a fire syringe

"BE A GOOD SCIENTIST. FOLLOW INSTRUCTIONS EXTREMELY CAREFULLY. WEAR PROTECTIVE CLOTHING WHEN WORKING ON ANY EXPERIMENTS THAT INVOLVE FIRE OR EXPLOSIONS."

CHAPTER XIV

Experiments and materials for the study of magnetism

1 Natural magnets

Magnetic iron ore is quite common in many parts of the world. If it cannot be obtained locally, any supply house will provide it for a small cost. Secure a piece of such iron ore. This is a natural magnet. Sprinkle some iron filings or finely cut pieces of steel wool on a sheet of white paper and observe how the ore attracts them. Try picking up heavier things made of iron, such as paper clips or carpet tacks. Bring the lump of ore near a compass and observe. Do all parts of the lump affect the compass in the same way?

2 Securing artificial magnets

Strong and useful artificial magnets for the study of magnetism can be obtained from old radio loudspeakers, from old telephone receivers and from old automobile speedometers. Magnets can frequently be purchased in the market and may always be obtained from scientific supply houses. Artificial magnets are made in many shapes such as horse shoe, U-shaped and straight or bar magnets.

3 How to magnetize a steel rod

Use a piece of magnetic iron ore or another magnet to magnetize a steel knitting needle. a darning needle, an iron nail, a piece of clock spring or watch spring. This may be done simply by stroking the bar several times with the magnetized substance. If you wish to make a bar magnet with opposite poles at either end, use an artificial magnet. Begin at the centre of the unmagnetized bar and stroke toward the end using one end of the magnet. After several strokings turn the rod around and stroke from the centre to the other end using the opposite pole of the magnet. Test your results by using the rod to pick up iron filings or by approaching it to a compass.

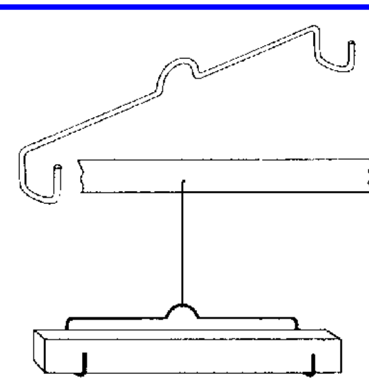
4 How to make bar magnets

Secure some flat pieces of hard steel. Old hack or metal saw blades are useful. Lengths of steel from a clock spring may be used. Cut the steel into 15 cm lengths. Next stroke the opposite ends of each piece with alternate ends of a strong magnet as instructed in experiment 3 above. Test each bar magnet with a compass. The two ends of the bar magnet should affect the compass in contrary ways. Hard steel is often quite difficult to magnetize. One should place the piece of steel on a table and strike the pole of the magnet against it as you stroke toward the end.

5 How to make a turntable cradle for magnet study

Select a piece of heavy wire. The wire from a coat-hanger will do very nicely. Bend it into the shape shown in the diagram. The distance between the two hooks at the ends should be small enough to cradle the shortest bar magnet that will be used.

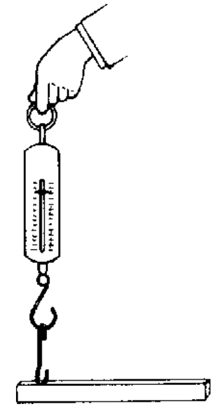
Suspend the cradle with fine copper wire or nylon fishing line from a convenient hook or other support. Place a bar magnet in the cradle and bring other magnets near it.



6 The concentration of magnetism in a magnet

Pour a considerable quantity of iron filings on a sheet of paper. Roll a bar magnet in the iron filings and observe that most of the filings stick to points near the ends of the bar. These places on a magnet where the magnetism seems to be concentrated are called magnetic poles. Repeat using magnets of other shapes such as a horseshoe or a U shaped magnet.

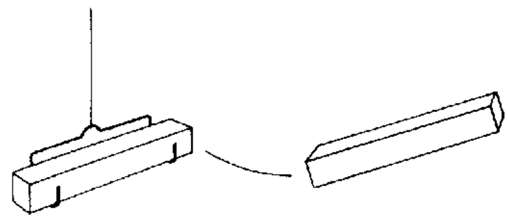
7 Variation of magnetism along a bar magnet tested by spring balance



Place a bar magnet on a piece of squared paper. Tie a soft iron nail to the hook of a spring balance and test the pull required to lift it away from points along the magnet 2.5 cm apart. It may be that the hook of the balance will serve instead of the nail, but care should be taken to see that it does not become permanently magnetized.

Represent your readings as a graph between pull required and distance along magnet from one end. Is the magnet 'strongest' at the extreme ends?

8 Do magnets act through space?



Suspend a bar magnet in a cradle such as is described in experiment 5 above. Bring other magnets near the suspended magnet and make observations to answer the question asked in this experiment.

9 Are the poles of a magnet alike?

Use the same materials as in experiment 8. Mark one end of the suspended magnet with a piece of chalk or paper. Now bring one end of another magnet near the marked pole of the suspended magnet. Reverse the magnet in your hand and bring the other pole near the marked pole of the suspended magnet. Do they react in the same way? How would you describe the action in the first case? In the second case?

10 The law of magnetism

Again use the same materials as in experiment 8. Test the magnets with a compass needle. Mark the end of each magnet which repels the north end of the compass needle and attracts the south end of the compass needle. These marked ends of the magnets are called the north poles. The unmarked ends are the south poles. The south poles of the magnets should repel the south-pointing end of the compass needle and attract the north- pointing end.

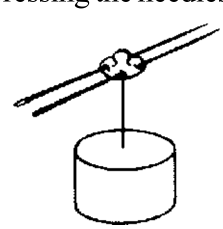
Now suspend one of the marked magnets in the turn cradle. Bring the north end of the other magnet near the north end of the suspended magnet. Do you observe attraction or repulsion? Next bring the south ends of the two magnets near each other. What do you observe? Bring the north end of the magnet in your hand near the south pole of the suspended magnet. What do you observe? Bring the south pole near the north pole of the suspended magnet. What do you observe? What can you say about like and unlike magnetic poles ? This is the law of magnetism.

11 Making simple compass needles

Magnetize a piece of steel strip or watch spring by stroking it with lodestone or another magnet. To convert it into a compass needle, it must have as frictionless a support as possible. This can be contrived in several ways. Close a short length (2 cm) of glass tubing at the end by heating in a flame. Support the small test tube just made on a pin pushed through a piece of wood or cork. Fix the strip of steel to the tube with sealing wax and adjust it so that it swings freely and evenly.

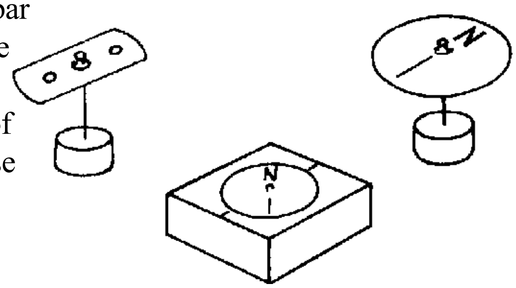
Another way of supporting the compass needle is to use a metal former from an old cloth-covered button. Clip the magnetized rod to the two projections and place the curved part of the button on a piece of glass or other smooth surface.

Another simple compass needle can be made using two magnetized sewing needles pushed through the holes of a large press stud. This can be balanced in another needle with its eye pushed into a cork. If a smaller press stud is used the flange must be squeezed between pliers whilst pressing the needles through the small holes.



12 A razor blade compass box

Magnetize an old three-hole razor blade by stroking it with a bar magnet. Push an old laundry stud or a piece of closed glass tube through the central hole. Glue a disc of card to the blade and suspend the combined compass on a pin stuck through a slice of cork. Mark the position of north on the top of the card. Enclose the compass in a cardboard box with a circular window in it made of cellophane. Draw a reference line on the box.



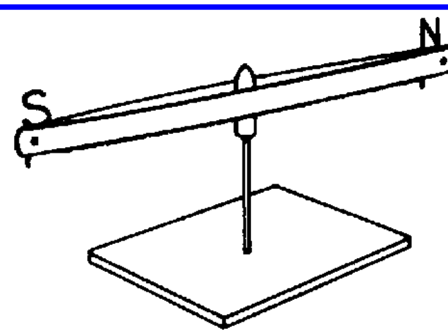
13 To determine magnetic north

Float a piece of flat cork 10 cm by 3 cm in a saucer of water.

Magnetize a short length of hacksaw blade or other steel and fix it to the cork so that its teeth are downwards and its length is along the cork slab. When it comes to rest, sight along its upper edge using two large pins. The line joining the feet of the pins is the Magnetic Meridian.

14 A demonstration compass needle

Rivet together two old hacksaw blades through the holes at each end and then magnetize them. Use a closed piece of glass tube as a support. Push this between the blades at the midpoint and balance it on a knitting needle driven vertically into a block of wood. Fix the bearing in position with sealing wax or other adhesive. Push wire indicators N and S between the blades at the extreme ends.

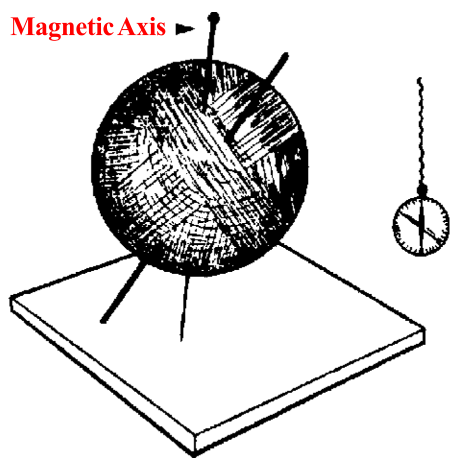


15 A model showing the earth's

A ball or round fruit is needed to represent the earth in this model. Support it on a wooden meat skewer inclined at an angle. This represents the axis of rotation of the earth.

Pierce the 'earth' with a magnetized knitting needle which will be in the direction of the magnetic axis of the earth.

Examine the external field using a small plotting compass such as is often used as an ornament to a watch chain.

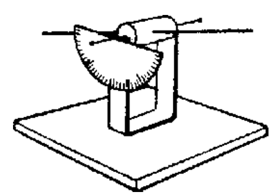


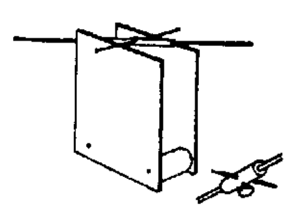
16 How to make a dip circle

Push a knitting needle through a cork in a direction parallel to a diameter of its end. Balance it horizontally on a U piece of brass strip, using pins as an axle. Take it off the knife edges and magnetize without disturbing the cork. When it is replaced on the bearings, one end will be pulled downwards by the earth's magnetic field. The protractor serves to measure this angle of 'dip'.

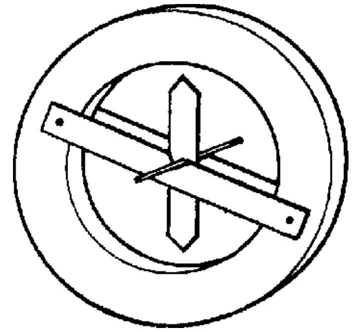
An alternative way of suspending the magnet is to use a piece of cycle valve tubing with a pin pushed through it as a supporting axle. Knife edges can be provided by two postcards held apart by corks maintained in position by drawing pins. The position of dip can then be marked with a pencil and measured later.

If metal 'connectors' are available, a more permanent device can be made by soldering gramophone needles to it.





17 A demonstration dip circle



Cut a ring of cardboard with an external diameter of 50 cm. Fasten two laths across a diameter to serve as supports for the dip needle. Cut a model dip needle from card and support it in notches cut in the laths.

Such a model is useful when discussing the various errors of the dip circle.

18 Exploring with a compass

Many things made of iron and steel are magnetized by the earth's magnetism. It is interesting to explore iron fence posts, iron bridges, etc., with a compass. Test them at both ends to see if they have magnetic poles. Drive an iron rod into the ground and see if it becomes magnetized. Test it at the top and near the earth. Test things around the school and at home with a compass.

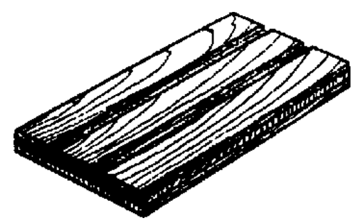
19 What substances are magnetic?

Collect a variety of small objects made of paper, wax, brass, zinc, iron, steel, nickel, glass, cork, rubber, aluminium, copper, gold, silver, wood, tin, etc. Place them in a box and test each object with a magnet to see which ones are attracted and which are not.

20 Magnetizing a bar by hammering

Secure an iron rod about one metre in length. An iron curtain rod will do. Test it with a compass at each end to see if it is magnetized. Hold the bar in a north-south direction and tilt. Strike the rod several sharp blows in this position and then test it again with the compass. A bar can often be demagnetized by holding it in an east-west direction and striking the end several times with a hammer.

21 Lines of force



A piece of plywood with two grooves cut in it to the depth of one ply is useful for holding magnets and magnetic materials while testing the patterns of their lines of force.

Permanent records can be made of such 'filing maps' if the paper used over the magnets is first dipped in hot candle grease and allowed to cool. Place it over the magnets under test, scatter filings on it from a height of 30 cm and tap the paper. Fix the pattern formed by warming the waxed paper with the medium flame of a Bunsen burner.

22 Mapping lines of magnetic force

An alternative to the familiar waxed paper method is to use a modern black line paper. This paper, employed by architects in place of the older blue-print paper, can be used in daylight.

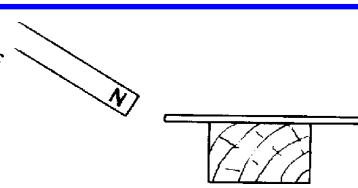
Place the magnet in position on the paper and scatter on the filings to produce the required pattern.

Expose to the sun or bright daylight for 10 minutes, or to the light of a small are for 2 minutes, shake off the filings and mop over with developer on a piece of cotton wool. The prints so made are positives, and the paper can be varnished to form a permanent record.

23 What substances do magnetic lines of force go through?

Secure small pieces of as many of the following substances as possible: wood, glass, copper, brass, zinc, pasteboard, plastic, iron, aluminium, etc. Place some iron filings on one side of the sheet and move a strong magnet on the underside. By observing the iron filings you can tell which substances pass the magnetic lines of force.

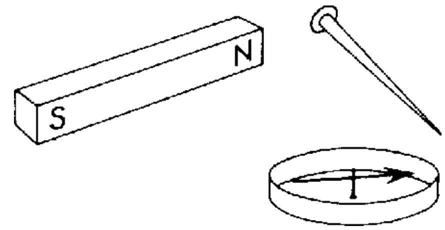
24 Magnetic induction



Place a bar of soft iron on a block of wood. Hold a tin-tack near it to test if it is magnetized. While the tack is near one end of the bar, bring a strong magnet near the other end. Is the bar magnetized? Remove the magnet and test again. Is the bar still magnetized? Magnetism produced in a substance in the vicinity of a magnet is called 'induced' magnetism. The effect involved is called 'magnetic induction'.

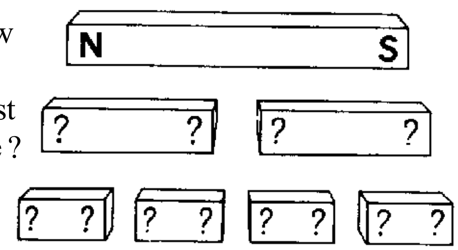
25 Testing for induced polarity

Test a strong magnet with a compass and mark the north pole and the south pole. Place a compass on the table and hold the pointed end of a 15 cm spike or piece of soft iron near it. Next bring the north pole of the tested magnet near the top end of the spike without letting them touch. Is a north or south pole induced in the end of the spike near the compass? What would you guess the polarity of the top end of the spike to be? Test it. Next hold the spike as before, but bring the south pole of the tested magnet near the top end of the spike. Is a north or south pole induced in the end near the compass? In the top end of the spike?



26 What happens when magnet is broken ?

Magnetize a piece of clock spring or a hacksaw blade about 25 cm long as instructed in experiment 3. Test the magnet with a compass to be sure that it has a north pole at one end and a south pole at the other. Mark the poles N and S with chalk. Does the compass show any polarity at the centre of the magnet? Use a pair of pliers and break the long magnet into two parts each about 12.5 cm long. Test the polarity of each end of the two magnets. What do you observe ? Mark the poles of each magnet N and S. Now break the two magnets into four magnets. Test each end and mark it N or S. Continue dividing the magnets, as many times as you can. Write a conclusion to the question posed by this experiment.



27 Making a magnet with iron filings

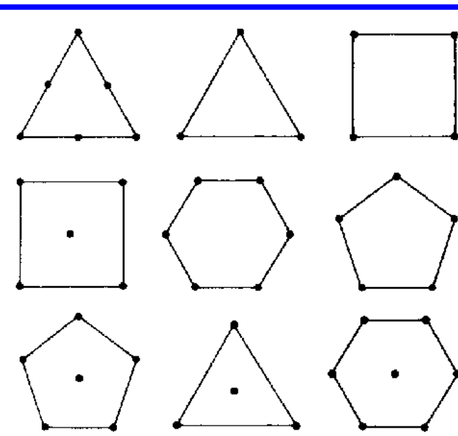
Fill a test tube or glass toothbrush tube about two-thirds full of iron filings and stopper the end with a plug of cotton or a cork. Stroke it with the poles of a strong magnet. Be careful not to shake the tube. Bring the tube of filings near a compass, and you will observe that it behaves just like a solid magnet. Shake the tube up well and again bring it near the compass. This time it does not influence the compass. From experiments such as this scientists are led to believe that the magnetism in a magnet is associated with very small particles of matter, perhaps molecules or atoms.

28 How to make floating magnets

Magnetize some used razor blades, being very careful not to cut yourself. Grease the blades lightly with oil, Vaseline or kitchen grease. Fill a soup plate with water and float the razor blades on the surface. Now bring a strong magnet under the floating magnets.

29 Some experiments with floating magnets

Magnetize seven or eight steel needles so that their points all have the same polarity and the eyes all have the opposite polarity. Push the needles through small hat corks about 13 mm in diameter so that about 1 cm of the needle is above the cork. Fill a cereal dish or a soup plate with sloping sides nearly full of water. Float the magnets, pointed end down, in the water. Now bring one pole of a strong magnet above the floating needles. Try the other end of the magnet. Such floating magnets can often be arranged in different patterns in the dish. Here are some to try.



30 A vibrator with a magnet

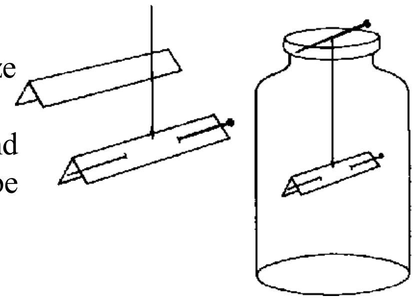
Set a U-shaped magnet on its side and place a needle or a razor blade on the lower pole. It will stand upright. Strike the free end with a pencil and observe how well it vibrates.

31 Making a needle float in air

Use a threaded needle. Draw the needle over one pole of a magnet resting on the table. Let the needle remain on this pole until it is thoroughly magnetized. Now carefully ease the needle from this pole and lift it by the thread until it is over the other pole. Careful manipulation will make the needle float in the air above the other pole. Can you explain why this happens?

32 How to make a card compass

Secure a wide-mouth glass jar. Fold a length of cardboard or stiff paper so that it will go into the bottle and not be too long to turn inside. Magnetize a steel darning needle (see experiment 3) that is just a little longer than the cardboard. Push the magnetized needle through the cardboard and suspend it on a thread so that the cardboard and needle balance. The needle may be moved in or out to get the exact balance. Tie the end of the thread to a match or longer piece of wood placed across the mouth of the jar.

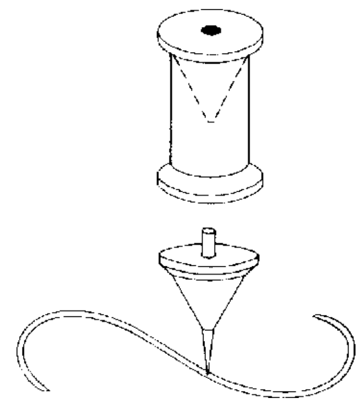


33 A magnetic fishing game

Tie a strong magnet to a string several decimeters long. Attach the string to a short fishing rod or stick. Spread a variety of small objects made of iron on a table behind a screen. Nails, tacks, screws, bolts, nuts, thumb tacks, etc., may be used. To each of the objects assign points, 5 for a large nail, 4 for a screw, 3 for a bolt, etc. The players take turns fishing over the screen with the magnet, and the score of each player is determined by what he picks up with the magnet.

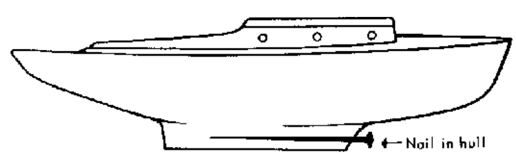
34 A magic magnetic spinner

Make a spinning top from a wooden spool which has been used for thread. The spool is first cut in two. One piece is then shaped to a point like a cone. Find a nail or other piece of iron rod that will fit tightly in the hole of the spool. Cut off a length that will go through the cone and stick out about 1 cm above the top. Grind the lower end, which just sticks out, to a very sharp and evenly rounded point to make a spinning peg. Magnetize the spindle and insert it in the wooden cone. Form a large S-curve from a piece of soft iron wire. Place this on a smooth surface. If you set the top spinning near one of the curves it will follow the wire to the end.



35 A magnetic boat

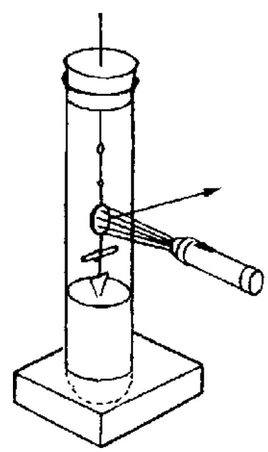
Fashion a small boat out of some soft wood. You may put a mast and sail on it if you like. Hollow out the inside of the boat or bore a small hole lengthwise in its hull. Magnetize an iron nail and either put it in the hole or simply lay it inside the boat. Use a plastic or aluminium pan for your ocean. You can fashion a shore line from sand or wood. Control your boat by means of a magnet which you move about under the container.



36 A sensitive magnetometer

Push a piece of copper wire through the cork of a test tube to serve as an upper support for the suspension. Make a carrier for the magnet from thin copper wire and solder a small vane to the lower end.

Attach a slip of mirror to the magnet carrier in order to reflect a beam of light. Pour oil into the test tube to a depth of approximately 3 cm. Lower the suspended magnet and carrier into the tube and adjust the upper support until the damping vane just dips into the oil.

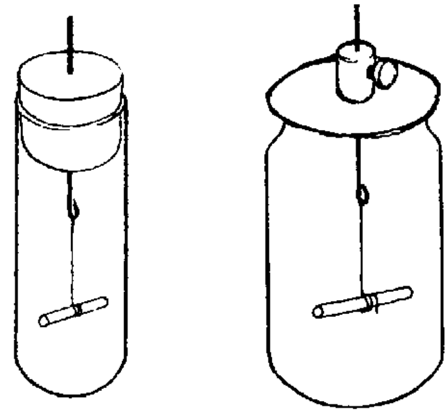


37 A vibration magnetometer

Small, strongly magnetized cobalt or ticonal magnets are now available which, suspended from silk in a specimen tube, are excellent vibration magnetometers. Since there is no 'damping' here, the time of vibration of the 'swing' is a measure of the strength of the magnetic field in which it is placed.

A larger model is easily made by using a preserve jar with a wooden top. A brass connector serves as a suitable clip for the upper support. The magnet can then be lowered to touch the bottom when the instrument is not in use. This precaution increases the life of the suspension.

(N.B. To damp a vibration means to lessen its amplitude.)



38 Making a magnetizing coil

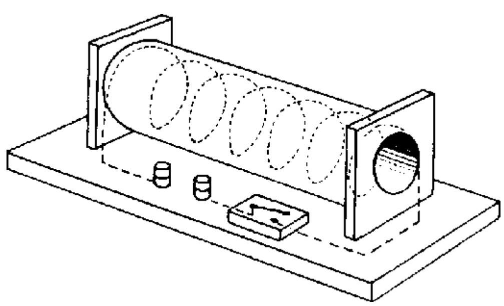
A piece of ordinary glass tubing wound with close turns of copper wire serves to magnetize knitting needles. A torch battery supplies the current required, but should not be left connected longer than necessary.

39 To make a magnetizing coil for the electric supply mains

This is just a solenoid through which a heavy current is passed for a short time. The mechanical dimensions are not critical, but the resistance of the wire must be chosen to suit the voltage employed. It will naturally be lower when used with a 1Zvolt accumulator than with the 230-volt mains. For use with a 1Zvolt car battery, 4 layers of 22 SWG insulated copper wire are suitable, wound on a cardboard tube about 30 cm long and diameter about 4 cm. If the coil is for use on the 230-volt mains, many more turns are needed. Fifteen layers will give a strong magnetic field, though the number can be reduced if the last four turns are of enamelled 'Euraka' resistance wire. As the current is only needed for a very short time, it is a good plan to include in the circuit a 'press down' switch; a car starter switch is suitable.

Obtain a cardboard tube of the dimensions mentioned. Make two end supports with a hole into which the tube can be glued. Wind on the wire, ·preferably using a lathe or hand drill. Secure the solenoid by screws passed through a wooden base and into the end supports. Connect the ends of the wire to two insulated terminals with the switch in series. Connect to the source of current, hold the object to be magnetized inside the coil, and press the switch momentarily if direct current is used. The polarity produced will be the same as that of the coil. With alternating current the polarity must be found afterwards, and the strength of magnetization will depend on the exact instant at which the current is switched off. It may therefore be necessary to make more than one trial.

The coil can be used for demagnetizing with alternating current. The procedure is then to place the magnet inside the coil, switch on the current and, whilst it is still flowing, withdraw the magnet along the axis to a distance of about 2 yards outside the coil before switching off. It is quite safe to use such a coil for demagnetizing a watch, though watchmakers use a much shorter coil.



CHAPTER XV

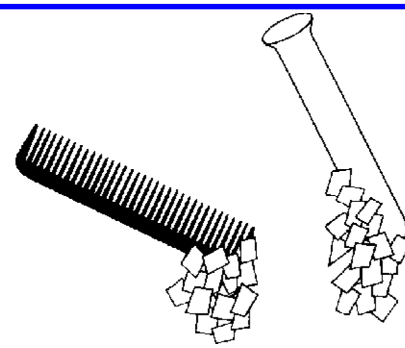
Experiments and materials for the study of electricity

A. STATIC ELECTRICITY

All these experiments work best when the air is dry.

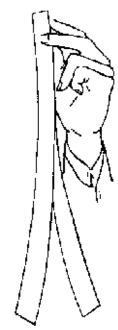
1 Electricity can be obtained by rubbing things together

Make a pile of finely divided cork particles by filing a cork. Cut up some thin paper into small pieces. Obtain a plastic comb, a plastic pencil, a plastic fountain pen, a piece of wax, a rubber balloon, a glass or china dish and any other non-metallic objects you may find. Rub each of these things briskly with your hair or a piece of fur and then bring near the pile of cork particles. Rub again and bring near the pile of thin paper. Observe what happens. Repeat the experiment rubbing each article in turn with a silk cloth. Repeat using a piece of flannel.



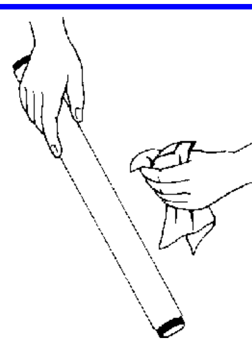
2 Static electricity is everywhere

Rub a blown up balloon on then bring it near some fine particles. Repeat using a comb and a plastic ruler. Rub a fountain pen on your coat sleeve and test it for a static charge. Hold two strips of newspaper, about 5 cm wide and 30 cm long, together. Stroke them lengthwise with the thumb and finger of your free hand. What happens? Try to devise other experiments showing that there is static electricity everywhere. your hair and paper or cork



3 Light from static electricity

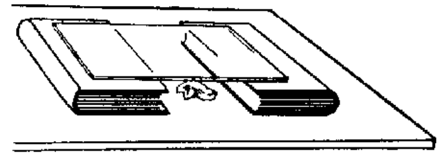
Secure a fluorescent light bulb. Rub it briskly with a piece of fur or flannel in a darkened room. What do you observe?



4 Dancing figures with static electricity

Secure an aluminium soup plate, about 2.5 cm deep, and a glass plate to cover it. Cut some little doll figures from thin tissue paper, as shown in the drawing. You may also cut out some other figures like boxers. The figures should be just a little shorter than the depth of the pan. Put the figures on the bottom of the pan and cover with the glass. Rub the top surface of the glass with a piece of fur or soft leather and watch the dance.

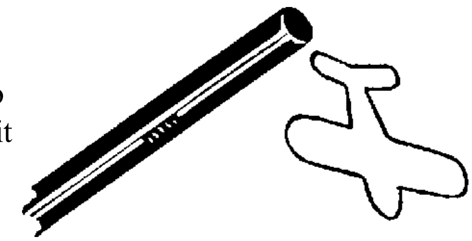
5 How to make the paper jump



Place pieces of paper underneath a sheet of glass resting on two books. Rub the glass with silk or flannel. The papers begin to jump about in an amusing way.

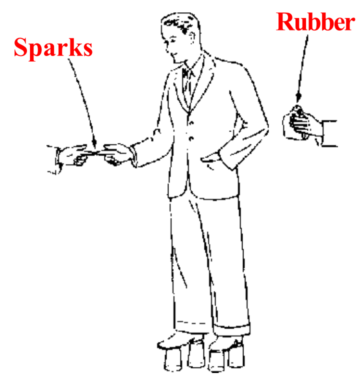
It is the charge induced on them by the charged glass which causes them to be attracted. When they have given up their charge they fall back again. The paper can be cut out in the shape of frogs.

6 An electrostatic airplane



Cut a piece of light aluminium foil into the shape of a small airplane. Bring a charged ebonite or plastic rod near to it. It jumps to the rod and receives the same kind of charge as the rod has, then it jumps away again. It can then be kept in the air as long as is desired, and its direction of flight can be guided by repulsion.

7 Sparks from rubbing

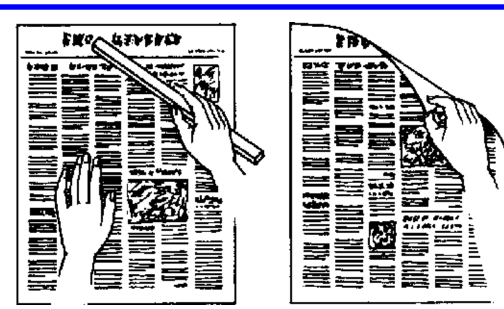


Obtain four water glasses and stand them upside down on the floor, close together. They should be near some metal object such as a water pipe. Have someone stand on the glasses. Brush his clothing for a full minute either with a piece of fur or a piece of folded rubber like a cycle inner tube or a hot water bottle. Have him stick his finger out toward the finger of someone standing on the floor. Repeat and have him bring his finger near the water pipe. Observe the results.

8 The balloon stays put

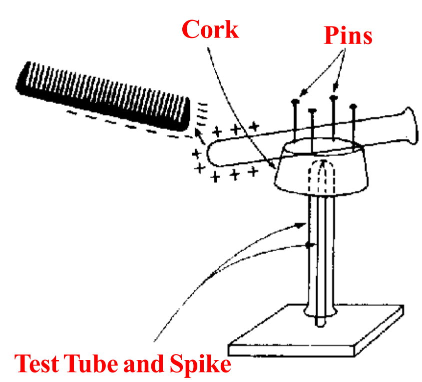
Blow up a toy balloon and rub it briskly with a piece of fur. Place it against the wall and observe that it stays where you place it. Repeat, rubbing the balloon on your hair. Again repeat, rubbing the balloon on a coat sleeve.

9 The newspaper stays on the wall



Spread out a sheet of newspaper and press it smoothly against a wall. Stroke the newspaper with a pencil all over its surface several times. Pull up one corner of the paper and then let it go. Notice how it is attracted back to the wall. If the air is very dry, you may be able to hear the crackle of the static charges.

10 There are two kinds of static charge

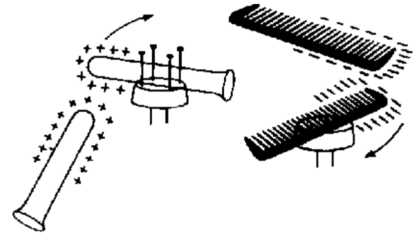


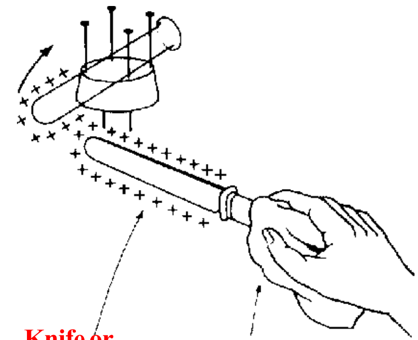
Make a turntable by driving a long nail through a wood base. Push a test tube into a hole made in a large flat cork. File the end of the nail to a sharp point and invert the test tube over it. Set pins in the top surface of the cork; they will brace the objects you place on the turntable. Secure two test tubes or other glass rods, a piece of silk such as a silk stocking, two plastic combs, and a piece of fur or flannel. Rub one glass rod with silk and set it on the turntable. Rub the other glass rod with silk and bring it near the one on the turntable. Repeat this experiment until you are sure of the results.

Again rub the glass rod with silk and place it on the turntable. Now rub a plastic comb with fur and bring it near the glass rod on the turntable. Repeat until you are sure of the results.

Rub a comb with fur and set it on the turntable. Rub the other comb with fur and bring it near the comb on the turntable. Repeat until you are sure your observations are correct.

Again rub a comb with fur and place it on the turntable. Rub a glass rod with sills and bring it near. Repeat until you are sure of your observations.



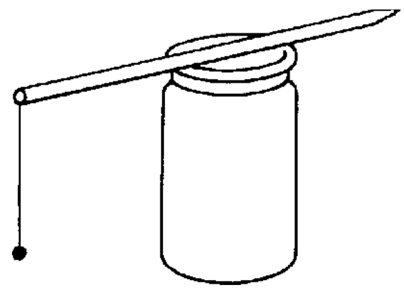


When plastic is rubbed with fur the plastic takes a negative charge of electricity and the fur takes a positive charge. When glass is rubbed with silk the glass takes a positive charge and the silk a negative charge. Your experiment has indicated that like static charges repel while unlike charges attract. This is a basic law of electricity.

11 How to make a pith hall indicator for static charges

Secure some pith from the inside of a plant stem. Dry the pith thoroughly and then press it tightly into small balls about 5 mm in diameter. Coat the pith balls with aluminium or gold paint. Attach each pith ball to a silk thread about 15 cm in length. Make a wooden stand for the pith ball. Bring objects rubbed with silk, fur or flannel near the pith ball and observe how it behaves. Notice that it is first attracted and then repelled. Such a pith ball system is called an electroscope.

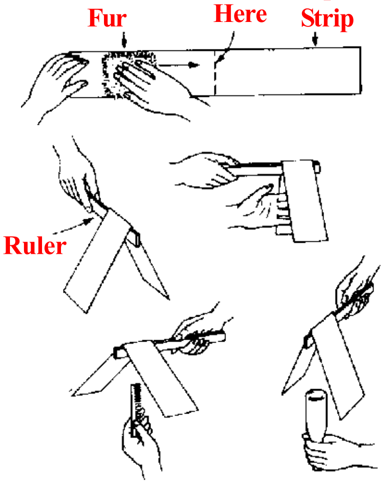
12 Metal foil ball electroscope



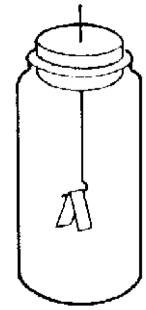
Roll up about 6 cms of metal foil from a cigarette packet into a bah of about 6 mm diameter. Use an adhesive to attach it to a piece of silk or nylon thread about 7.5 cm long. Secure the free end to a ball pen or other insulator and rest the pen across the mouth of a jam jar so that the ball hangs clear of the side. Bring any charged body near the ball; it should first be attracted and then jump away. Now rub another plastic pen on a celluloid set square or protractor. Hold the pen near the ball and let it take a charge. Now bring the protractor near the charged ball. What does this tell you about the two kinds of charge produced by rubbing ?

13 How to make an electroscope from newspaper

Cut a strip of newspaper 60 cm long and 10 cm wide. Crease it in the centre and hang it over a ruler as shown in the diagram. Hold it on the table and stroke several times with a piece of fur or flannel. Lift it from the table with the ruler and observe how it acts. Rub a comb or other plastic object with the fur or flannel and bring it between the extended leaves of newspaper. Repeat until you are sure of your results. Now rub a glass bottle with a piece of silk and bring it near the extended leaves of the newspaper. Observe the results and repeat until you are sure they are correct. What does this experiment show?



14 How to make a metal leaf electroscope



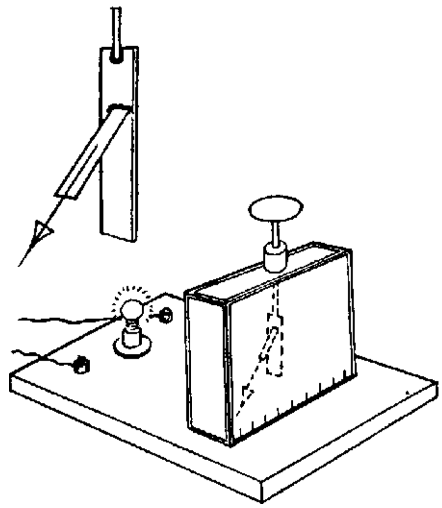
To make a device for detecting charges of electricity, a jam jar, some wire, and pieces of light foil or paper are needed.

A waxed cork is necessary to prevent the charge from leaking away. Push an L-shaped piece of brass or copper through it, and hang a piece of tissue paper or a strip of aluminium foil from the lower end.

If a charged body is brought near the rod, the leaves of the paper fly apart because they have received the same kind of charge.

Insulating wax (see Chapter XVIII, item 21) or Perspex are better insulators and therefore more satisfactory than the waxed cork.

15 How to make a shadow electroscope



A very useful piece of apparatus can be made with a chalk or cigar box. The lid and bottom should be removed and replaced by a piece of clear glass in one side and a piece of linen or paper in the other (front in the diagram). The glass can be kept in position by tin corner plates, and the paper can be glued on. A hole drilled in what is now the top of the apparatus should fit a candle, ebonite or amber insulator with a brass rod down its axis. The top of the brass rod carries a metal disk forming the 'cap' of the electroscope and the other end has a strip of tin soldered to it. The gold or aluminium leaf is attached to the upper part of this tin, but the leaf is shorter. A thin glass thread, easily made in a flame, is stuck to the leaf with glue. It has a small arrow at its lower end. An electric bulb shines a light through the glass side of the apparatus and casts a shadow of the leaf and pointer on the screen. The advantage of this arrangement over the usual projection electroscope is that there is no inversion of the leaf, and movement and position of the leaf can be seen by a large class. It is also possible to put a scale on the paper calibrated in volts.

16 Fun with a kissing balloon

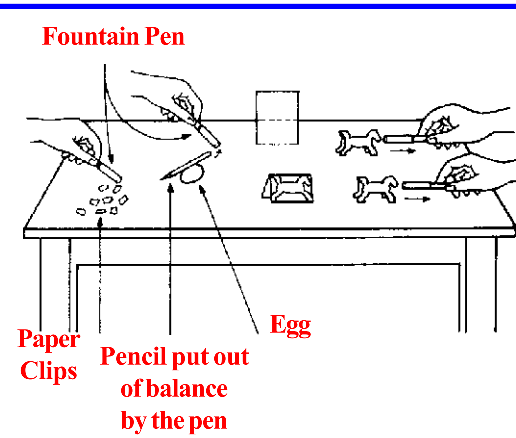
Blow up a toy balloon and tie a string to it about one metre long. You can draw faces on it with ink. Use a soft stick dipped in ink. Now hold the string while someone strokes the face on the balloon with a piece of fur or flannel. Let the balloon go and watch it touch everything around.

17 More fun with a balloon

Fix two balloons as in the experiment above. Rub the faces with fur. Hold the strings together and observe how they repel. Put your hand between them and observe what happens. Bring one of the balloons near your face. Repeat, using three balloons.

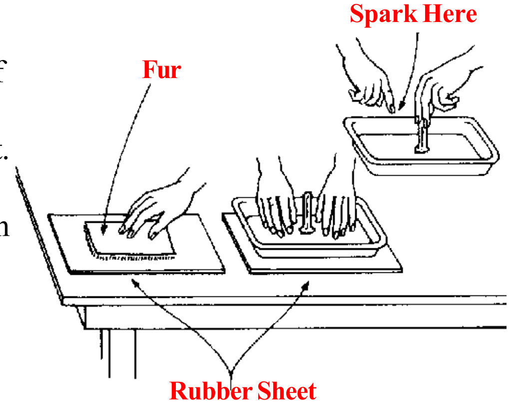
18 A static horse race

Cut small horses from a piece of folded paper so that they will stand on a table. Rub a hard plastic comb or fountain pen with fur and notice that you can pull the paper horses along the table. With several horses, you can have a horse race.



19 How to get many sparks from static electricity

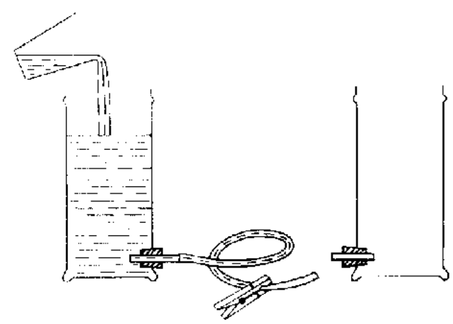
Obtain a piece of aluminium about 24 cm square. An aluminium cake tin will do. Heat the metal evenly over a flame. Touch a stick of sealing wax or a wax candle to the centre of the aluminium until it melts and sticks solidly to it as a handle. If you want a more permanent handle you can punch a hole through the aluminium and screw a plastic or wood handle to it. Unfold an old rubber inner tube from an automobile tyre and place it on a table. Stroke the surface of the rubber briskly with a piece of fur or flannel for half a minute. Now place the aluminium on the rubber and press it down hard with your fingers. Remove your fingers and lift the metal by the handle. Bring your finger near the metal and you should get a spark. You can take many charges from the rubber without further rubbing. Just press the metal against the rubber, press with your fingers and lift by the handle.



B. SIMPLE ELECTRIC CELLS AND CIRCUITS

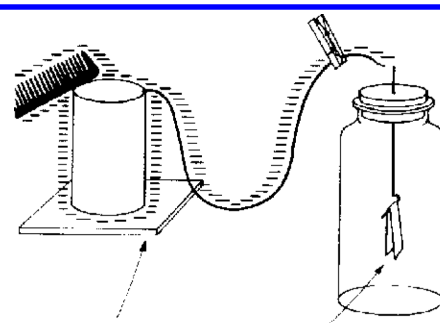
1 To show how water flows in a tube

To make water flow from one can to another the source must be at a higher level. Water flows downhill. You can demonstrate this by using two large tin cans. Punch a hole near the bottom of each and then enlarge the hole so it will take a one-hole cork or stopper. Put a length of rubber tube on one can. Pinch the tube near the end with a spring clothes peg. Place the can on the table and fill it with water. Attach the tube to the other can. Let it also stand on the table. Remove the clothes peg and watch the water flow. When does it stop flowing?



2 To show bow electricity flows in a conductor

Use two tin cans as in the experiment above. Fasten the bare end of a wire to one can. Place both cans on plates that have been turned over. Fasten a spring clothes peg near the free end of the wire. Now use the device for getting many sparks which you made in experiment 19 of the previous section. Hook the free end of the wire to the can to which the other end is already attached. Place a charge on the rubber pad and bring the metal plate into contact with the can to which the wire is attached. Repeat this twenty times until you have a good charge on the can.



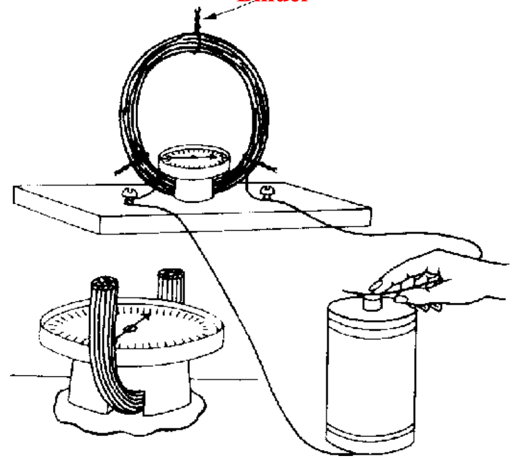
Place the pith ball electroscope which you made in experiment 11 of the previous section so that it is in contact with the other can. Next unhook the wire from the can, using the clothes peg as a handle and hook it over the other can. Observe the pith ball. If your experiment is successful the electricity will flow from one can to the other, and this will be shown by the pith ball.

3 Another way to show how electricity flows

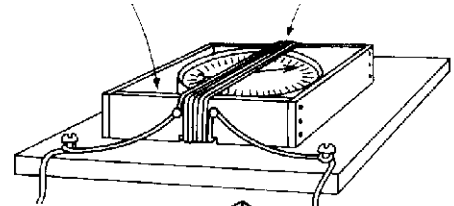
Use the can with the wire attached from experiment 2 above. This time attach the other end of the wire to the leaf electroscope which you made in experiment 14 of the previous section. Place a charge on the can with your spark device or from a plastic comb rubbed with fur. Observe the leaf of the electroscope.

4 How to make simple instruments to show electric currents

Procure some cotton-covered bell wire and neatly wrap from 50 to 60 turns to form a coil around a jar that is about 8 cm in diameter. Slip the coil from the jar and fasten it securely with short pieces of wire or with tape. Mount the coil on a wood base. A little platform to hold the compass can be made by cutting a hole in the cork for the coil to go through and then fastening the cork and coil to the base with melted sealing wax. Place a compass on the cork so that it points parallel with the direction of the coil. Connect a dry cell to the coil and observe the compass needle.

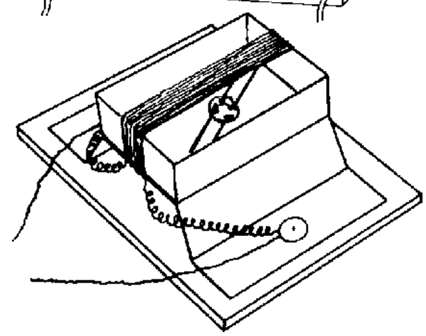


A more sensitive instrument can be made by building a little frame from cigar box wood just large enough to hold the compass. Place the compass in the frame and then wind about 20 turns of bell wire over the frame as shown in the diagram.



The press-stud compass needle described in Chapter XIV, experiment 11, can be used in both the above galvanoscopes. A useful model can also be devised using this compass needle in a matchbox. Remove the drawer from the box, and split open the case as shown in the diagram. Wind 20 turns of 26 S.W.G. double cotton-covered wire tightly round the drawer. Support the compass needle on a pin pushed through the bottom of the box.

Fix the split-open case to a plywood base with drawing pins. Wind the bared end of the coil round the drawing pins, making electrical contact so that they may be used as terminals.

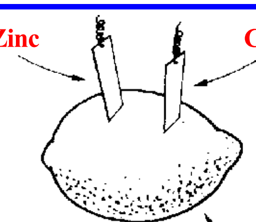


5 Electrical energy from chemical energy

Take two coins made of different metals. Clean them well with steel wool or fine sand paper. Fold some paper towelling or blotting paper into a pad so that it is slightly larger than the coins. Soak the blotting paper in salt water. Place one coin on top of the pad and the other underneath. Hold them between your thumb and finger. Connect both ends of the coil from your sensitive meter to the coins and watch the compass.

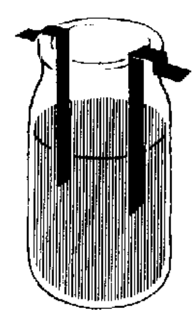
6 Electricity from a lemon

Connect one wire from your sensitive meter to a piece of zinc cut from the can of a used dry cell battery. Connect the other wire to a piece of copper. Roll a lemon on the table, pushing on it with your hand to break up some of the tissue inside. Push the two metal strips through the skin of the lemon, making sure they do not touch. Observe the compass needle. Try this experiment using a potato. Does the distance between the plates affect the meter reading?

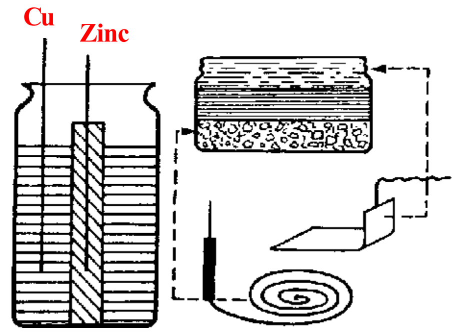


7 How to make a simple electric cell

If dry batteries are not available, a simple voltaic cell can be used for many experiments. Copper and zinc plates dipped into dilute sulphuric acid contained in a jar work well, but the plates must be shaken occasionally to remove the gases. A few crystals of potassium dichromate will remove the gases chemically.



8 Other simple electric cells



You can make a simple Daniell cell for class use with a boot polish or shallow meat jar.

First put in a layer of copper sulphate crystals about 1.5 cm deep, moistened by about 0.5 cm of copper sulphate solution. Bury in this a pancake spiral of copper wire with an insulated lead. Pour in a layer of moist plaster of Paris and allow it to set.

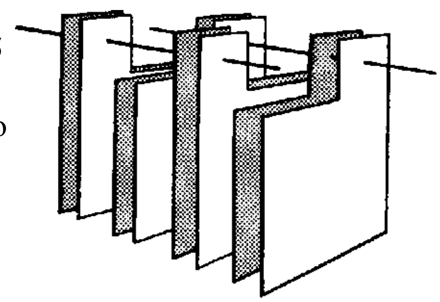
For a negative plate use a strip of zinc sheet with a wire attached to it and fill up the jar with dilute sulphuric acid. This small quantity of acid can be thrown away when the cell is not in use.

A larger cell for supplying current can be improvised from a jam jar and a piece of cardboard tube.

Mix copper sulphate with plaster of Paris to a thin cream and allow to set after pouring it into the space between the jar and the central cardboard tube.

Mix another paste using plaster of Paris and zinc sulphate with a little sulphuric acid added. When the first plaster has set, pour this mixture into the central tube. Insert a copper plate and a zinc rod as electrodes before the pastes are hard.

9 How to make a simple accumulator or storage battery



Strip the lead covering from some electric cable. Cut it into pieces, 1.5 cm by 3 cm with a short projection or 'lug' on the short side of each.

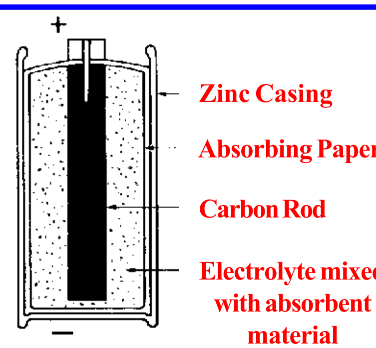
Now prepare pieces of thin wood 1.5 cm by 3 cm from a matchbox to act as 'spacers' to separate the plates. a. Simple electric cells and circuits

Arrange a pile of plates with lugs placed alternately and separate each plate by a spacer.

Connect the lugs on each side by a copper wire.

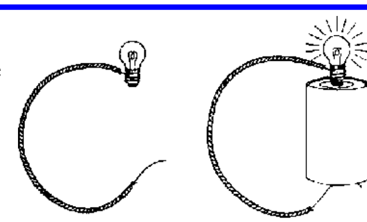
Immerse this arrangement in dilute sulphuric acid and pass a current to 'form' the plates. Even after a few minutes the accumulator will light a small torch bulb. Alternate charging and discharging will improve the condition of the plates.

10 How a dry cell is constructed



Remove the outer covering from an old dry cell. With a saw, cut the battery in half and observe its structure. Observe the carbon or positive pole in the centre, the zinc can which is the negative pole and the material between the two poles which is the chemical that acts on the plate of the cell. Notice how the zinc has been eaten away by the chemical. Observe that the chemical materials were sealed into the zinc can with hot pitch.

11 Using a dry cell in a circuit



Wrap the end of one of the short pieces of bell wire around the screw like base of a flash- light bulb so that it holds the bulb tightly. Bend the remainder of the wire in the shape of the letter C. Set the tip of the flashlight bulb on the centre terminal of a flashlight cell and adjust the free end so that the springiness of the wire holds it against the bottom of the cell. If the connexions are tight, the bulb should light. Any flashlight bulb should operate when connected in this way, but the kind made for a single cell flashlight will give a much brighter light.

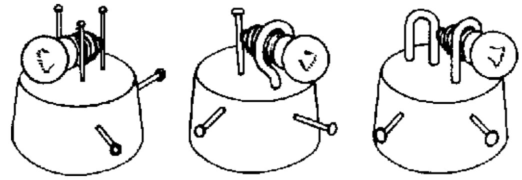
Look closely at the bulb and notice the fine metal wire held in position by two heavier wires inside. A hand lens will make this easier to see. The fine metal wire is made of wolfram, formerly called tungsten. Passage of the electric current through the wolfram wire causes it to become very hot and give off light.

Turn the cell upside down and reverse the terminals. Note that the lamp still operates, though the electricity is flowing in the opposite direction.

Make a diagram showing the path of the current through the bulb and around to the other end of the cell. Develop the meaning of the term 'electric circuit'

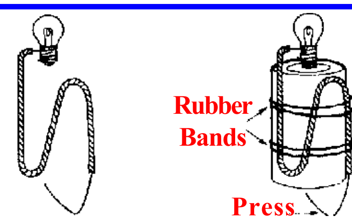
12 Flashlight bulb holders

Wire nails, screw eyes or staples can be used for supporting flashlight bulbs. Three nails driven into the top of a cork as shown in the diagram will support the bulb. Two more nails or screws in the side of the cork and touching two of the vertical nails serve to make electrical connexions.



13 How a flashlight works

Bend the bell wire and fasten it to the cell with a piece of friction tape or rubber band. Adjust the wire so that the tip of the bulb touches the centre terminal of the cell. Use the free end of the wire as a switch by pressing it against the bottom of the cell.

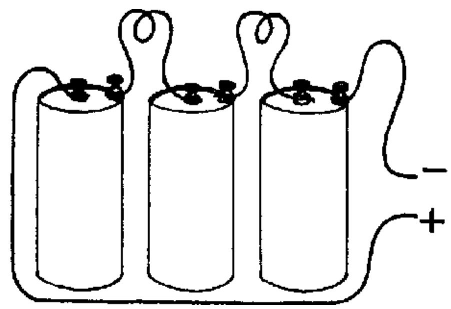


14 How to connect cells in series

Connect three dry cells in series as shown in the diagram. Note that the outside terminal of each cell is connected to the centre terminal of the next cell or vice versa. When the cells are connected in this way, the total voltage or electrical pressure is the sum of the voltages of the cells. In this case, the total voltage is 4.5 volts since the voltage of each cell is 1.5 volts.

Now connect the two lead wires to a lamp for a three-cell flashlight. Disconnect one of the wires and attach the same lamp to a single cell. Note the difference in brightness.

Connect the same lamp to two cells in series and compare the brightness with that produced by one cell and by three cells. Cells connected in series



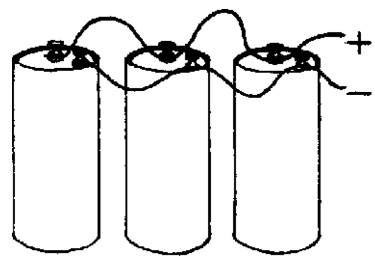
Cells Connected in Series

15 How to connect cells in parallel

Connect three cells in parallel by attaching all the centre terminals to one wire and all the outside terminals to another wire. Connect the lead wires to a receptacle and insert a bulb for a one-cell flashlight.

Disconnect one of the cells and note that there is no difference in the brightness of the lamp. Disconnect two cells and still the brightness does not change. When cells are connected in parallel the total voltage is no greater than that of a single cell.

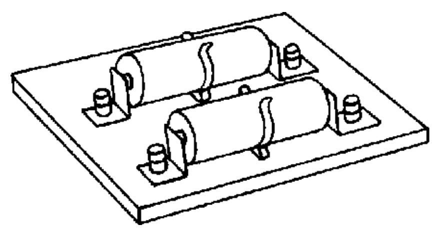
Develop the distinction between the term 'cell' and 'battery'. A battery is two or more cells in connexion.



Cells Connected in Parallel

16 Torch battery holders

When several torch cells are needed for an experiment they can be held in spring clips fastened to a wooden base. These can be made of steel baling strip bent in the form of an angle bracket and secured by a terminal so that series and parallel arrangements are possible. For greater security, circular clips of standard pattern can be added to grip the cells round the circumference.



17 How lamps are connected in series

Connect three lamps in series and attach them to a single cell. Connect the same three lamps to two cells in series, then three cells in series. Unscrew one of the bulbs and note that the other two lamps go out, because the circuit is broken. Relate this to Christmas tree lights. In many Christmas tree cords, the lamps are connected in series. If one lamp in the series burns out, all the other lamps go out because the circuit is broken.

Lamps Connected in Series

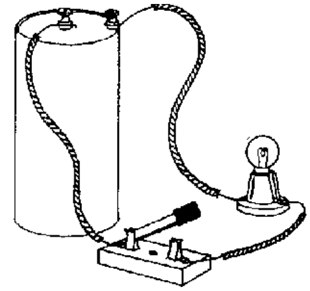
18 How lamps are connected in parallel

Connect three lamps in parallel and attach them to a single cell. Unscrew one of the bulbs and note that the other two stay lighted. Increase the brightness of the lamps by adding a second cell in series. Unscrew one bulb, then two bulbs, then three bulbs.

Lamps Connected in Parallel

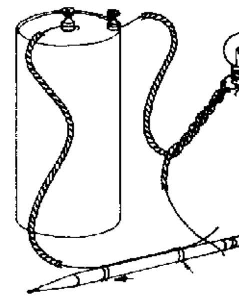
19 How a switch is used to control an electric circuit

Place a knife switch in a circuit with a cell and a lamp and turn the light on and off by operating the switch. Replace the lamp with a bell or buzzer and operate the switch. Replace the knife switch with a pushbutton switch. Discuss the appropriateness of each kind of switch for different uses.



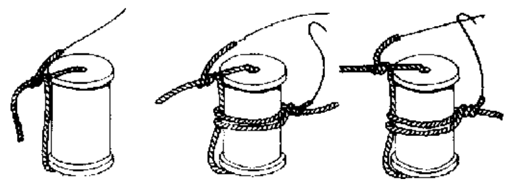
20 How to make a simple switch

A simple switch can be made by fastening the end of a piece of bell wire to a pencil with two rubber bands as shown in the diagram. A second wire spliced under it makes a suit- able connection.



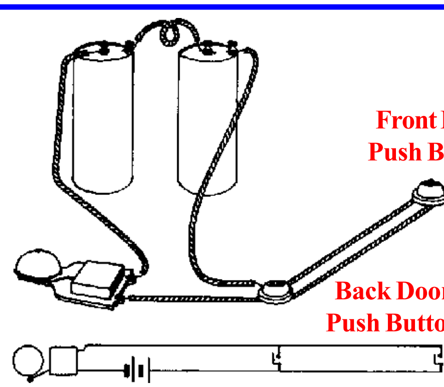
21 Another simple switch

Run a piece of bell wire through a spool (reel) and fasten it. Wind a second piece around the spool (see the second figure).



22 How a door bell can be rung from two pushbuttons

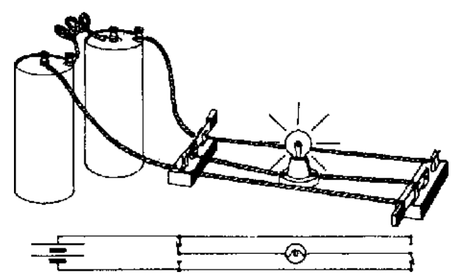
Using two cells, two pushbuttons and a bell, show how a doorbell can be operated from two different points, such as the front door and back door of a house. Lay out the circuit on a table as shown in the diagram. Draw an electrical diagram of the circuit, using standard symbols.



23 How a light is controlled from two switches

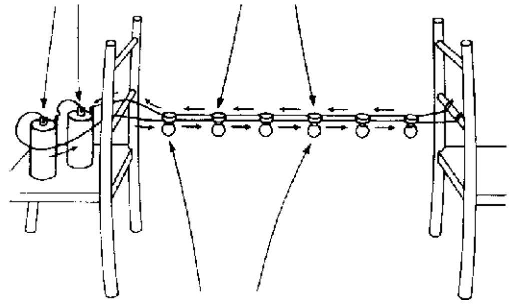
With two double throw knife switches, two cells and a lamp, show how a hall light can be operated from either the upstairs or the downstairs switch. Lay out the circuit on a table as shown in the diagram. Draw an electrical diagram of the circuit, using standard symbols.

Adjust the free ends of the wires so that the switch can be opened and closed easily.



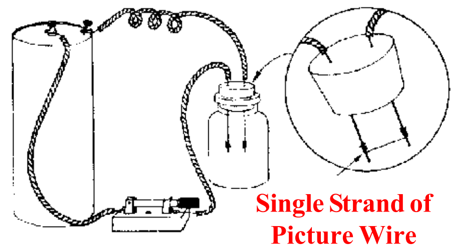
24 A miniature street lighting system

Cut two lengths of insulated bell wire about three metres long. Remove the insulation at six places along each wire and connect miniature light bulb sockets in parallel' along them. Fasten the wires between two chairs as shown in the diagram, leaving the wires apart at one end. Connect the wires at the other end with two dry cells. Screw torch light bulbs into the sockets.



25 How we get heat and light from electricity

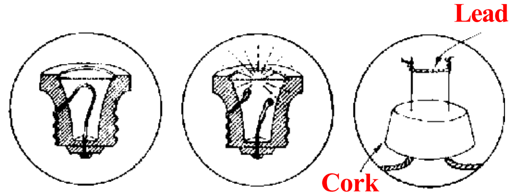
Push the ends of two pieces of bell wire through a flat cork that fits a small bottle. A suitable flat cork can be made by cutting off the end of a longer cork, or a two-hole rubber stopper may be used instead. Now untwist a piece of ordinary iron picture cord and cut off a short piece of a single strand. Wind the ends of this short piece of picture wire around the projecting ends of the copper wires and insert the cork into a bottle. The result will serve as a crude model of an electric lamp.



Connect the electric lamp model into a circuit with one or more dry cells and a switch. Close the switch until the fine wire (filament) begins to glow, then open the switch again. With care the lamp can be lighted several times before the filament is consumed, but finally the heated iron wire combines with the oxygen of the air inside the bottle and bums away. Commercially made lamp bulbs contain no oxygen, and the wolfram wire is heated to such a high temperature that it glows brightly. In addition to protecting the filament, the glass bulb also makes an electric lamp safe to use.

26 How fuses protect electric circuits

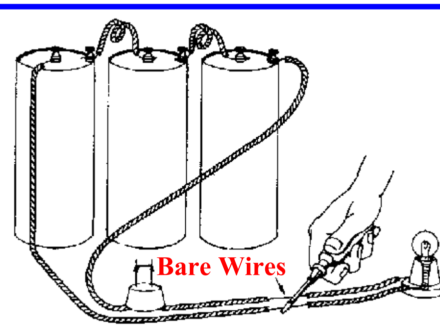
Examine normal and burned out fuses. Fuses are safety devices that break an electric circuit when the circuit is overloaded. The fuse wire melts when an unsafe amount of current is flowing through a circuit.



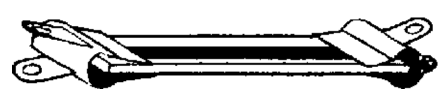
Cut a very thin strip of metal foil from a candy bar or other wrapper and fasten it between the ends of two wires projecting through a cork. This will represent a model of a fuse that should work with dry cells. Experiment with different types and widths of foil until the working model operates satisfactorily.

27 How a short circuit burns out a fuse

Place the model fuse shown in a circuit with several cells and a lamp. Then short circuit the lamp. If the fuse does not melt, cut a thinner strip of foil. Experiment with different kinds and widths of foil until the fuse carries the current when connected properly but melts when there is a 'short' in the circuit.



28 How to make a simple fuse holder Tin foil used for cigarette and packing purposes is useful for experiments on fuses. It can be cut in strips and stuck on a piece of gummed tape which will hold it flat. The metal foil with paper backing which was used during the war for radar camouflage is excellent for the above experiment and can be cut easily with a pair of scissors to give different fusing values. The ends can be held by bulldog paper clips to a slat of wood or a ruler. The device can then be incorporated with the circuit board set if desired. Different lengths and widths of tin foil should be tried to find the fusing current.



29 How electrical resistance varies with temperature

Connect a coil of about two metres of florist's thin iron wire in series with a torch battery and bulb. Heat the coil with a match; the increase in resistance will reduce the current so that the bulb no longer glows.

C. MAGNETISM AND ELECTRICAL ENERGY

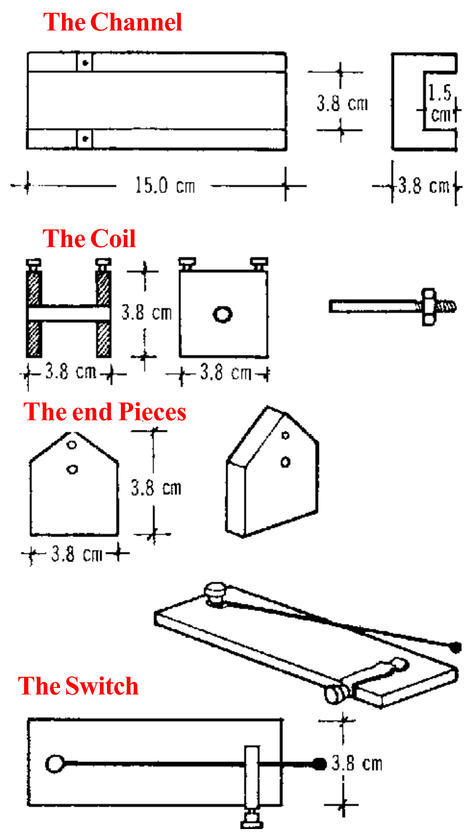
1 An apparatus for building up simple electrical instruments

The different pieces of apparatus used in elementary electricity have so much in common, electromagnets, switches, etc., that it is worth while constructing some multiple sets of apparatus in which they can be used in several different ways. The following arrangements have been found useful for boys of 11-13, and require little more than a penknife to assemble, once the basic parts are made. The devices suggested are not entirely foolproof, because little is learned of the difficulties of a subject if one needs only to follow instructions to the letter.

The apparatus consists of a short wooden channel which acts as a base for all experiments; a square-ended former for winding a coil which fits the groove fairly tightly, a few terminals, bits of tin, etc., are all that are required to make a Morse sounder, buzzer, bell indicator, electromagnet repulsion meter and attraction meter.

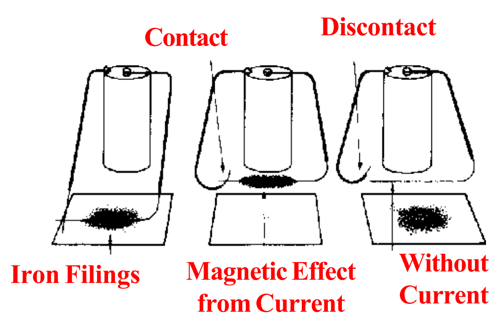
The coil is made of two square end pieces of wood with holes in their centre. They are joined by cardboard tube glued into these holes.

An old carriage bolt with the head cut off makes a convenient iron core.



2 Magnetism from an electric current

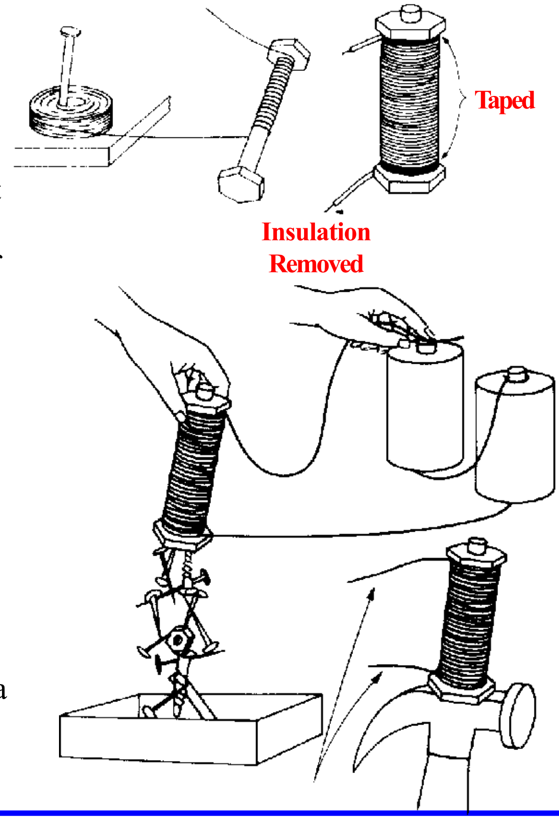
Cut two lengths of copper wire and remove the insulation from the ends. Connect the wires to a dry cell and arrange the bare ends as shown in the figure. Place some iron filings on a piece of paper and run one of the bare ends through them. Now let the current flow through the circuit and quickly lift the wire and observe the iron filings. Break the contact and the iron filings will drop from the wire. Do not leave the cell connected long; it will quickly run down when connected this way.



3 Another way to show the magnetic effect of a current

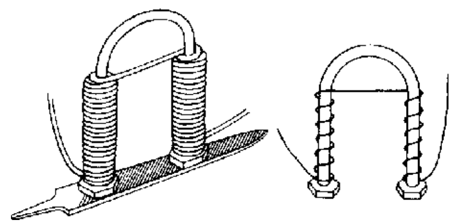
Repeat the experiment above, replacing the iron filings with a magnetic compass. Observe the difference in the compass when it is placed over the wire and under the wire.

4 How to make an electromagnet from a bolt



Secure an iron bolt about 5 cm long which has a nut and two washers. Place a washer at each end and screw the nut just on to the bolt. Wind layers of insulated bell wire on the bolt between the washers, making certain to leave 30 cm of wire sticking out when you start winding the coil. When you have filled the bolt between the washers with several layers of turns of wire, cut the wire, again leaving 1 about 30 cm sticking out. Twist the two ends of the wire close to the ends, then wind short lengths of tape at the ends of the bolt to keep the wire from unwinding. Remove the insulation from the two ends of wire. Connect two dry cells in series and attach your electro- magnet to them. Pick up some tacks and nails. Disconnect one wire from the battery while the tacks are still attached. Pick up other objects made of iron or steel. Test the poles of each end of the magnet with a compass while the current is turned on.

5 How to make a horseshoe electromagnet



Secure a slender bolt or a piece of iron rod about 5 mm in diameter and 30 cm long. Bend this into the shape of the letter U. Wind a coil of several layers of bell wire on each arm of the magnet, leaving the curving part free as shown. Begin at the end of one arm. Leave about 30 cm of wire sticking out for connections. Wind about three layers on this pole, then carry the wire across the top to the other end; be sure to wind this pole exactly as shown in the diagram. Wind about three layers of wire on this pole. When you have finished, tape the wire to keep it from un- winding. Remove the insulation from the ends of the coil, attach to two dry cells, and test the poles of the electromagnet. One should be a north pole and the other a south. If each has the same polarity, you have wound the second coil in the wrong direction. It will be necessary to unwind the coil and rewind it in the opposite direction.

Try picking up different things with the magnet. Compare the strength of this electro-magnet with the straight one you made.

6 How to increase the strength of an electromagnet

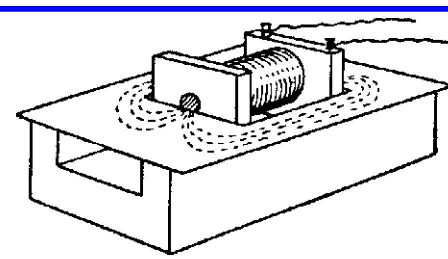
Wrap 100 turns of bell wire on a straight iron bolt. Connect the ends of the magnet with one dry cell and count the number of tacks you can pick up with the magnet. Make three trials, and take the average as the number that this magnet with one battery will pick up. Next attach two batteries to the magnet and repeat. Count the number of tacks. How is the strength of the magnet affected by increasing the current flowing through it?

Next wrap another 100 turns of wire on the magnet in the same direction. Attach to one battery and see how many tacks you can pick up. Repeat three times and take the average. Compare this number with the number picked up with one battery and a magnet of 100 turns of wire. How does increasing the number of turns of wire affect the strength? Make a statement on increasing the strength of an electromagnet.

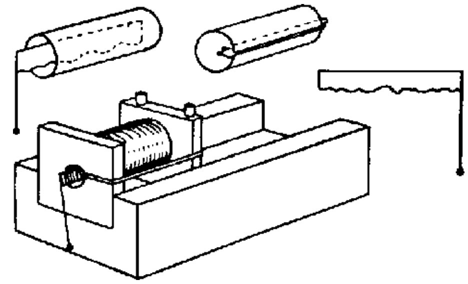
7 How to study the magnetic field of a coil

Use the apparatus made in experiment 1 of this section.

A postcard with a square hole cut in it enables the coil to pass through. The card acts as a tray on which the effect of using different cores in the coil can be studied by making iron filing maps.



8 How to make a repulsion meter

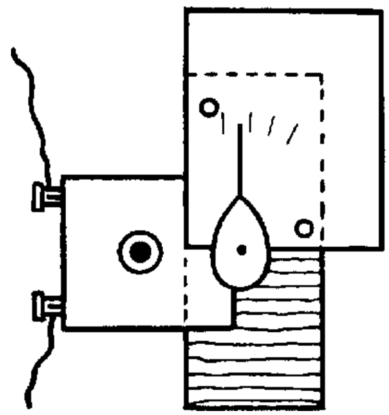


Use the equipment made in experiment 1 of this section.

A piece of tin can about 4 by 5 cm with a wire soldered to one end is required for the 'movement' of the meter. A blob of solder on the end of the wire acts as a gravity control to the meter.

The coil becomes magnetized when a current is passed. Both the fixed and moving elements are magnetized in the same direction, and repulsion occurs. The fixed element is a soft iron wire held in position by a rubber band. It will give readings 0-5 amps, depending on the wire and the magnetic properties of the metals used.

9 How to make an attraction meter

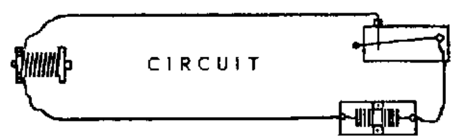


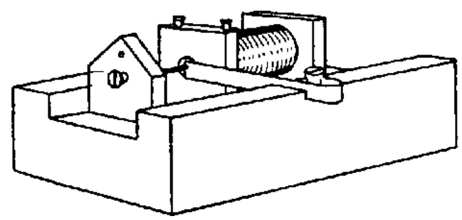
Use the equipment made in experiment 1 of this section.

For this apparatus the channel is laid on its side with the coil fitted as before. The iron core is pushed in and a current is passed. This attracts a pear-shaped piece of tin can pivoted on a pin stuck in the end of the block. A fine wire soldered to the tip of the metal acts as a pointer and graduations can be made on a piece of card held in position by drawing pins.

These are only a few of the devices which can be assembled from the above components. A boy of 12 can discover many more: the electric signal, the sucking bar, the relay, etc.

10 How to make a telegraph key and sounder





Again use the equipment made in experiment 1 of this section.

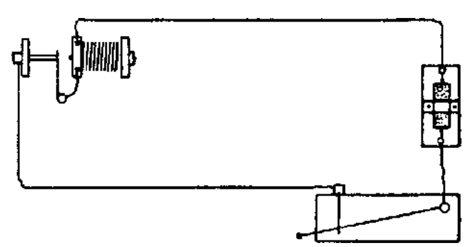
The coil should first be wound with any available copper wire, the ends being fastened under the terminals.

The completed coil is pressed into the groove and the iron core slid in; if necessary, wedge it in place with a piece of paper.

A strip of tin can about 10 cm long is then pressed into the saw cuts in the edge of the channel and secured by a terminal. One of the end pieces with a terminal in its lower hole will act as the sounder.

When the switch is depressed, the coil becomes a magnet, and the piece of tin can is pulled forward to hit the metal core with a 'click': as it springs back at the release of the switch, it hits the terminal on the end piece with a 'clack'.

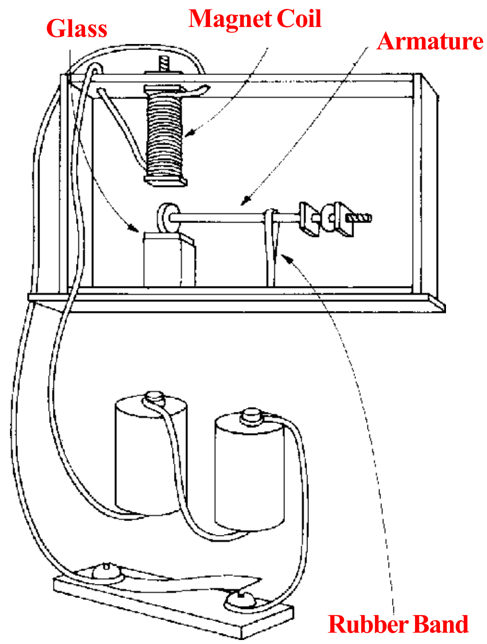
11 How to make an electric buzzer



Use the equipment made in experiment 1 of this section.

A simple rearrangement of the circuit converts the sounder into a buzzer. The contacts soon become fouled, and it is necessary to scrape them with a penknife.

12 How to make a cigar box telegraph and a key



Seventy-five to 100 turns of magnet wire neatly wound on to a 6.5 to 8 cm bolt will serve for the coil. Leave enough of the threaded end for two nuts and the thickness of the box, so that the coil can be fastened to the box. For the armature, a 10 cm bolt, 5 mm in diameter and with a round head, is most satisfactory. Support it between two nuts by a screw-eye fixed to the back of the box so that the head will extend just beneath the coil. A block of wood with a small piece of window glass cemented to it makes an effective anvil. Attach the anvil securely to the box. Hot sealing wax is ideal for both purposes. Any glue, however, will do. The height of the anvil should be such as to allow not less than 3 mm of clearance space for the end of the armature, and it should not exceed this amount by more than a trifle. The remaining feature now is a spring to pull the armature away from the magnet in case it tends to cling after the current is broken. A rubber band will work well. Slip it over the end of the armature and attach it to the box with a thumb tack. Give it just enough tension to prevent the armature from sticking to the magnet.

You are now ready to assemble a key. Secure a small piece of board about 8 cm by 15.5 cm and about 0.5 cm thick. Cut a strip of metal from a can about 2.5 by 13 cm. Go over it thoroughly with sandpaper or steel wool to remove any lacquer or tarnish from its surface. A piece of clock spring is also excellent for this purpose. Holes may be punched with a large nail and a sharp blow from a hammer. Set a screw in one end of the block and attach the metal at the other end so that it will bridge the space when the metal is pressed to the screw head.

Connect your telegraph sounder, two cells and key in series as shown. You are now ready for your trial message. If, on vibrating the key, you do not get a series of clicks, it means that either your connections are loose or an adjustment of the rubber band is needed.

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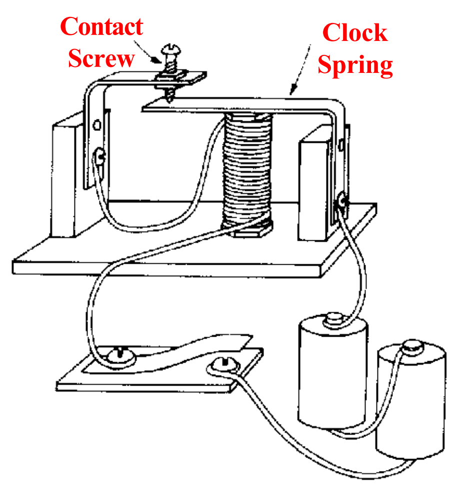
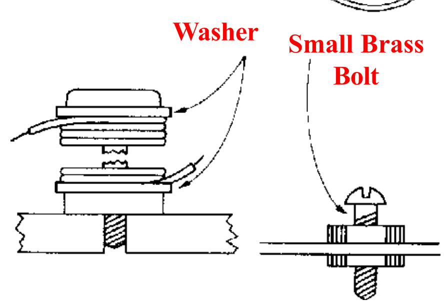
13 Another way to make a buzzer



A buzzer is essentially the same as a telegraph instrument except that it produces a buzzing sound instead of a clicking sound when you close the circuit. It is arranged so that it will automatically make and break the circuit many times per second while you hold down the key. The armature vibrates rapidly enough to produce the buzzing sound, which continues as long as the key is down. The buzzer is very fine for sending code—a short buzz for a ‘dot’ and a longer buzz for a ‘dash’. It sounds just like radio code and is therefore better than the telegraph instrument for learning to send and receive by radio.



For the base and mountings, cut out three pieces of board to the following dimensions respectively, 13 by 15.5 cm, 5 by 5 cm and 5 by 7.5 cm. Drill a hole smaller than the bolt through the baseboard about 6.5 cm from one end to hold the magnet. For the magnet coil secure an 8 cm by 4 mm bolt at the hardware store. Put on two washers as collars to hold the wire and a nut leaving a little more than 1.5 cm of the threaded end clear. Wind on 100 turns of bell wire in a neat fashion, leaving about 45 cm of the ends free. Either tie the wire at the last turn or tape it to prevent unwinding. Now mount the coil by turning it into the prepared hole securely.

For the vibrator bend a 10.5 cm strip of thin iron about 2 cm wide into a right angle so that one arm will be 7.5 cm long. A piece of softened clock spring is excellent. To soften the spring bring it to red heat and allow to cool slowly. Punch two holes in the short arm by laying the strip on the end of a block and forcing the point of a large nail through with a sharp blow from a hammer. Attach the strip to the smaller block with screws, and nail the block to the base. Care should be taken to have the vibrator not more than 3 mm above the magnet. If it is not just right, it can be adjusted later by bending the vibrator strip.

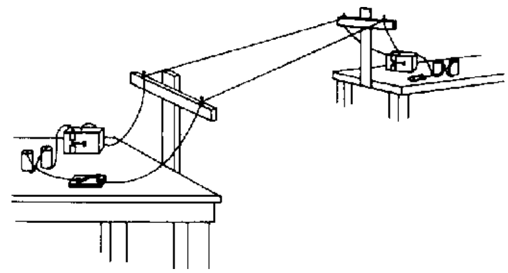
For the contact point, secure a small brass bolt about 2.5cm by 6 mm, and two nuts to fit, and a 5 cm angle iron. Set the brass bolt in one of the holes of the angle iron. Mount this angle iron with screws on the 5 by 7.5 cm block so that when it is nailed in position the horizontal arm of the angle iron will stand about 1.5 cm above the vibrator.

Now connect your buzzer with two cells and a key of your own construction. Be sure all connections are tight and that all wire is free from insulation where the connections are made. Press the key down and hold it while you turn the contact screw down into contact with the vibrator. If it does not vibrate, use sandpaper or steel wool to polish the surface thoroughly under the contact point. As soon as you get it vibrating, you can improve the tone by finer adjustment of the contact screw and also by bending the vibrator to ensure a space about the thickness of a dinner knife between the vibrator and the magnet.

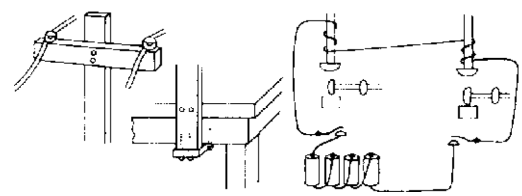
Now you can practice the code. If several butters are made, you may connect them to a line in the room, or you may signal between two houses.

14 How to connect up a two-way telegraph system

If you can secure two telegraph sounders and two keys like the ones made in experiment 12 above, you can set up a two-way telegraph system by following the diagrams below.



When one key is being used for sending, the other one must be fastened down so that the electric current will go through it.



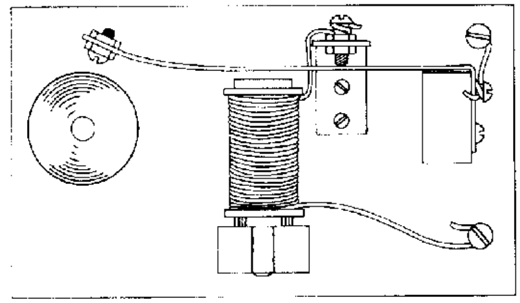
15 How to make an electric bell

If you study the diagrams, you will see how simple it is to adapt a few worthless pieces of material to your purpose of making a bell that will ring nicely on electric dry cells. You will need three pieces of board—one for the base, about 13 by 18 cm, one to hold the magnet, and one to hold the vibrator, each about 5 by 5 cm. Wind not less than 100 turns of cotton-covered magnet wire or bell wire on to an 8 cm bolt for the magnet. Plan to have several centimetres of wire free at the ends when finished. Use a nut and two washers to form the spool. Leave at least 1.5 cm of the threaded end of the bolt free for attaching the magnet to the block as shown in the diagram. Mount the magnet about midway on the base with nails of the proper size.

For the vibrator or clapper, an 18 cm piece of softened clock spring not less than 1.5 cm wide is excellent. The clock repair man in your town should be willing to give you an old spring. Soften a portion of the spring by heating it red hot—over the gas flame of the cook stove, if you do not have a gas burner. Be sure it gets red hot and then let it cool slowly. This takes some of the springiness out of it and softens it so that it will not retain magnetism. Punch a hole very near one end and two more holes about 2.5 cm apart at the other end. In one end set a small bolt, with two nuts to fit, to serve as the hammer. Bend about 4 cm of the other end at right angles and attach it to the wooden block with small screws; attach the block to the base. It should be placed so that the vibrator will stand about 6 mm from the magnet when finally adjusted.

For the contact point, a 2.5 cm angle iron will serve very well as the support, and a small bolt about 10 mm long, preferably of brass, set with two nuts as in the figure, makes a satisfactory contact. Attach to the base with screws at a point about 9 cm from the hammer end of the vibrator, being careful to locate it so that the vibrator can be adjusted correctly, as described above. Before setting, you should spring the vibrator out from the magnet just enough so that when the contact point is set, the vibrator will be pressing against it with a fairly firm pressure.

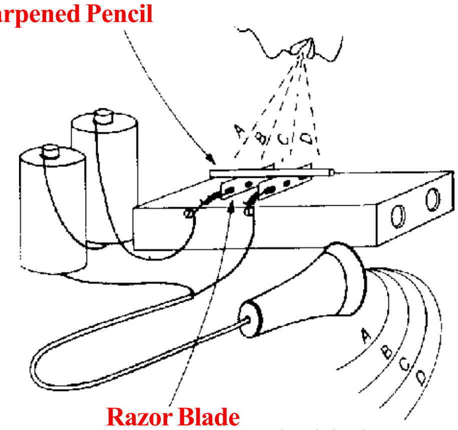
Before mounting the gong, the wires should be connected and the contacts adjusted, as follows. The plan for connecting the wires is clearly shown. Now connect to two cells and make the proper adjustment of the contact point by setting it in or out. The watch spring should vibrate vigorously. Be sure that all connections are good and that the clock spring is sandpapered or scraped down to the clean metal where it presses against the contact point. The end of the contact bolt, too, should be sandpapered. While the hammer is vibrating, find the best position for the gong, then fasten it to the baseboard. A little bending of the spring or changing of the pressure at the contact, or the space between the vibrator and magnet, or re-sandpapering the contact points, may improve its performance.



16 How to set up a simple telephone line

Secure two copper plates about 10 cm square. Punch a hole in each and attach about a metre of bell wire after removing insulation from the ends. It is best to solder the wire to the copper plates. Remove the carbon rod from an old dry cell. Break it up into pieces about 5 mm in diameter. Make a selection of carbon pieces of about the same size. You will need a small handful. Next secure a cigar box and an alarm clock. Place the clock face up on the cigar box. Place one copper plate on the alarm clock. Connect the wire from this plate to two dry cells connected in series. Connect a telephone receiver to the other side of the battery and to the wire of the other copper plate. Next place the pieces of carbon on the copper plate and then cover them with the other copper plate. Listen in the receiver, and you will hear the ticking of the clock. You may have to adjust the top copper plate by moving it a little one way or another.

17 How to make a simple telephone transmitter

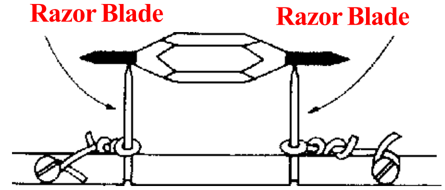


Cut parallel grooves, about 4 cm apart, into the top surface of a cigar box with the point of a pocket knife. Force the back of a razor blade firmly into each. This should hold the blades securely in position. If it does not hold them securely, set them in with hot sealing wax (heat the blade and rub it on the wax and, while still hot, force it into the prepared groove). Twist wires into the blades for connecting purposes. Now sharpen a short piece of pencil at both ends and set across the sharp edges of the two blades. Be sure to have the pencil sharpened back far enough, so that the carbon, and not the wood, contacts the blades. Your telephone is now complete.

Obtain a telephone receiver from some convenient source. If you know someone connected with the telephone company, he may be able to get you a discarded one. Connect with dry cells as illustrated in the diagram.

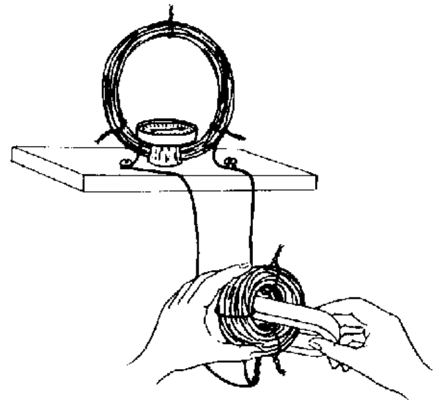
To test your connections, put the receiver to your ear and raise and lower the pencil. Move it about, and you should hear noise in the 'phone something like static on the radio.

To get your 'phone tuned up for the voice, set a clock on the box and, while listening in the receiver, adjust the position of the rod or pencil until you can hear the clock ticking two or three times louder than ordinary. When a sensitive position is found, remove the clock and speak directly and distinctly into the box. Your friend, with the receiver to his ear, should hear what you say. Of course, he should close his other ear unless you have a long line.



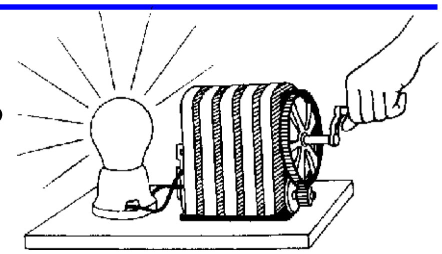
You have now achieved the near magic of making a cigar box reproduce your voice and send it over a wire. Try to figure out how it works. You realize that the sound waves of the voice cause the box to vibrate. Rest your fingers on the box while you make some sounds and feel the vibrations. This vibrating of the box causes the pencil to rattle or vibrate likewise. This, in turn, interrupts the steady current and makes it pulsate as it goes through the electromagnet of the receiver. This causes the diaphragm in the receiver to rattle or vibrate and produce the same kind of sound waves as those that strike the box at the other end of the line. Rub the box and listen. Drop grains of sand on the box and listen in the phone to hear them strike. Jar the table and listen. Do these tests seem to confirm the above explanation?

18 Producing electricity with a magnet and a coil



You will need to use the sensitive current detector which you made in experiment B 4 above for this experiment. Attach a coil of about fifty turns of bell wire to the current detector, leaving the lead wires long enough so that the magnet is well away from the compass. Move the coil over one pole of a permanent horseshoe magnet. Observe the compass needle. Now remove the coil from the pole and observe the needle. Move the coil on and off the other pole of the magnet. Next hold the coil and plunge the magnet into the coil. Whenever magnetic lines of force are broken by a coil a current is set up in the coil.

19 Electricity from a band generator

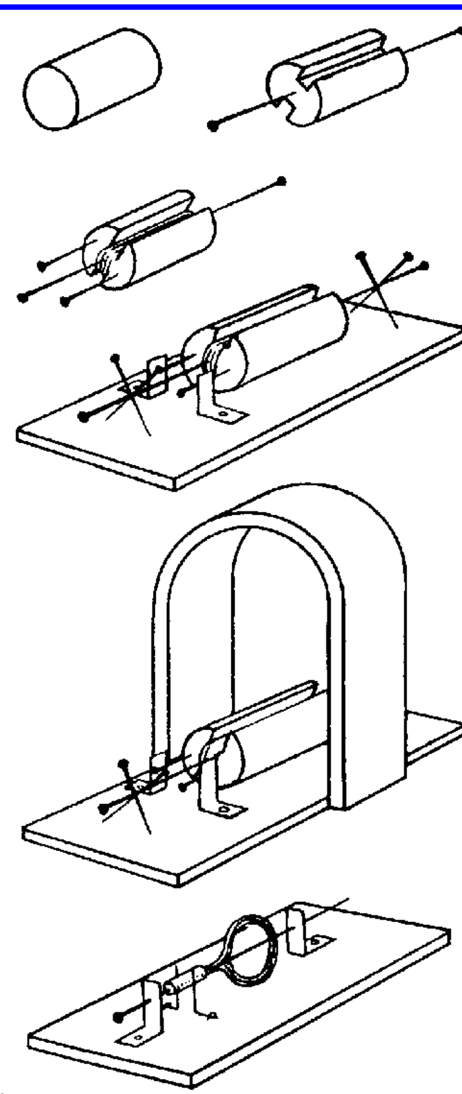


You will need a magneto from an old- fashioned wall telephone. This type of telephone is still used in some localities. If you have a friend who works for the telephone company, it is very probable that he could get one for you without cost, because they are often replaced with a more modern type.

Remove the magneto from the cabinet and mount it toward one end of a board about 15.5 by 30 cm. Attach a regular lamp socket near the other end. Connect the socket to the terminals of the generator. Place a 10 watt, 100 volt lamp into the socket.

The machine is now ready to use. Turn the crank and light the lamp. Turn it slowly, and the lamp glows faintly. Turn it fast, and it glows brightly. Why? Close your eyes and while you turn, let someone screw the bulb out and in. Can you tell when the bulb is out and when it is in by the amount of effort you must use to turn the crank? Why is it harder to turn when the lamp is lighted?

20 How to make a pin and cork motor



The armature of this motor is made by winding a coil of thin insulated wire in a groove cut into a cork with a razor blade.

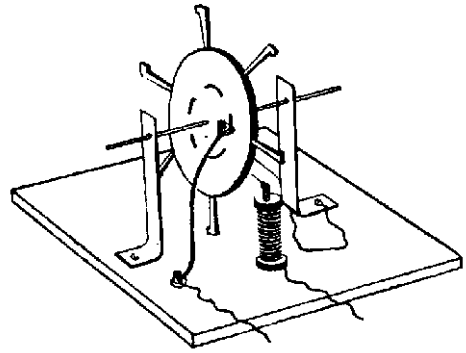
Two pins, one stuck in each end, act as an axle. The ends of the wire (bared) are wrapped round two more pins which serve as terminals through which the current enters and leaves the coil. Strips of thin tin or copper foil are used as brushes, being held to the baseboard by drawing pins.

A horseshoe magnet placed over this arrangement completes the model, which can be driven by a dry cell.

A midget armature can be made by using one pin and no cork. The wire is first wrapped round a pencil and tied into a loop with cotton. The ends are also secured with cotton to a piece of gummed paper rolled round the pin, which serves as commutator.

Small pieces of bent tin act as supports and fine wires lead the current to and from the commutator.

21 How to make an attraction motor



In this motor, a soft iron armature is attracted by an electromagnet. Continuous motion is secured by attaching a current breaker to the armature, so that the various segments of the motor are attracted in turn. The iron parts are 7 cm ‘cut’ nails; six are required for the armature, and one for the electromagnet.

To make the armature, cut three circles of cardboard 6 cm in diameter. In one of them, cut six equally spaced radial slots to fit the nails, and glue the other two circles to it, one on each side. Now mark a circle of 2 cm radius on the armature, and thread 18 gauge bare copper wire through 12 holes equally spaced round its circumference. This will provide six contacts which should be connect- ed to the axle by winding the free end of the wire round it. A knitting needle is used for the axle.

To make the electromagnet, drive a nail through two cardboard disks or through two old tap washers, to act as end-pieces for the coil. Wind two layers of insulated bell wire on the nail and drive the completed electro- magnet into a piece of wood which will serve as the baseboard.

Make the armature supports from two strips of tin cut from an ordinary can; punch holes for the axle and for fixing it to the base, using a pointed nail.

The method of assembly and the remaining details, including the bare wire to act as contact breaker, can be seen from the drawing.

If low voltage alternating current, say from a bell transformer, is available, the contact breaker can be dispensed with. The alternating current is then fed straight to the electromagnet, and after a little practice the armature can be spun at just the right speed to keep in step with the alternations of the current. This illustrates the action of the mains electric clock motor.

22 Another simple motor

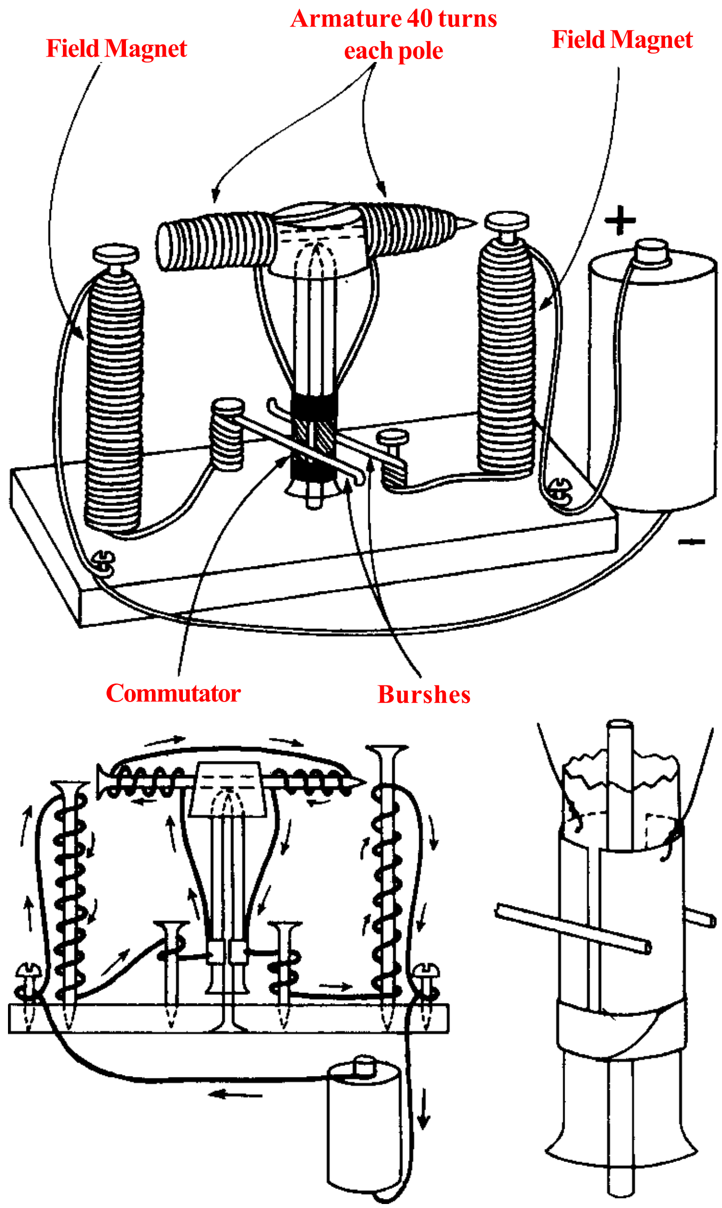
This simple model will give you real satisfaction. It uses current from the battery to excite the field magnets as well as the armature coil.

Prepare a board 20 by 25.5 cm for the base. Drill a small hole through the centre and drive a 15.5 cm spike up through it. Wind 100 turns of insulated bell wire neatly onto two other 15 cm spikes, leaving about 30 cm for free ends. Drive these spikes into the base 15.5 cm apart. Drive two small nails on the diagonal and 5 cm from the spike at the centre. Strip the free ends of each coil and twist them several times around the nails and bend them so that they will rest in contact with the central spike. These ends will serve as brushes. Care must be taken to have the field coils wound in the proper direction. The diagram is a complete plan for the direction of windings. It will work in no other way. The other ends of the coils may be fastened to screws in the corners of the base.

Your field magnets and brushes, two of the four essential parts of a motor, are now complete. The armature coil and commutator remain to be constructed. Drill a hole crosswise through the top of a 4 cm cork and force a 13 cm spike through it. Wind about 40 turns of insulated bell wire on to each end, being sure the direction of windings is as shown. Scrape the free ends. Now gouge out the centre of the cork neatly; round with a penknife and insert the closed end of a 10.5 cm or 13 cm test tube. This completes the armature coil.

You are now ready to make the commutator. Cut out two rectangular pieces of sheet copper about 4 cm long, and wide enough to reach around the test tube with about 6 mm space between. Curve these to fit the tube. Punch small holes and into each twist one of the scraped free ends of the armature windings. Then bind these commutator plates securely into position at top and bottom with adhesive tape.

Your rotor, consisting of armature and commutator, is now complete. Set it into position on the vertical bearing and bring the brushes into contact with the commutator. Now if your windings and connections are all as shown, connect to one or two cells and with a slight push of the armature it should start off at a lively speed. If it does not go, examine the brushes to see whether they make a light, but certain contact. It may also help to change the angle of the brushes. To test this point, untwist the brushes from the nails and hold them lightly against the commutator plates with the fingers. While holding them, always parallel, swing them around at different angles while a helper turns the armature with his hand. Note the point at which the armature picks up most speed and set the brushes at that point. With a little patience you will be successful and will be well rewarded for your efforts in making this interesting and instructive toy.

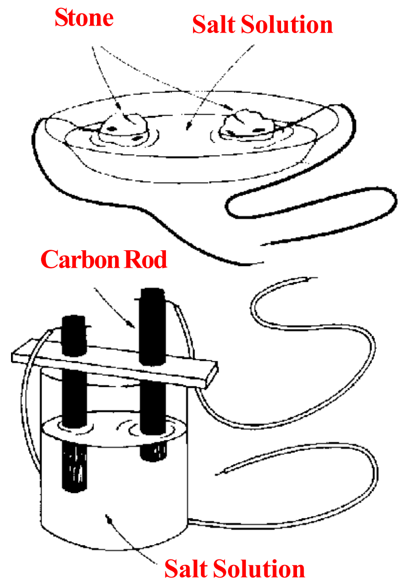


D. HEAT AND LIGHT FROM ELECTRICAL ENERGY

1 How to get heat and light from electrical energy

See experiment B 25 of this chapter.

2 How to make a simple rheostat



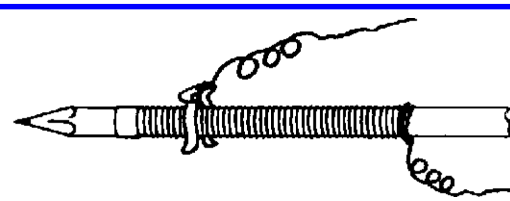
In some of the experiments which follow, you will need to reduce the strength of the electric current.

This can be done by causing the current to flow through a poor conductor, called a resistance or rheostat, at some point in the circuit. There are several different kinds of rheostats possible. You will find it easier to use what is know as a water rheostat. Water is a poor conductor of electricity. Therefore, allowing a container of water to constitute one stretch of the path through which the current must travel will cut down the strength of the current. Pure water would conduct almost no current. A few grains of salt added to the water will make it sufficiently conducting to serve your purpose. Now, the farther the current has to flow through this salt water, the more its strength will be reduced. So, if you can arrange a scheme that will permit you to vary this distance at will, you will be able to increase or decrease the strength of current as needed.

A convenient way to set up such a rheostat is illustrated. Secure a Pyrex glass bake dish or an earthen tray about 25 or 30 cm across. (Caution: do not use a metal tray or container.)

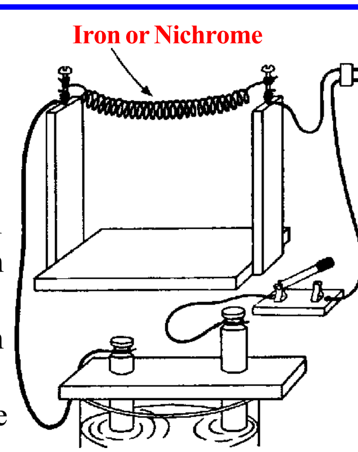
Secure two metal can covers of any kind about 8 cm in diameter. Punch a hole in the side of each and attach the clean ends of insulated wire for connectors. Set the covers into the dish a few centimetres apart and place in each a fair-sized cobble-stone to weight it down. Now dissolve a level teaspoonful of table salt in two litres of water. Pour enough of this into the bake dish to submerge the covers. Your water rheostat is now complete. You can connect it into any circuit and regulate the strength of current at will merely by changing the distance between the covers. Use insulating material for moving the covers, and do not put your hands into the water. Instead of the can covers, carbon rods may be used as shown in the second figure.

3 A resistance wire dimmer



A small rheostat for controlling model stage lighting or dimming electric torch bulbs can be made from 30 SWG bare nichrome wire. Wind about 100 turns around a pencil and anchor one end to two or three turns of thick copper wire which will serve as one terminal. Hold the other end of the resistance wire down by a strip of adhesive tape. Solder a piece of connecting wire to a midget spring clip and fit it over the resistance wire.

4 How to heat a wire red hot with electricity

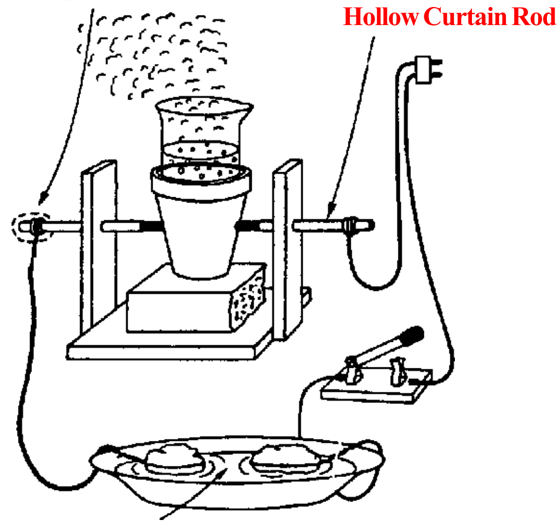


This experiment will give you an opportunity to study how electricity will heat different kinds of wire. Build a wooden support with baseboard 15 by 15 cm and two vertical strips about 20 cm high. Drive a screw or nail partway into the upper end of each support. Now to prepare a spiral-form element, wind about 1.5 metres of iron wire, size between No. 30 and 24, in one layer neatly onto a pencil. Slip this off and stretch it long enough to reach from nail to nail and twist the ends to support it. Connect this with a water rheostat and lamp socket (but be careful!). Be sure the rheostat is wide open before plugging into the socket. Then gradually reduce the resistance and notice how the wire gets hotter until it glows bright red. Hold your hand close to it. Touch a piece of paper or a splinter of wood to the wire and kindle it. Now increase the current until the wire burns or melts off.

Try to secure a piece of nichrome wire and use it instead of the iron. Nichrome wire is the kind that is used for electric heater elements. Can you get this much hotter than the others before it burns apart?

Does this experiment suggest a way to make an electric heater?

5 How to make an electric are heater



The electric are is not only the brightest light known but also almost the most intense source of heat known to man. The brightest point at the end of the carbon rod gets as hot as 3760 degrees Centigrade! Boiling water is 100 degrees Centigrade. Iron melts at 1535 degrees Centigrade.

You certainly will not want to miss the opportunity of making an electric are heater or furnace, especially when it requires only a small plant jar, two carbons from discarded flashlight batteries, two pieces of hollow curtain rod and some bits of wood.

Secure an ordinary 8 cm unglazed plant jar. Drill two holes directly opposite each other and a bit more than 2.5 cm from the bottom. If you do not have a drill, you can work a hole through with the end of a triangular file in your hand, or with almost any sharp- pointed metal object. When you get the holes broken through, ream them large enough with the file or other appropriate object to allow the carbon rods to slip through easily. Now cut off two pieces of hollow curtain rod about 12 cm long. If you have no better means of cutting metal, this thin metal can be cut easily by filing a groove all the way around with a triangular file and then breaking it off. Insert the carbon rods into the ends of the metal tubes, and you have all the essential parts of your furnace complete.

You now need a rack to support these parts. Nail two vertical strips of wood about 15 cm long to a baseboard about 15 by 15 cm. Place half a brick or even a small piece of flat stone onto the baseboard and put the pre- pared plant jar onto this. It will improve your heater to cement the brick to the base, and the jar to the brick, with black asbestos furnace cement. Obtain this from the hardware store or the plumbing shop. Just smear a bit of the cement onto the bottom and press the jar into place. Determine the height at which the holes shall be drilled in the vertical wooden supports in order to have the rods project through them and into the jar so that both will be in horizontal alignment. Bore the holes large enough to allow the metal tubes to slide easily. This done, insert the rods, and your furnace is ready to go.

Connect the furnace into the circuit with water rheostat and lamp socket as shown in the diagram. Establish the are as described in D 7 below. (Caution: Do not take hold of the rods unless you have their ends covered with tape, or keep gloves on your hands.) It is advisable to wear dark glasses when using your furnace.

6 How to make an electric toaster

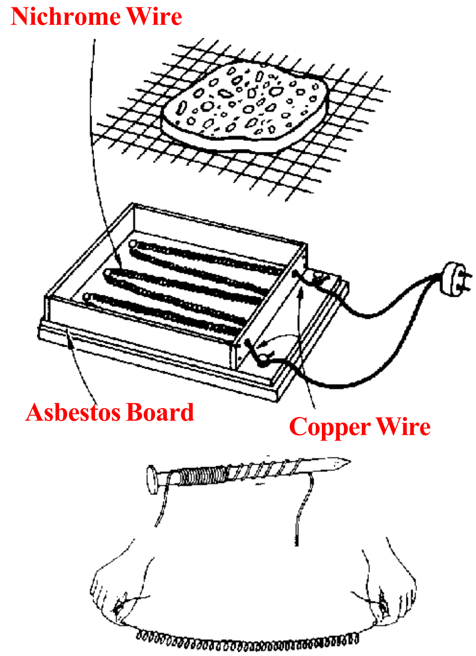
Your problem is to find a convenient way to mount 5 metres (no less!) of nichrome wire in a space not much larger than a slice of bread. Nichrome wire is the kind of wire used in all electric heating devices you ordinarily buy for home use. The wire can be obtained at the electric repair shop. You should use No. 24 gauge wire (0.559 mm diameter) for 110 volts. For other voltages, ask the electrician to tell you the length and gauge of wire for a 500-watt element.

The method of winding the wire into a spiral is shown in the figures. Measure off the wire and wind it neatly onto a round rod about 5 mm in diameter. Keep the turns pushed over into close contact each time you wind on a few. This keeps them regular. You should of course leave about 10 or 12 cm at each end. Now slip the coil off the rod and slowly draw it out far enough so that it will remain in the form of a spiral about 75 cm long. Now twist about 10 cm of copper wire tightly on to each end of the element close to where it begins to spiral to serve as lead-in wires.

To prepare your mount for the element, secure a 30 cm square of asbestos board from the lumber dealer. Cut out one piece 15 by 20 cm for the base and cut four strips 2.5 by 15 cm each for the sides. Put these together as shown. They may be put together by drilling holes and using small screws or by using furnace cement. Asbestos furnace cement is excellent. It may be obtained at the hardware store or plumbing shop. Now cut a piece of board to fit the base; with two narrow strips of asbestos board to furnish air space, attach the frame to the board.

You are now ready to install your element. At the front end drill four small holes equally spaced and three holes equally spaced at the opposite end. Turn small screws about 2.5 cm long partly into the holes. Drill two holes through the front of the frame for the copper lead-in wires. Also set two screws into the front corners of the base for terminals. Now loop your element back and forth onto the screws. Plan this part so there will be equal amounts of the element in each segment. Set each segment into a thread of its screw support so that they will all be supported about 5 mm above the base. Bring the copper lead-ins through the holes prepared for them and twist them around the terminals. This completes your toaster, except for a grill to hold the toast. Cut out a square piece of wire screen with a 1 cm mesh for this or use some small grill from the kitchen. Make sure that the grill can never touch the element or the terminals.

For a connecting cord you may be able to find a broken flat iron cord. Strip the ends of the wires and twist them around the terminals. Plug the other end of the cord into a lamp socket or baseboard receptacle and proceed to toast bread and cook or heat any food you desire. (Caution: Keep pupils' fingers well away from the exposed wires. Take out the plug if any water is spilled onto the toaster.)



7 How to make an me lamp

Use the carbons from two discarded flashlight batteries to serve as the electrodes. Connect the carbons, salt water rheostat, and an ordinary double wire electric lead. An old flat-iron cord with some of the outer fabric stripped off the lower end is good for the purpose. Set the rheostat plates wide apart and plug into the socket.

Now pick up the carbons with clothes pegs, one in each hand, or if you wear dry heavy gloves you may hold them in the fingers, (Caution: Never pick up the carbon rods directly with the bare fingers. Why?) Touch the ends together lightly while someone else slowly reduces rheostat resistance. Never close the rheostat far enough to cause the metal covers to touch each other. Why?

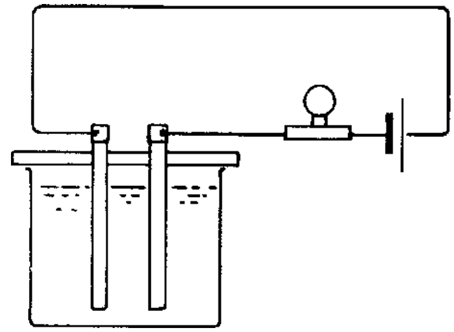
Touch and then barely separate the carbon rods repeatedly while the rheostat is being closed. You should notice the ends heating to a glow and flashes of white light each time you separate them. (Caution: It is highly advisable to wear dark sun glasses when doing this part of the experiment.) At this stage supply just a little more current by closing the rheostat more, and you should have a steady and very brilliant light as you hold the rods steadily with about a 3 mm gap. Practice this until you succeed.

You have now been able to produce a very brilliant light with electricity. Does any of the carbon seem to be consumed? What carries the electricity across the gap? What do you think of this type of lamp as a means of lighting homes?

E. ELECTRICITY AND CHEMISTRY

In Chapter IX, experiment A 1, it was shown how water is decomposed when an electric current passes through it. This is just one example of a general phenomenon: many liquids are similarly affected by an electric current. The process is called electrolysis, and substances which behave in this way are called electrolytes. The effects are often complicated by interaction of the products of electrolysis with the electrodes by which the current is led into the electrolyte, but some of the principles can be studied in the following experiments.

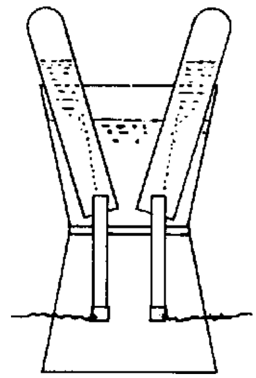
1 Conduction effects in different types of liquids



Liquids can be divided into different chemical classes. The following can easily be studied: (a) distilled water, oils, methylated spirit; (b) acids and alkalis, e.g. dilute sulphuric acid, dilute hydrochloric sulphate and silver nitrate.

Obtain two small carbon rods from an old torch battery and pass them through holes about 2.5 cm apart in a strip of wood 2.5 cm wide and 10 cm long. Solder copper wires to the brass caps and join up a series circuit as shown in the diagram, using a 6 volt dry battery as current supply and a 2.5 volt bulb as current detector.

Put the liquid under test in a small jar and immerse the rods. You will find that some of the liquids do not conduct electricity, gases are released from others, and that in some cases changes take place on the surfaces of the rods.



2 Collecting the gaseous products of electrolysis

If the gases released by electrolysis are collected separately they can be identified. A simple apparatus for doing this, called a voltameter, can be constructed using an ice-cream carton as container for the liquid, carbon rods as electrodes, and small glass test tubes or tubular pill bottles for collecting the gases. Solder copper wires to the carbon rods as before, and fit them through the holes made with a cork borer in the bottom of two cartons; the second carton is used as a stand for the apparatus. Hold the two carton bottoms together, and using balsa wood or other cement, seal the rods in position with about 2.5 cm protruding into the upper cup. Pass connecting wires through holes in the side of the lower cup. Pour dilute hydrochloric acid into the upper cup and fill the glass tubes with it, inverting one over each carbon rod. Connect the wires to a 6-volt dry battery as before and wait for results. As chlorine is soluble, it is necessary to wait until the solution is saturated, but finally equal volumes of hydrogen and chlorine will be collected.

3 To make a bleaching solution by electrolysis

Make a strong solution of common salt by dissolving as much as possible in half a tumbler of water. Fit a cardboard wedge between the carbon rods of the voltameter used in the last experiment, thus dividing it into two equal compartments. Pour in the salt solution, and put a piece of red litmus paper in each compartment. Connect the rods to a grid bias battery, using 7.5 volts. Bubbles of hydrogen will immediately be released at the cathode (negative) but no chlorine will appear at the anode (positive) for the reason given in the last section. After about twenty minutes, however, the litmus paper in the anode compartment will be bleached, while in the cathode compartment the paper will turn blue owing to the formation of sodium hydroxide.

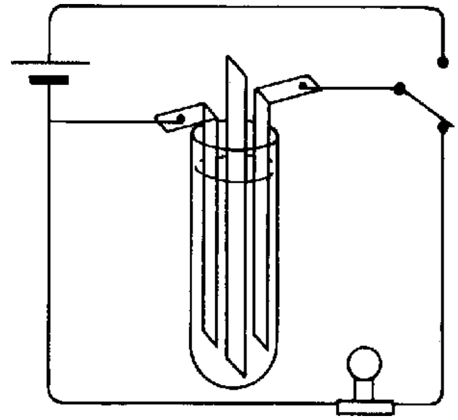
When bubbles of chlorine appear, stop the current, remove the wedge, and stir up the liquid. Sodium hypochlorite will then be produced. This is the compound contained in commercial bleaching fluids; examine its effect on a test tube of water coloured with a drop of ink.

4 To examine the electrolysis of special solutions: (a) zinc sulphate; (b) lead acetate

(a) Pour a weak solution of zinc sulphate into the voltameter and electrolyse it, using a 9-volt grid bias battery. Almost immediately a spongy mass of zinc appears on the cathode.

(b) Add a few grams of lead acetate to half a tumbler of water. To remove cloudiness, stir the solution with a glass rod which has been dipped in acetic acid. Pour the liquid into the voltameter and connect to a battery as before. Lead quickly deposits on the cathode in the form of a ‘tree’ which is fascinating to watch as it grows.

5 To study the action of a simple lead accumulator



From a sheet of lead about 1.5 mm thick cut strips 15 cm long and about 15 mm wide for use as plates of the cell. Punch holes near the end of each plate and thread through copper connecting wires. Wash the plates in water and clean them with steel wool or emery cloth. Put them into a boiling tube containing a little dilute sulphuric acid and separate them by a wooden splint. Also bend over the tops of the plates so that they can never touch one other. First transform these plates into spongy lead and lead peroxide respectively by passing current from a 6-volt dry battery. After a few minutes one of the plates becomes a red-brown colour, whilst the other remains grey. When this has happened disconnect the battery and connect in its place a 2 volt torch bulb. If the bulb does not light, join the plates to the battery al2ain for a few more minutes and then carry out the test.

Now arrange a circuit as shown so that the plates can be charged and discharged through the bulb at the turn of a switch. Connect the battery for one minute, then discharge through the bulb, noticing the time in seconds that the bulb remains alight. Repeat this experiment, charging in turn for 2, 3, and 4 minutes and recording the time taken to discharge through the bulb.

As a further test take a few more readings with the plates half immersed in acid. Put a thermometer in the acid and notice if there is any change in temperature after charging for some time. If facilities are available, try to detect any change in the density of the acid after charging for half an hour.

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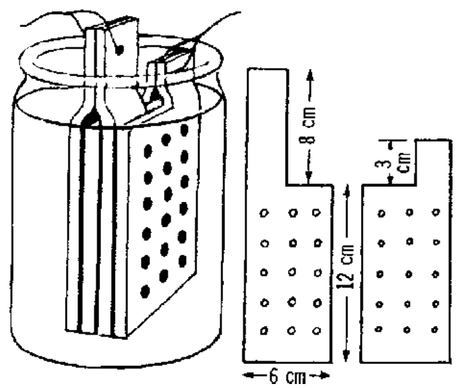
6 How to make a more serviceable accumulator



The preceding way of forming the plates is only suitable for demonstration purposes.

To make a working accumulator, larger and thicker plates must be used, and chemicals must be embedded in holes drilled in the plates.

Use lead sheet about 5 mm thick—old gas or water pipe hammered out will do. Prepare plates of the dimensions shown, with holes drilled in them, and fill up the holes with the following pastes:

Positive plate 1 part litharge. 4 parts red lead. 1 part sulphuric acid.
Negative plate 6 parts litharge. 1 part sulphuric acid.

Separators of wood, about 5 mm thick, the same as before but with holes drilled in them, will be required.

Assemble the plates by fastening the two negative plates together and holding in the separators, etc., by a rubber band, or a piece of string. Insert the whole into a jam jar filled with dilute sulphuric acid (S.G. 1.5), so as to just cover the plates.

The cell should be charged as before. When charged, the positive plate will be a red- chocolate colour, and the negative plate a light grey.

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7 Electro-plating nickel and copper

Electro-plating is now familiar to everyone. It is done by forming a layer of metal on the object which is used as a cathode in a voltameter containing a salt of the metal to be deposited. To get lasting results the object must be carefully cleaned and degreased; the correct anode must be used, and the solution must be carefully prepared and used at a temperature of about 5^0C. The copper anode used for copper plating and the nickel anode for nickel plating need only be degreased.

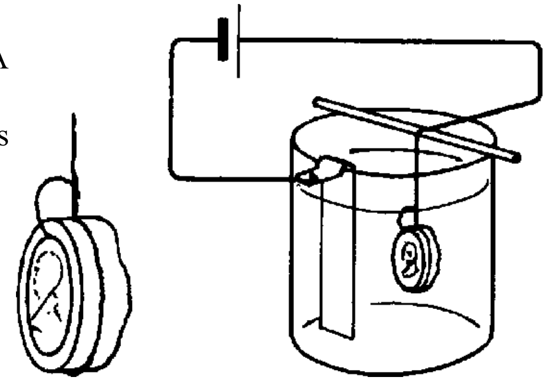
The following baths have proved satisfactory.

Copper	*Nickel*
Cupric Sulphate 200g	Nickel Sulphate 240g
Sulphulic Acid 60 g	Nickel chloride 54 g
Water up to 1000 ml	Boric acid 30 g
	Water up to 1000 ml

Copper plating. Pour the electrolyte into a jar and immerse in it a strip of copper which serves as an anode. Clean a sheet of brass with fine emery cloth, and degrease it with a mixture of magnesia and water on a wad of cotton wool. Rinse it in water, immerse it in the bath and connect it to the negative terminal of a 3-volt torch battery. Complete the circuit by joining the anode to the positive pole of the battery. Note the deposit of copper produced. Too heavy a current may result in a spongy deposit; the correct value for a hard deposit is 4 amperes per 100 cm2 of area.

Nickel plating. Use a strip of copper as a cathode, cleaning and degreasing it as before. A nickel spatula can be used as an anode, but if this is not available a strip of lead may be used; this will mean that the electrolyte becomes weaker during use. Join up to the battery as before, when a good deposit of nickel will be obtained. The surface, after washing, can be polished using jewellers' rouge or cigarette ash on a piece of soft cloth.

8 To copy a scout badge or medal by electrolysis



This process, called electrotyping, is much used in industry. A mould is made of the object to be copied. This is then made conductive by various methods and a shell of this impression is made by depositing copper on it electrolytically. The object is removed from the mould, and the copy is strengthened by pouring type metal into it.

First warm the badge in a clean Bunsen flame and make an impression on the end of a short piece of candle or alkaline rod. Make the surface of the mould conducting by scraping some lead from a pencil over it, or by coating it with colloidal graphite. Another way to do this is to scatter some iron filings over it after moistening it with copper sulphate; the copper will displace the iron and cover the surface of the mould with a layer of copper. Now heat a, piece of copper wire and press it into the wax in such a way that connection is made to the conducting surface without disfiguring the shape. Use the wire to hang the mould in a copper-plating bath. Also suspend a strip of copper in the solution to serve as an anode, facing the mould. Connect to a 3-volt torch battery through a small rheostat and leave it overnight. The next day a good strong layer of copper will have been deposited. Strip this from the mould, and if necessary strengthen it by pouring molten solder into the back of the shell. Trim the badge with a pocket knife and solder a safety pin to the back. If desired it can now be plated as in the last experiment.

"BE A GOOD SCIENTIST. FOLLOW INSTRUCTIONS EXTREMELY CAREFULLY. WEAR PROTECTIVE CLOTHING WHEN WORKING ON ANY EXPERIMENTS THAT INVOLVE FIRE OR EXPLOSIONS."

CHAPTER XVI

Experiments and materials for the study of light

A. LIGHT TRAVELS IN A STRAIGHT LINE

1 Making tracks

Find a dusty road or a sandy beach. Fix your eyes on a distant object and walk towards it without changing your line of vision. Now observe the tracks you have made, and you will see that you have been following a straight line.

2 With a string

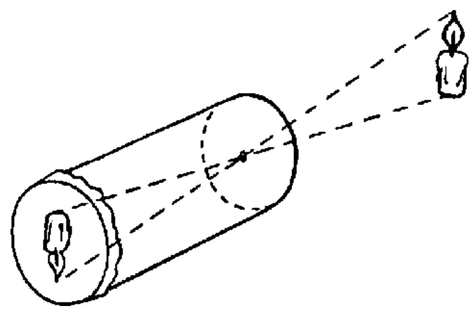
Obtain a piece of string that is at least 25 metres in length. Fasten one end of the string to a post or a tree. Pull the string taut and hold it to the eye. Look along the string, and you will see the object to which it is fastened. Now look in another direction, not along the string, and you do not see the object. This shows that light comes to the eye from such objects in a straight line.

3 An experiment with cards

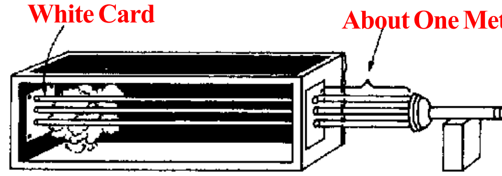
Cut four pieces of cardboard about 10 cm square. Tack them to small wood blocks so that they will stand upright. Punch a small hole through each card at exactly the same place so that when the cards are set up and arranged in a straight line you can look straight through all four holes. Place a candle dame so that it can be seen by looking through all the cards spaced about 30 cm apart. Now pull one of the cards a little out of line with the others and try to look through them at the candle flame. Can you see it? Why not? What does this show?

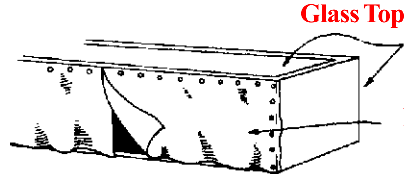
4 A pinhole camera

A simple pinhole camera can be made by making a fine hole in the bottom of a tin and receiving the image on tissue paper, stretched across the top of the tin. Roll a sheet of brown paper round the tin so that a tube projects and shields the tissue paper. This will keep daylight from the screen, and enable an image of a window or candle dame to be observed. What do you notice about the image? How does this show that light travels in straight lines?



5 Making a smoke box to study light rays



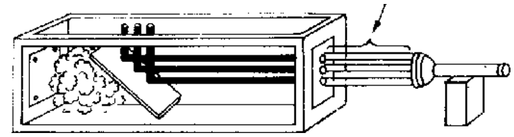


Obtain or construct a wooden box about 30 cm wide and about 60 cm in length. Fit panes of window glass in the top and front of the box. Leave the back open, as shown in the diagram, and cover with loosely hung black cloth which drapes like a curtain. Hang this curtain in two sections making about a 10 cm overlap at the centre of the box. Paint the inside of the box with matt black paint. About midway between the top and bottom of one end and about 8 or 10 cm from the glass front, cut a window 10 cm long and 5 cm wide. This is to let in light rays. You can cover the window with different kinds of openings cut from cardboard and fastened with drawing pins.

For the first experiment cut a piece of black cardboard with three equidistant holes about 5 mm in diameter. Fix over the window with drawing pins. Fill your box with smoke. This can be done with dry rotten wood, incense candles or smouldering cigarettes placed in a dish and set in one corner of the box. Next set up an electric torch about one metre from the window. Focus the light down to a parallel beam and direct it at the holes in the window. Observe the light rays in the box made visible by the smoke. Does this experiment show that light travels in straight lines ?

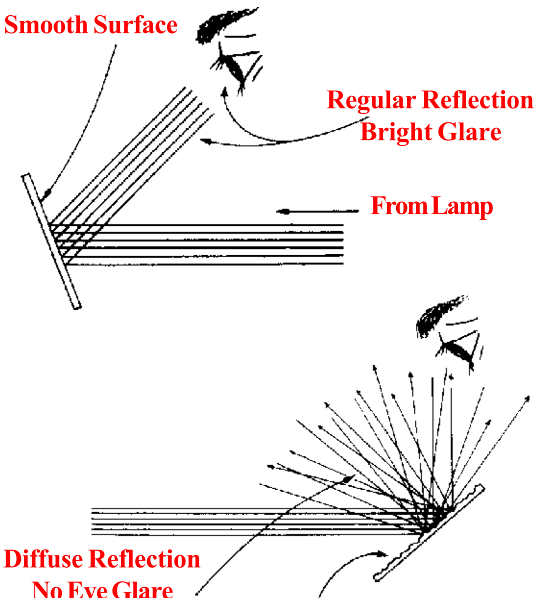
B. THE REFLECTION OF LIGHT

1 Regular reflection with the smoke box



Fill the smoke box with smoke. Shine the torch beam on the three holes in the window as in the last experiment. Now hold a plane mirror inside the box and observe how clearly the rays are still defined after reflection from the mirror. When light rays are thus reflected without scattering they are said to be regularly reflected.

2 Diffuse reflection with the smoke box



Place a piece of clear cellophane on a pane of glass and roughen it by rubbing with a piece of steel wool until the surface has a uniformly dull appearance. Fix the piece of dulled cellophane to the glass with glue or rubber bands. Hold in the beam of the torch inside the smoke box and observe the results. Compare with the regular reflection in the previous experiment. When light is scattered by reflection from an irregular surface it is called diffuse reflection. Place your eye in direct line with the reflected beam from a mirror. Repeat, using the dulled cellophane reflector. Observe and describe the differences.

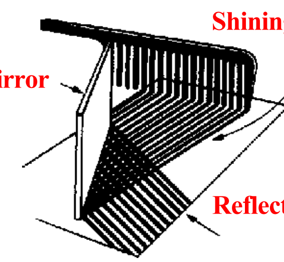
3 Reflection with a rubber ball

Study reflection from a door or wall by bouncing a rubber ball straight and at angles to the reflecting surface. Try to observe and compare the angle at which the ball strikes the surface with the angle at which it is reflected.

4 Reflection with a mirror

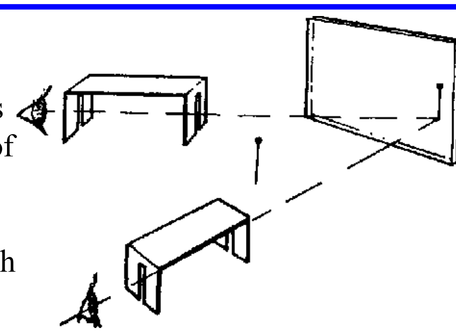
Place a plane mirror on the floor where a beam of sunlight will strike it and be reflected. Stand a drinking straw upright at the place where the beam strikes the mirror. Compare the angle made by the incident beam and the straw with the angle made by the reflected beam and the straw.

5 Making reflected beams of light



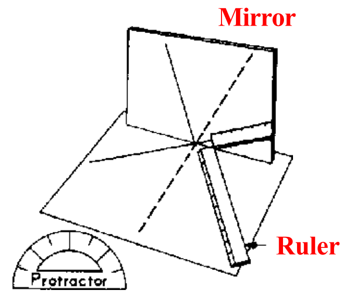
Hold a comb in a sunbeam falling on a piece of white cardboard. Tilt the cardboard so that the beams of light are several centimetres long. Place a mirror diagonally in the path. Observe that the beams which strike the mirror are reflected at the same angle. Turn the mirror and observe how the reflected beams turn.

6 How to make a sighting stool for the study of reflected light



Though 'pin optics' are rather out of fashion at the moment, this method is capable of yielding accurate results. Confusion often arises with juniors because pins are used both as object and to track rays of light. This confusion is avoided if sighting stools are used in the first experiments. A piece of tin, 12 by 1.5 cm, is bent in the form of a stool; the ends form legs and a slit is cut with a hacksaw blade in each of them. A pin is used as object, and its image is sighted through the slits. Pencil marks are then made to track down the path of the light.

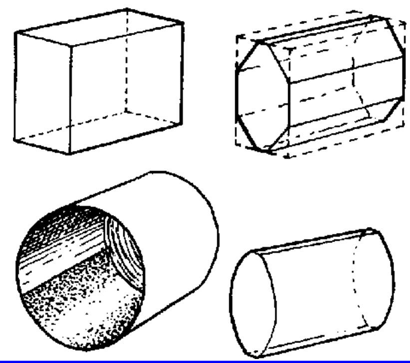
7 The laws of reflection



Draw a broken line on a piece of paper with a ruler. Next draw a straight line from it at any angle. Set a small mirror upright at the point where the two lines meet. Turn the mirror until the reflection of the dotted line is in line with the real dotted line. Now look into the mirror and line up one edge of your ruler with the reflection of the straight line. Draw this line with your pencil and measure the angles on each side of the broken line with a protractor.

Repeat this experiment several times, changing the size of the angle each time. The evidence should show that light is always reflected at the angle at which it strikes the

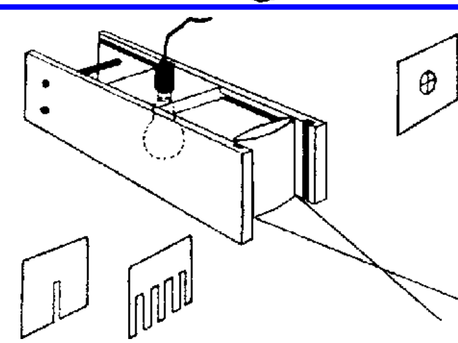
8 How to make a cylindrical lens for a ray box



File down the edges of a piece of Perspex or lucite 5 by 3 by 6 cm. Grind it by using the inside of a can with a layer of emery paper glued inside.

Final polishing is done with metal polish and cotton wool. Protractor

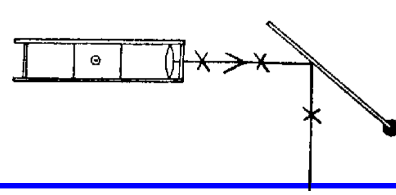
9 How to make a ray box for beams of light



The cylindrical lens described in experiment B 8 above can be used in a ray box. This apparatus consists of two sides of an oblong box 22 by 6 cm held together in this case by 2 BA rod, with the lens placed at one end of the box. The box has no bottom, and in use rests on paper pinned to a drawing board. The light source is a 12-volt 24-watt automobile lamp. The lamp holder has a sleeve of brass tubing just fitting in a hole in a wooden slide, which forms the top of the box. The groove in front of the lens is for screens and filters. A piece of card with a slit in it provides narrow rays and a painter's graining comb will give a bundle of rays. Convergent, parallel or divergent beams are obtained by adjusting the position of the slider. Ah the usual experiments with rays can be performed using slips of plane mirror, glass blocks and prisms. A curved piece of tin will show a caustic curve.

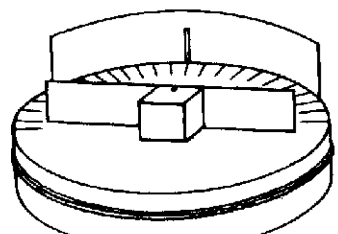
In experiments with lenses and in refraction, the lamp should be pushed down as far as possible so that the light does not pass over the top of the obstacle. A card with a hole and cross wires can be used in front of the lens, as a source for optical bench experiments.

10 Laws of reflection with a ray box



A slip of mirror can be made to stand vertical by inserting one end in a piece of cork with a groove in it, or in a paperclip. Beams of light shone along the paper are marked by crosses. The incident, and reflected rays, and the normal, are recorded by joining up the crosses by pencil lines.

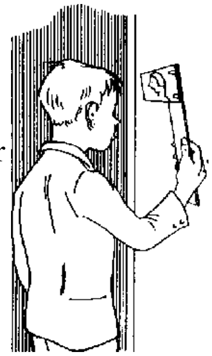
11 A simple optical disc



Obtain a shallow can of roughly the same diameter as an ordinary protractor. Cut out a piece of white card to put on the top of the can: glue it down and mark degrees on it. Fix a strip of mirror to a small block of wood and mount it on a nail which fits loosely through a hole in the centre of the scale and the can. Cut a narrow slit in a rectangular sheet of metal as shown in the diagram, and bend the sheet round the circumference of r the can, fixing it in position so that the slit is opposite the 900 mark on the circular scale. Place the can on the bench so that the sun or a distant source of light throws a ray which passes through the slit to the centre of the scale. Adjust the mirror so that the light is reflected along its own path. Now rotate the mirror through 100. What do you notice about the angle through which the reflected ray is turned?

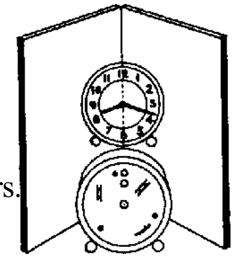
12a A mirror on a stick

Fasten a mirror to the end of a ruler with a paperclip. Stand on one side of a door and hold the mirror outside the door opening. Explain how reflected light enables you to see around the corner.



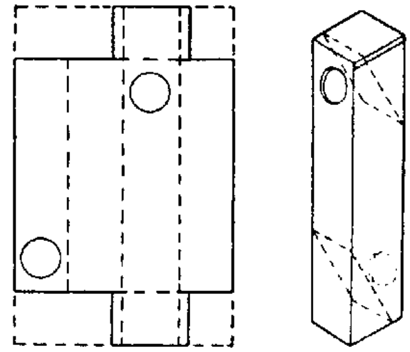
12b The clock face and a mirror

Stand two mirrors at right angles to each other with their edges touching. These edges may be joined with strips of tape. Place a clock in front of the mirror with the midline of its face opposite the junction of the two mirrors. Observe the image and compare with the image seen with a single mirror.



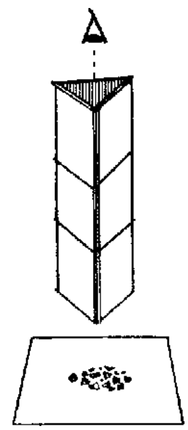
13 How to make a model periscope

Score three lines parallel to the long side of a postcard and 2 cm apart. These will divide the card into four strips. Cut away pieces from the ends 2 cm wide as shown in the diagram. Cut holes in the positions shown, using a cork borer, and then fold up the card into a rectangular box. Stick small pieces of mirror opposite the apertures, using plasticine or gummed paper.



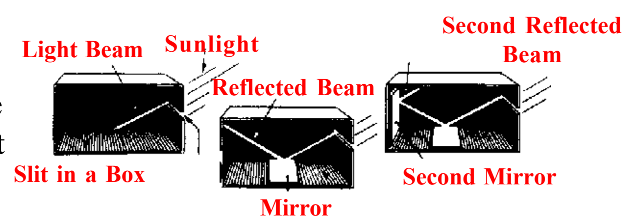
14 How to make a kaleidoscope

Fasten together two slips of mirror about 10 cm by 3 cm and a piece of card the same size, with a rubber band or gummed paper. Look down the axis of the triangular prism so formed. Objects viewed through it will form a regular pattern. If silvered glass is not available, black paint on the outer side of plain glass will give quite good results.



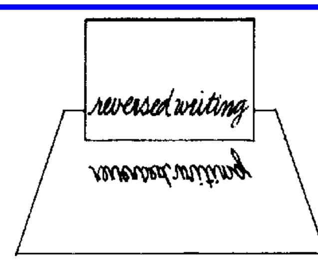
15 Double reflection

Cut a slit about 1 cm wide in one end of a small cardboard box. Be sure to cut the slit all the way to the bottom of the box. Set the box on one side and place it in bright sunlight. Adjust the box so that the beam of sunlight falls along the bottom of the box and place mirrors as shown in the diagram.



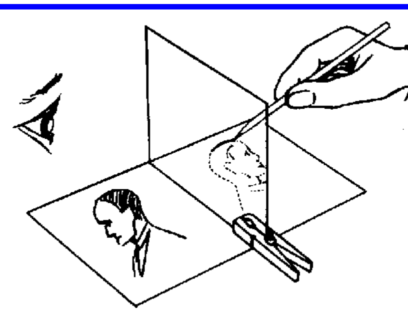
16 Reversed writing

Produce reversed writing by placing a piece of carbon paper, carbon side up, under a sheet of plain paper. Write something on the paper and you will have reversed writing on the other side. Read the reversed writing by holding it in front of a mirror. Write some thing while you look in the mirror at the paper and watch the pencil.



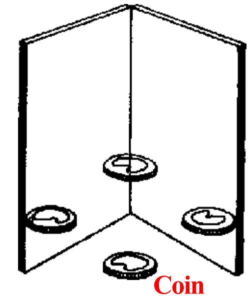
17 Copying drawings by reflection

Use a wooden clothes peg to support a sheet of clear glass vertically on the bench. Place the drawing to be copied on one side of the glass and a piece of white paper on the other. Look through the glass at the white paper and draw over the reflection of the drawing. Why must the glass be vertical? How does the copy differ from the original? Why is it an improvement to shield daylight from the paper you are drawing on?



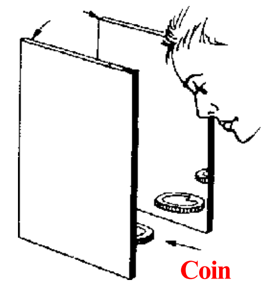
19 Making money with reflection

Hinge two mirrors together with a piece of tape and set them up as shown in the diagram. Place a coin between the mirrors and observe the number of images formed. See if you can increase the number of images by varying the angle of the mirrors. Place a lighted candle between the mirrors and observe the images.



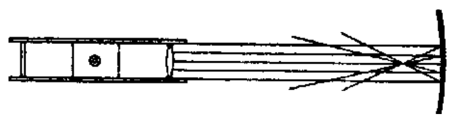
20 Reflection with parallel mirrors

Stand two mirrors on edge with the reflecting surfaces facing each other. Place a coin or a lighted candle between the mirrors. Look in one mirror and see how many images are formed. Look in the other mirror.



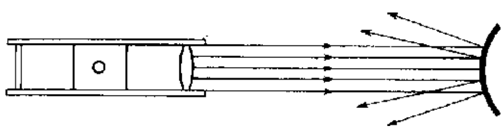
21 Reflection from a concave mirror with a ray box

Use the ray box constructed in experiment B 9 above. The focal length can be measured directly by directing a parallel beam of light on to a curved strip of tin, or a part of a metal ring.



22 Reflection from a convex surface

Obtain a convex mirror such as an automobile wing mirror. Use this with the ray box and observe the reflected rays of light. Compare with the reflection from a plane mirror and a concave mirror.



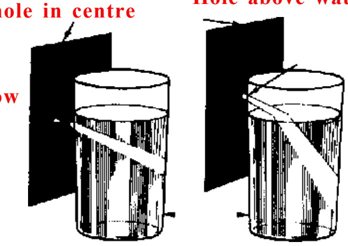
C. THE REFRACTION OF LIGHT AND ITS USES

1 The stick appears to bend

Place a stick in a tall jar of water, so that part of the stick is above the surface. Observe where the stick enters the water and appears to be bent. This is caused by the bending or refracting of the light rays as they reach the air from the water. Light travels faster in air than in water and so is bent slightly when it passes from one medium to the other.

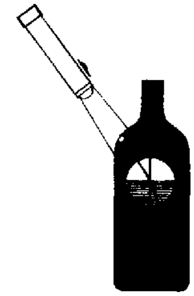
2 Refraction in a beam of light

Pour a few drops of milk into a glass of water in order to cloud the water. Punch a small hole in a piece of dark paper or cardboard. Place the glass in direct sunlight. Hold the card in front of the glass. A beam of sunlight will shine through the hole. Hold the card so that the hole is just below the water level and observe the direction of the beam in the water. Now raise the card until the beam strikes the surface. Observe the direction of the beam of light. Experiment to find out how the angle at which the beam strikes the water affects the direction of the beam in the water.



3 How to make a refraction bottle

Paint the outside of a medicine bottle black. Scratch a circle off one side and fill the bottle with water until the surface is just level with the centre of this circle. Shine a beam of light through the top of the bottle (the paint should be removed from a small area). A drop of milk in the water will make the beam show up better. The angles of incidence and refraction are now measured with a protractor.

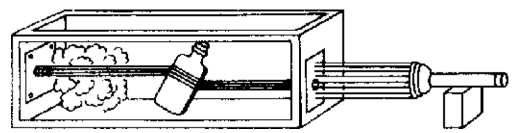


4 Refraction shown with the smoke box

Over the window of the smoke box (see experiment A 5 above) fasten a piece of black cardboard with a single hole in it about 8 mm square. Arrange the torch to shine a beam of light into the box as in previous experiments. Fill a large rectangular bottle with water and add a few drops of milk or a pinch of starch or flour to make the water cloudy. Cork the bottle. Fill the box with smoke. Hold the bottle at right angles to the beam of light and observe the direction of the light through the water. Next tilt the vision so that the edge of the cup just interferes with your seeing the coin in the bottom. Hold this position while another person pours water carefully into the cup. What do you observe? How do you account for this?

5 Making a coin appear with refraction

Place a coin in the bottom of a teacup on a table. Stand away and arrange your line of vision so that the edge of the cup just interferes with your seeing the coin in the bottom. Hold this positionwhile another person pours water carefully into the cup. What do you observe? How do you account for it?



6 How a prism affects light rays

Use the smoke box exactly as you did for experiment C 4 above. Hold a glass prism in the single beam of light and observe how the beam is refracted.

7 How lenses affect light rays

For these experiments, you can take the lenses from an old pair of spectacles or used optical instruments, or purchase reading glass lenses and hand magnifiers.

Cover the window of the smoke box with a piece of black cardboard in which you have punched three holes. The holes should be the same distance apart, but the distance between the two outside holes should be a little less than the diameter of your lens. Arrange the torch to supply the light rays as in previous experiments. Fill the box with smoke and hold a double' convex lens in the path of the three beams of light so that the middle beam strikes the centre of the lens. Observe the beams on the opposite side of the lens from the source of light. How are they affected ?

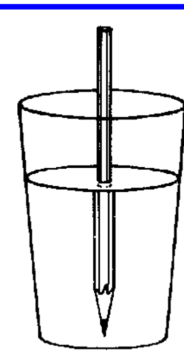
Repeat the experiment using a double concave lens. Compare the observations made in this experiment with those made in experiment C 6 above. Think of the double convex lens as made up of two prisms put together base to base and the double concave lens as two prisms put together tip to tip.

8 Rough lenses from bottle bottoms

Bottles can be found with convex or concave bottoms. These can be cut off by any of the methods indicated (page 218) and the rough edges removed by rubbing on a stone surface. Whilst rarely good enough to provide a clear image, They can be used to illustrate how bush fires may be Started by old bottles lying in dry grass, etc. and focusing the sun's rays.

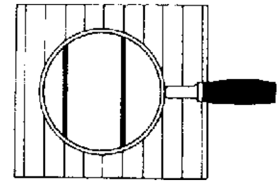
9 How lenses magnify

Dip a pencil (or your finger) into a glass of water, and look at it from the side. Is it magnified? Observe a fish in a fish bowl, looking at it from the top and from the side. Do the bowl and the water magnify the fish? Observe olives or other things placed in circular jars.Are they magnified? Clear glass marbles act as lenses also.



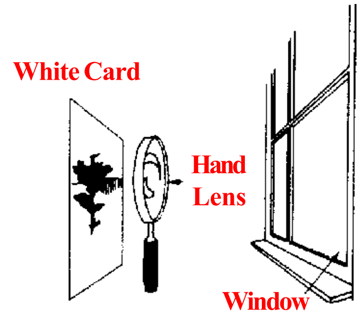
10 How to measure the magnifying power of a lens

Focus a hand lens over some lined paper. Compare the number of spaces seen outside the lens with a single space seen through the lens. The lens shown in the diagram magnifies three times.



11 How a convex lens forms a picture image

Darken all the windows in a room but one. Have a pupil hold a lens in the window directed at the scene outside. Bring a piece of white paper slowly near the lens until the image picture is formed. What do you observe about the position of the image?



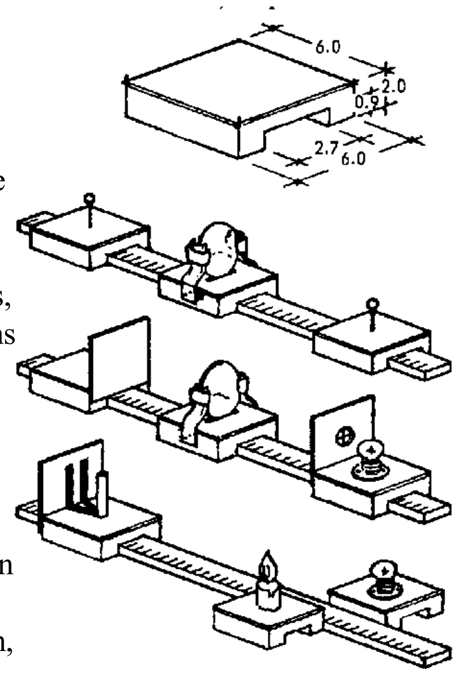
12 How to make a simple apparatus to study lenses

All that is needed for an optical bench is a firm surface, a way of holding mirrors and lenses, and a convenient way of measuring distances.

A metre scale laid hat on the bench serves as the basis of this simple apparatus. Wooden blocks, with grooves that just fit over the scale, can be adapted as holders. A layer of cork or soft cardboard glued on the top makes it easy to stick pins, such as object and search pins, into each block; strips of tin screwed to the side make convenient lens holders. A groove in the top of a block helps to keep the lens in position, and rubber tubing over the tin increases the grip.

Light sources and screens can be improvised with card and torch bulbs fastened to the blocks. It is worth while to make complete sets of this apparatus so that individual work on lenses can be attempted. The groove is easy to make with a chisel after two sawcuts have been made in the wood.

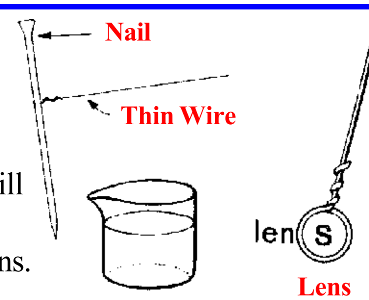
Many other experiments, for instance on interference and diffraction, can be attempted using this apparatus.



13 A simple microscope

Make a single turn of copper wire around a nail to form a loop. Dip the loop into water and look through it. You will have a microscope like the earliest ones used. Often such a lens will magnify four or five times.

If you tap the wire sharply against the edge of the glass a drop of water will fall off. Because of adhesion between the wire and the water, the liquid remaining will form a lens which is very thin at the centre, i.e., a concave lens.



14 A water drop microscope

Place a drop of water carefully on glass. Bring your eye close to the look at something small through drop and glass. This serves as microscope.

15 A model compound microscope

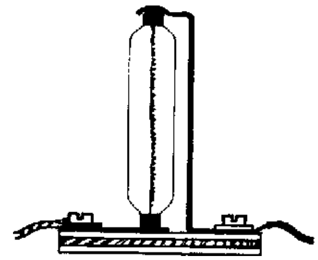
Arrange a short focus lens on the optical bench made in experiment C 12. Place a lighted candle behind a piece of window screen on one side of the lens. On the other side of the lens place a white cardboard sheet at the point where the dearest image of the screen is formed. Remove the cardboard sheet and place another double convex lens slightly farther away than where the cardboard was. Look through both lenses at the screen. It will appear enlarged.

16 A model refracting telescope

Arrange a long focus lens on the end of the optical bench pointing at some scene through a window. As in the previous experiment, bring a white cardboard up on the opposite side of the lens to the place where the sharpest image of the scene is formed. Now bring a short focus lens up behind the cardboard until the cardboard is a little nearer the lens than its focal length. Remove the cardboard and look through the two lenses at the scene.

17 How to make a line light source

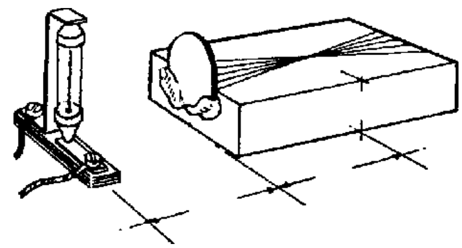
A bulb as used in direction indicators and interior car lights provides a useful line source of light for optical experiments. A convenient holder can be made from a piece of plywood. Strips of tin tacked to the wood, or held by screw terminals, can be used to make electrical connection



18 Image and object relationships for a lens

The lens can be fastened to the front of a wooden block with plasticine. The image position is where the rays cross. It is interesting to plot a against v and test the formula

$$1/u + 1/v = 1/f$$

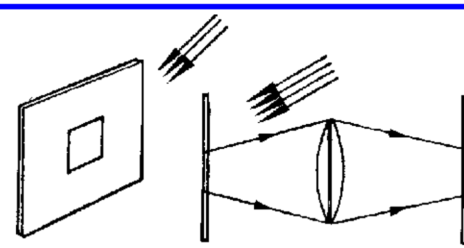


19 Image and object relation for a lens (without source)

A piece of mirror about 5 cm square can re- place a source of light. The object is then a 1 cm square at the centre of the mirror from which the silvering has been removed.

The mirror should face the light, when the image can be caught on a piece of cardboard on the side away from the light.

The relationship $\frac{\text{image size}}{\text{object size}}$ can also be tested.



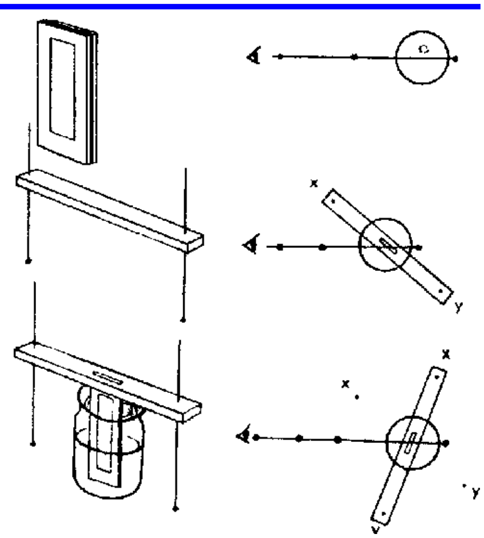
20 Critical angle

Make an air cell from two microscope slides by cutting a tinfoil frame and sticking it between the slides with Canada balsam or Bostik cement.

Fit this in a slot in a piece of wood about 20 cm long. Push knitting needles through the ends of the wood to act as pointers, indicating the position of the lath.

When this rod rests on a beaker of water with the air cell inside it, the needles should just touch the paper on which the beaker stands. This is the critical angle apparatus.

In use a base line of three pins is used, a diameter of the beaker. The rod is moved until total reflection occurs. There will be two positions for this, and the points of the needle should be marked in each case.

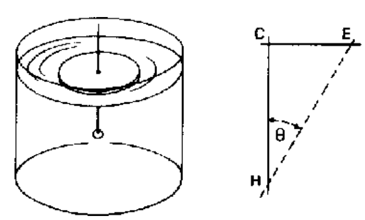


21 To measure the critical angle for water

Cut a disk 4 cm in diameter from a piece of waxed cardboard.

Pass a long pin through the centre of the card and float it head downwards in a vessel of water. Viewing the pinhead from above the surface it will be found that its position can be adjusted until it just disappears behind the card. In this position, a ray of light from the pinhead is refracted so that it passes along the surface and cannot reach the eye.

The angle a can be measured directly or by measuring (CE / CH) and using tangent tables.

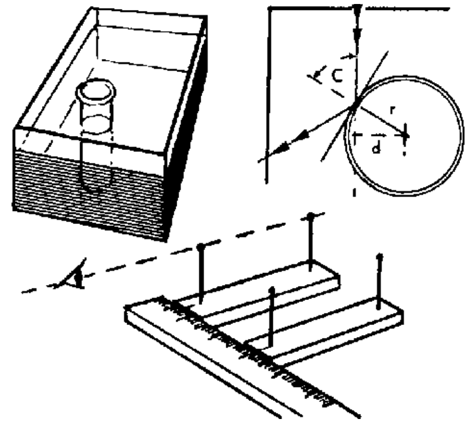


22 Another critical angle experiment

Put a small specimen tube or pill bottle in a rectangular glass tank, and look through the sides. The centre part of the tube will act as a cylindrical diverging lens, but the edges will appear to be silvered.

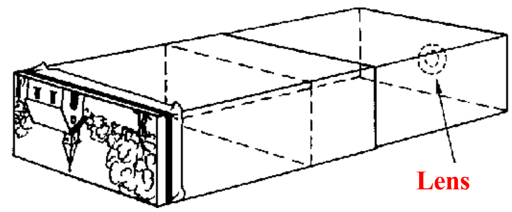
From the ray diagram it will be seen that sin C = (d / r)

These two distances can be measured by using sighting stools with their ends against a ruler parallel to the face of the tank.



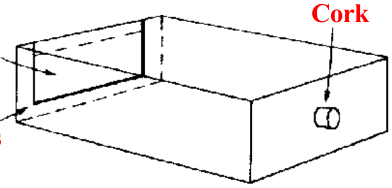
23 How a camera works

Secure two boxes which will telescope over one another rather tightly. Cut one end out of each box and slip the boxes over each other, with the cut ends together. Now cut the back end from one box and fit a piece of grease- proof or tissue paper over it. Cut a hole the size of a lens in the other end and fix a convex lens in the hole. Now move the boxes in and out until the lens focuses an image of an outside scene on the paper screen. In a camera the sensitive film is placed where the paper is on the model.



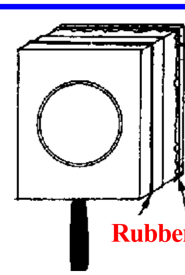
24 How to take a picture with a pin- hole camera

Make a pinhole camera (see experiment A 4 of this chapter) from a wooden box such as a chalk box. Paint the inside black. Bore a 1 cm hole in the centre of one end. On the inside of the box cover the hole with a piece of thin metal foil. With a needle punch a hole in the centre of the metal foil and be sure that the hole is very neat. Inside the opposite end of the box fit some guides, into which you can slide sections of cut film. Fit a cork tightly in the hole to cover the pinhole. In a dark room cut some photographic film to the proper size to slide into the guides. Cover the top of the box and take your camera outside. Point it at the scene you wish to take a picture of. Remove the cork for a second or two and replace it. In the dark room remove the exposed him and develop it or wrap it in black paper and take it to a photographic shop for developing.



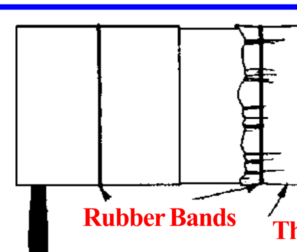
25 A simple view camera

A simple view camera can be made as follows. With a hand lens focus the image of a distant hill or tree on a card. Measure the distance between the lens and the card and cut down a small carton so that its height equals this distance. In the centre of the bottom cut a hole a little smaller than the lens. Fix the lens over this hole with a piece of cardboard containing a hole the same size as the first. Tie a sheet of thin tissue paper over the open top of the box. This view camera may be used in a darkened room with the lens directed towards a window.



26 A focusing view camera

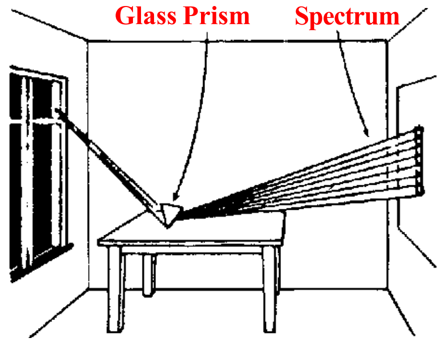
A focusing view camera can be made in much the same way as one described in experiment C 25. A second box telescopes into the first to allow focusing. The brighter the object viewed and the darker the screen of tissue paper, the better the results will be.



D. EXPERIMENTS WITH COLOUR

1 What is the colour of sunlight?

Darken a room into which the sun is shining. Punch a small hole in the window shade to admit a thin beam of light. Hold a glass prism in the beam of light and observe the band of colours, called a spectrum, on the opposite wall or ceiling. Can you name the colours thus found in a spectrum of the sun?

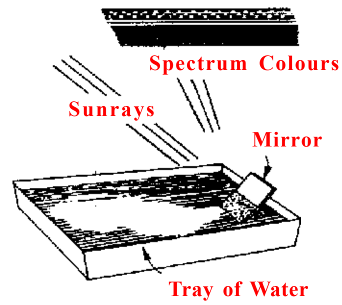


2 Potting spectrum colours together

Hold a reading glass lens in the colour band on the opposite side of the prism from the white sunlight. What happens to the colour band on the wall?

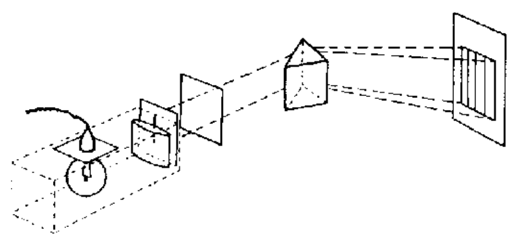
3 Another way to make a spectrum

Set a tray of water in bright sunlight. Lean a. rectangular pocket mirror against an inside edge and adjust it so that a colour band or spectrum appears on the wall.



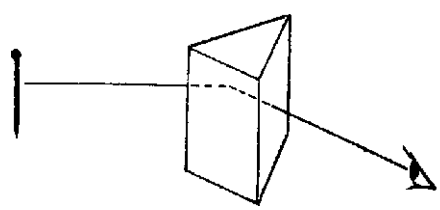
4 Studying a spectrum with the ray box

A glass prism will produce a good spectrum from a parallel beam of light using a ray box. In front of the lens the ray box should have a narrow slit, which can be cut from a piece of card. Interposing coloured gelatine filters and packing papers in the beam will suppress certain colours. For instance, when a trans- parent purple paper is used, only red and blue lines will be seen on the screen.



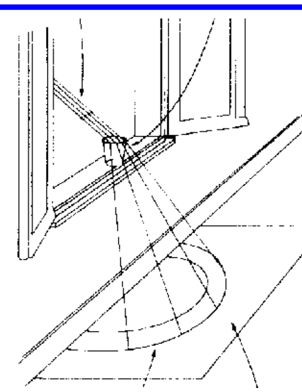
5 How to see a line spectrum

To make a simple optical slit scratch some silver off the back of a mirror with a needle, or remove in the same way some of the emul- sion from a fogged photographic plate. For viewing a line spectrum, the slit can be replaced by a needle held parallel to the refracting edge of the prism, and illuminated by the light under examination.



6 How to make a rainbow

Stand a tumbler very full of water on a window ledge in bright sunlight. Let it project a little over the inside edge of the window ledge. Place a sheet of white paper on the floor and you will be able to see a rainbow or spectrum band.

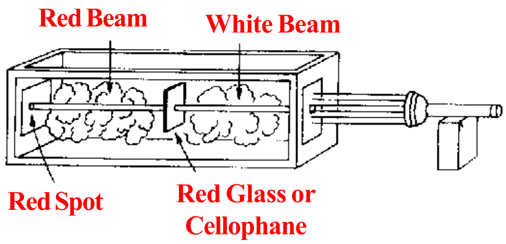


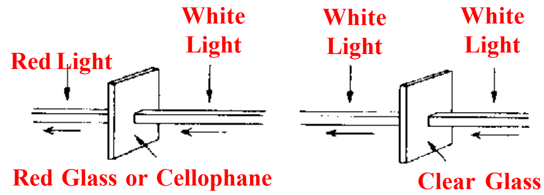
7 Another way to make a rainbow

Early in the morning or late in the afternoon of a bright sunny day, spray water from a hose against a dark background of trees with your back toward the sun. You will see a lovely rainbow.

8 The colour of transparent objects

Use the smoke box (see experiment A 5 above) as in previous experiments. Have a single ray of light enter the box. Hold a clear sheet of glass or cellophane in the beam of light and note that the beam on the white screen in the box is white. Next hold a sheet of red glass or cellophane in the white beam and observe that the beam which reaches the white screen is red. All the other colours of the white light have been absorbed by the red. Experiment with other coloured transparent sheets. You will observe that such objects have colour due to the colours they transmit and that they absorb other colours.





9 The colour of opaque objects

Get a good spectrum on a wall or a sheet of white paper in a darkened room. Place a piece of red cloth in the blue light of the spectrum. What colour is it? Place it in the green and in the yellow. How does it appear? Place it in the red light. How does it appear? Repeat using blue, green and yellow coloured cloth. You will observe that they appear black except when placed in the same coloured light. Thus opaque objects have colour because of the light they reflect; they absorb the other colours of the spectrum.

10 Mixing coloured pigments

Take a piece of blue chalk and a piece of yellow chalk. Crush them and mix them. The resulting colour is green. These are not pure colour pigments. Notice that green is between yellow and blue in the spectrum. The yellow absorbs all colours but yellow and green. The blue absorbs all colours but blue and green; thus the yellow and blue absorb each other. and the green is reflected to the eye.

Try the same experiment by mixing paints from a painter's box.

11 Mixing coloured lights

(a) Mixing of coloured lights can be achieved by using water colours painted on disks of cardboard.

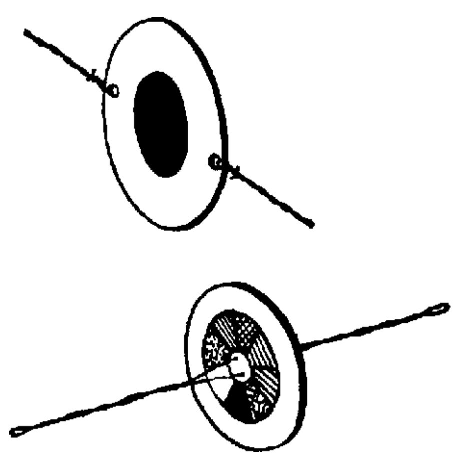
One suggestion is to paint a yellow 'egg yolk' on one side of a 10 cm disk, and a blue 'yolk' on the other side. When the disk is suspended by short pieces of string, and twirled between the fingers and thumbs, the result is nearly white, if the colours are carefully chosen.

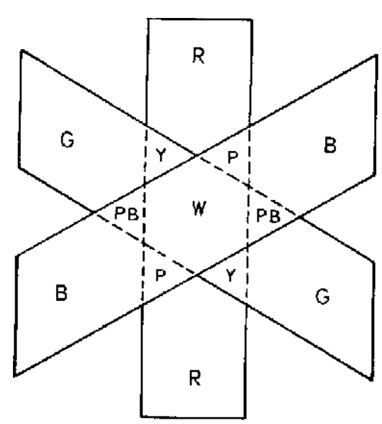
Other colour mixtures can be investigated in a way similar to that used on the toy 'colour tops'. Radial segments are painted, say, alternately red and green. The resulting mixture of red and green lights reflected to the eye by spinning the disk on string is, of course, yellow in this case.

(b) Three of the boxes described for experiments on rays in elementary optics can also be used for mixing coloured lights. Any similar box containing a car bulb will serve the same purpose.

Place red, green and blue theatrical filters in the front of the box and cast rectangular patches of light on a white screen.

Red and green give yellow.
Blue and red give purple.
Green and blue give peacock blue.
Red, green and blue give white.





12 Colours in a soap film

Make a strong soap solution such as would be used for blowing soap bubbles. Fill a flat dish with the solution and dip an egg cup or a tea cup into the solution until a film forms across the cup. Hold this in a strong light and observe the colours you can see. Thin films often have colours.

13 Colours in an oil film

Fill a shallow dish with water. Colour the water with black ink until it is very dark. Put the dish in a window where light from the sky is very bright, but not in direct sunlight. Look into the water so that light from the sky is reflected to your eye. While looking at the water place a drop of oil or gasoline on the surface at the edge of the dish nearest to you. You should see a brilliant rainbow of colours flash away from you toward the opposite edge. By blowing on the surface you will observe a change in the colours.

14 Colours from a feather

Look at a distant candle flame through the end of a feather. You should see two or three candle flames on each side of the actual flame and a flattened X with four coloured arms. If the feather is good you will see two blue and red bands in each of the four arms.

15 How colours change

Paste some coloured illustrations from a magazine on a piece of cardboard. Pour three tablespoonfuls of salt in a saucer and add several tablespoonfuls of alcohol. Mix and light. This produces a very brilliant light that gives out only yellow. View the picture in this light in a darkened room and observe how all colours but the yellow change.

E. OPTICAL PROJECTION

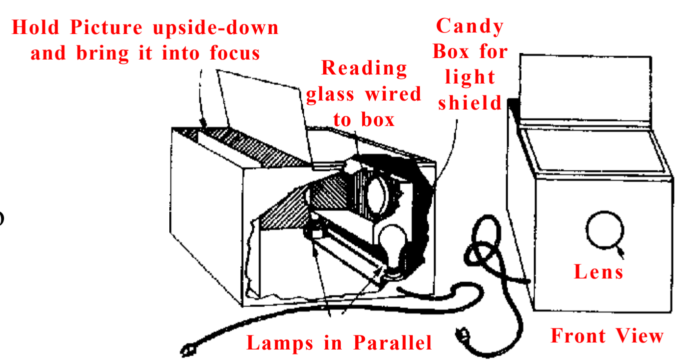
In order to produce a good image or picture on a screen, a lens must be of good quality. A magnifying glass may be used, but better results are obtained with an old camera lens. Used in this way the lens is called the 'objective' or object lens, and the magnification obtained depends on its focal length.

Opaque objects must be strongly illuminated because only the light reflected from the surface will pass through the lens. Transparencies can be illuminated from behind; in this case an extra 'condensing' lens is used behind the slide or film to ensure even illumination of the image produced on the screen.

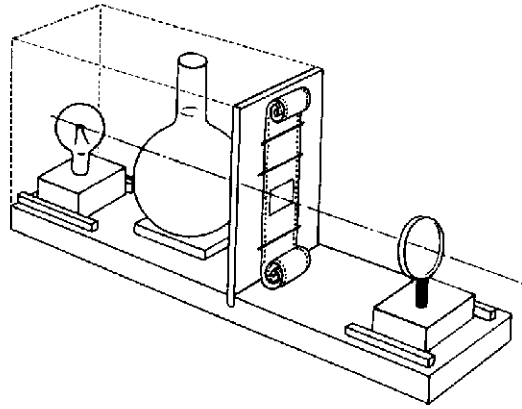
1 How to make a projector for coloured pictures

A projector for coloured pictures can be made from simple materials as shown in the diagram. Use a box slightly longer than the focal length of the lens to be used. For most lenses the box should be between 30 and 100 cm long. Use a small candy box as light shield for the lens as shown. Connect two lamp sockets in parallel and put one on either side of the shield. Two 50-watt lamps should provide sufficient illumination. Use gummed tape to fasten down the front portion of the top of the larger box and hinge the rear portion.

Place a picture upside down in the back of the box, focusing by moving it back and forth until a clear image appears on the wall or screen in front of the projector.



2 To construct a projector for film slides or strips



The base of the instrument is a piece of wood 40 by 10 by 3 cm. A plywood board 10 cm wide and 25 cm long fits into a groove cut across the base, and serves as filmstrip carrier. A hole 35 by 23 mm cut in this wood serves as an 'aperture' or gate to limit the light passing to one frame of the strip. The strip itself is held close to the gate, in a vertical position, by staples made from wire paper fasteners. These are easily bent to the width of the film; the ends are cut off short and sharpened with a file, and they can then be pressed into position on the plywood board.

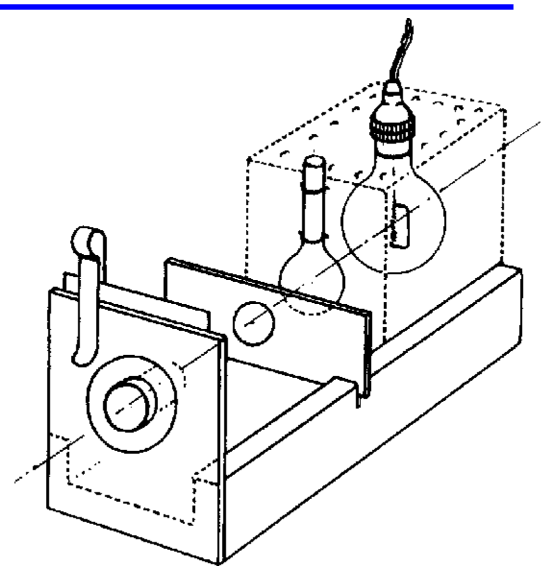
No reels are necessary. The strip can be moved on from one frame to the next by pulling on the end of the film; there is sufficient 'curl' to hold it stationary.

The lamp, which is an automobile head- lamp in a holder mounted on a block, is adjustable; it can be slid between two strips of wood nailed to the base. A carafe or flask of water can be used as condensing lens and should be placed so that the whole of the gate is illuminated by the image of the lamp. When it has been so positioned, the lamp and condensing flask are fixed in place with glue.

The object lens is mounted on a piece of wooden dowelling which is a fairly tight fit in a hole drilled into a block of wood arranged, like the lamp support, to slide between two wooden guides. The lens can then be adjusted for height by sliding the rod in or out of the hole so that the centre of the lamp, condenser and objective are all the same distance from the baseboard.

A plywood, metal or cardboard case is required to enclose the lamp and the condenser as shown by the dotted line in the diagram. A darkened room is necessary for this apparatus. Commercial instruments using 100 watt bulbs can be used in a semi-darkened room, but the problem of dissipating the heat from the lamp is then considerable.

3 A simple micro projector



The optical system of this instrument is the same as that of the strip projector. The differences in construction are necessary because of the size of the objects (microscope slides or small objects similarly mounted), and the need to use a very short focus objective to obtain high magnification. The lamp is a 1Zvolt car bulb, the condenser is a small glass bulb 1.5 to 2 cm in diameter blown on a piece of quill tubing, and the object lens is the objective of a commercial micro-scope.

The base of the apparatus is a small wooden trough 10 by 7 by 4 cm made by nailing two strips of wood 4 cm wide to the sides of a piece measuring 10 by 5 by 1 cm. These sizes are not critical, and may be varied to suit the other available materials. A support for this objective is provided by closing one end of the trough by a piece of plywood 9 by 7 cm with a 2.5 cm hole in it.

Into the channel fits a rectangular lamp- house; this is easily improvised by fixing a car bulb and holder inside a household mustard or other rectangular tin. Holes drilled round the top provide ventilation, and a hole 1.5 cm in diameter serves to support the condenser. Copper wire passing round the stem of the bulb and through holes punched through the tin hold the condenser firmly in position.

The slide holding the object to be projected fits into grooves cut across the edges of the channel, and is thus held in a vertical plane so that the light from the condenser passes through it. The position of the grooves is, determined in the way indicated below.

The microscope objective fits tightly into a hole in a piece of plywood, 7 by 4 cm, which is held in contact with the end plate by a trouser cycle clip in such a position that the lens can be adjusted to be on the axis of the optical system.

The diagram shows the components mount- ed further apart than in actual practice; this is done to show the relative positions more clearly. In adjusting this apparatus the slide, lamp house and condenser are moved forward together until the light passes through the objective and forms an image (of, say, a botanical specimen) on a ground glass screen 30 cm square placed about 60 cm away from the end of the trough. Once the correct position for the slide has been found, the saw cuts are made in the edge of the trough and serve for all other slides used. This apparatus can also be used for projecting Newton's rings and diffraction phenomena.

"BE A GOOD SCIENTIST. FOLLOW INSTRUCTIONS EXTREMELY CAREFULLY. WEAR PROTECTIVE CLOTHING WHEN WORKING ON ANY EXPERIMENTS THAT INVOLVE FIRE OR EXPLOSIONS."

CHAPTER XVII

Experiments and materials for the study of the human body

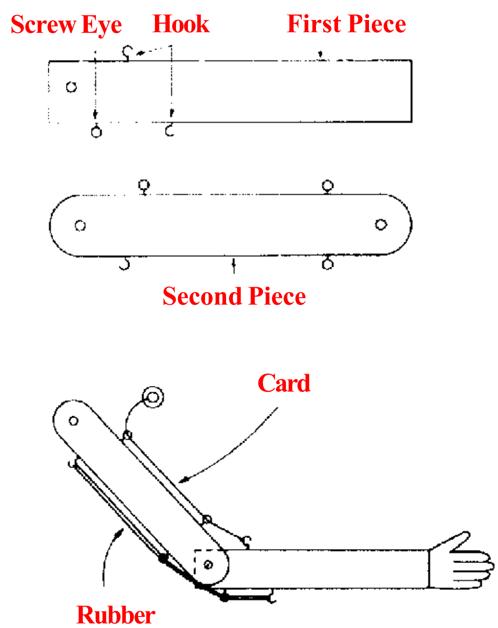
A. THE BONES AND IMUSCLES

1 A model of the arm

Obtain two pieces of wood about 5 to 8 mm thick (plywood will work very well), 5 cm wide and 30 cm long. Drill a hole in the upper corner of one piece of wood. Round the ends of the other piece and drill a hole near each end as shown in the diagram:

Next, put two cup hooks and a screw eye in the first piece of wood approximately at the places indicated. In a similar way place one cup hook and three screw eyes in the second piece. Put the two pieces together with a short bolt and nut as shown in the diagram below.

Cut some long strands of rubber from old bicycle or automobile inner tubes and fasten them to the cup hooks on the under side of the two pieces after threading them through the screw eyes. Thread a strong cord through the screw eyes on the upper side and attach to the hook. When the string is pulled, you will have a good representation of the way the bones and muscles of the arm work.

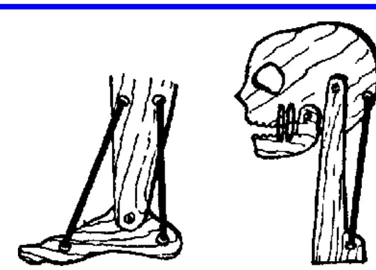


2 A model of the foot

Cut, from thin wood or cardboard, sections to represent the foot and leg as shown in the diagram. Attach rubber strands cut from old inner tubes, as indicated.

3 A model of the head and neck

The diagram indicates how this model may be improvised from wood or cardboard.



4 The walking hairpin

Hold a dinner knife tightly in your hand. Place a hairpin astride the knife and lift it just enough for the legs of the hairpin to rest lightly on the table with the pin in a slanting position. Observe that the pin walks along the knife blade. This is caused by the slight movement of the arm muscles.

YOUR SENSES

1 Your sense of smell

With pupils sitting perfectly still and evenly distributed in the room, release, in one corner, some substance with a penetrating odour. A little ether or ammonia poured on a cloth works well for this purpose.

Ask pupils to raise their hands as soon as the odour is detected. Note the progress of the diffusion of the odour through the air across the room.

Quote examples of ways in which the sense of smell protects us from danger.

2 The best reading distance

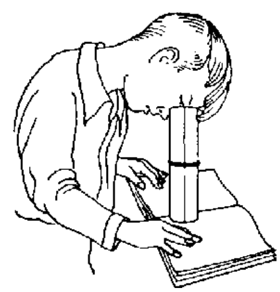
Ask pupils to read something and to hold their books at the distance where reading is most comfortable; 35 to 40 cm is normal. If the most comfortable distance is greater or less than this, spectacles may be needed to correct the vision.

3 Proper illumination

With the curtains or blinds drawn, hold a lighted 40-watt electric lamp exactly 60 cm above an open book. This amount of illumination is about right for comfortable reading. Show that the illumination rapidly diminishes as the lamp is moved farther away. At a distance of a little under 1 m, a 100-watt bulb is needed to provide the same illumination that a 40-watt bulb gives at 60 cm.

Demonstrate proper reading positions to prevent glare. Decide whether there is proper lighting in all parts of the classroom. If not, discuss methods of correcting the unsatisfactory conditions.

4 The adjustment of the eye



Roll 10 or 12 sheets of white paper into a hollow roll so that each sheet extends twice around the roll. Slip a rubber band around the roll. Set the roll on the page of a book and press one eye against the top so that no light is admitted at the bottom or the top. It should be impossible at first to read any of the words. If any of the words can be read immediately, add a few more sheets of paper to the roll.

With the other eye closed, keep looking through the roll for a minute or two without admitting any light. The print will slowly become legible in the dim light diffused through the paper.

As soon as the print can be read clearly, look quickly into a mirror and note the size of the pupils of the eyes. Keep watching the pupils for a minute and see how they change in size as the bright light of the classroom enters the eyes. Each of the children should have the opportunity to perform this experiment for himself.

Suggest some advantages of this ability of the pupils of the eye to change in size: contraction of the pupils protects the eyes against very bright light; enlargement helps us to see in very dim light; adjustment of the pupils helps us avoid danger.

5 Can you find your blind spot?

At the place where the optic nerve enters the eyeball there is a little blind spot only a few millimetres in diameter. You can find this blind spot by a very simple experiment. Draw a black dot on a white sheet of paper and about 5 cm to the right draw a black cross. Close your left eye and stare steadily at the black dot with your right eye, while the sheet rests on the table. Now pick the sheet up and move it slowly towards your eye while still staring at the dot. You will find a point where the image of the cross to the right will disappear. You can find the blind spot of your left eye by closing the right one and staring at the cross. When the book is brought near your eye, the black spot will disappear.

6 Optical illusions

There are several very striking optical illusions in everyday life. When near the horizon, the sun and moon appear to be much larger than when seen high in the heavens. When seen rising behind a hill, they seem to move much more rapidly than they do when they are above us. Measurement of the sun's or moon's regular diameter by an instrument or of their bearing when rising and setting does not confirm our first impressions. Our estimates of sizes and distances near the horizon are inaccurate because we adopt comparatively near terrestrial objects as our standard of comparison.

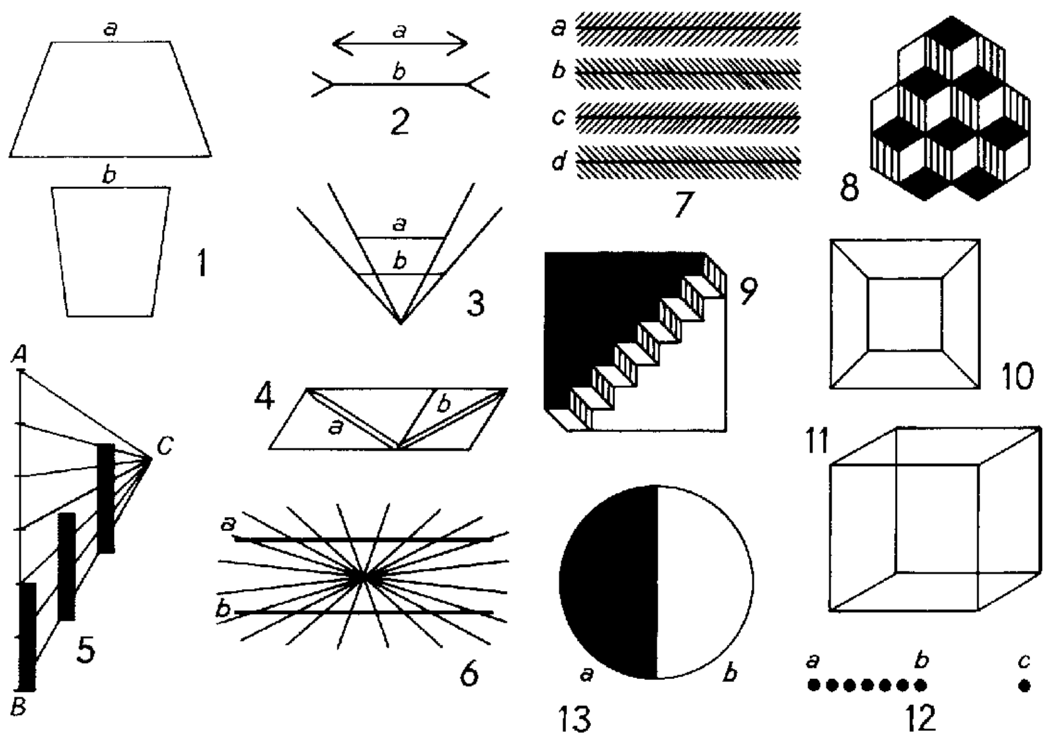
Make use of the theodolite or astrolabe and sextant made in Chapter VI, in measuring the speed of the sun or the moon during its setting or rising. Compare its movement when it is above us.

Vision is not merely a static copy of the changing world. We have to learn to use our eyes as we have to learn to use any other instrument. Our estimates of distance, direction and position do not merely depend on what the retina of the eye (see experiment C 1 below) tells us. They involve complex movements of the muscles that move the lens of the eye, of the muscles that change its curvature and of the muscles that move the eye itself in its socket, together with the movements of the muscles of the neck and limbs and all the signals which these muscles send to the brain when they move. We learn to co-ordinate our bodily movements with those of our eye muscles and with the pattern of light on the retina from the common experience of everyday life.

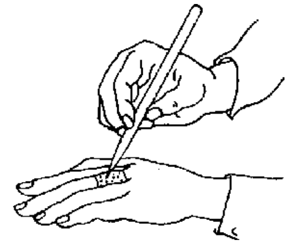
Part of our everyday experience is that light travels in straight lines. We learn to put things in line. The delicate adjustment which makes us able to grasp a thing by seeing it, or to direct our gaze to the thing we touch, is easily upset.

The following diagrams are of some well- know optical illusions. See that accurate measurements do not confirm your impressions.

Nos. 1, 2, 3, 4. Look at lines a and b and compare their lengths.
No. 5. The black fence-posts appear to differ in height.
Nos. 6, 7. Look at the horizontal lines; are they parallel?
No. 8. Count the cubes and then carefully recount them.
No. 9. Look steadily at the staircase. Then turn your book slowly so that the staircase becomes inverted.
No. 10. The inside square appears to shift back and forth.
No. 11. Sometimes you appear to be looking at the top of the cube and sometimes at the bottom.
No. 12. Look at the figure and compare the distances ab and be.
No. 13. Glance at the figure; is it a true circle ?



7 Your sense of feeling



With a pencil mark off a 1 cm square on the back of the first joint of the middle finger. Sharpen the pencil and press the point firmly against the skin at many places within the square. Nerve endings that register sensations of touch, heat, cold and pain are located in the skin. Find the points within the square that produce each of these sensations. Quote examples of situations in which the sensations of touch, heat, cold and pain might help us avoid harm or danger.

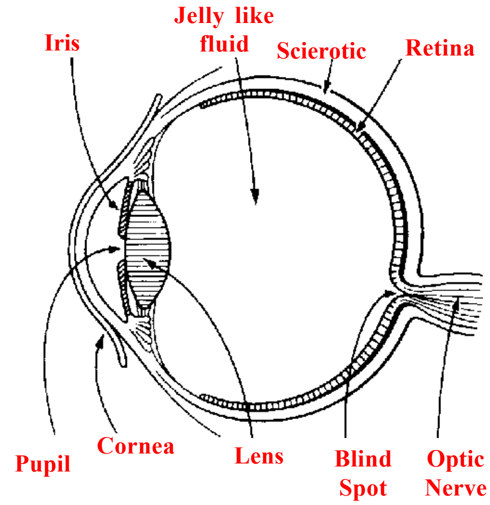
8 Testing your temperature sense

See Chapter XIII, experiment B 1.

C. SOME ORGANS OF THE HUMAN BODY

I The eye

1 How to dissect an eye



A bull's or a sheep's eye can be used. Remove the clear front skin or cornea. This will reveal the iris, and behind it the crystalline lens.

This lens divides the eye into two parts, the front containing a thin liquid called 'aqueous humour' and the back a jelly-like liquid, the 'vitreous humour'.

Removing the lens and vitreous humour, the retina or sensitive surface can be seen. It is more richly served with sensitive cells at a spot opposite the lens called the yellow spot. The nerves carrying the sensations pass out through a hole in the outer sclerotic membrane; this spot is therefore not sensitive to light and is called the blind spot.

2 How an image of an object appears on the retina

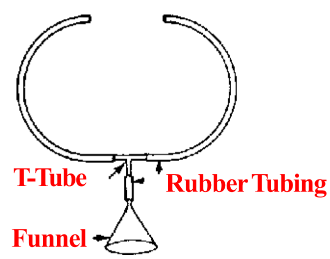
See Chapter XVI, experiment A 4, on the pinhole camera.

3 How the lens of the eye forms an image on the retina

See Chapter XVI, experiment C 11, on image formation by a convex lens.

II The heart

1 Making a simple device for listening to the heart beat



Make a stethoscope and have pupils use it to listen to the heart action.

A very satisfactory demonstration stethoscope can be made from a small funnel, a glass T-tube or Y-tube, and some rubber tubing. Slip a piece of rubber tubing 7 or 8 cm long over the tip of the funnel. (Any kind of small funnel will do, such as a glass laboratory funnel or the kind used to fill babies' milk bottles.) Insert the T-tube into the other end of the short piece of rubber tubing and attach longer pieces of tubing to both arms of the T-tube.

To use the stethoscope, have one pupil hold the funnel firmly over his heart while another holds the ends of the long tubes in his ears. Heart sounds will be heard very clearly though of course, pupils will not be able to interpret them. A doctor uses a stethoscope to find out if the heart action is normal.

This experiment will naturally lead to a discussion of what the heart does and its importance in maintaining good health. Dangerous activities that might injure the heart and diseases that sometimes result in heart impairment might also be discussed.

2 Taking the pulse rate

Demonstrate the proper method of taking the pulse rate by placing two fingers on the wrist and applying slight pressure by pushing against the back of the wrist with the thumb. Practise finding the pulse rate by counting for 15 and 30 seconds.

3 The effect of exercise on the pulse

Have several pupils take their pulse rate at rest and after vigorous exercise. Summarize the results in a table.

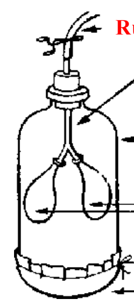
4 Watching the pulse beat of the heart

Stick a drawing pin into the end of a kitchen match. Hold your hand out with the inside of the wrist up and level. Place the head of the drawing-pin on your wrist at the point where you can feel the heartbeat. Observe the match as it sways each time the heart beats.

III The lungs

1 How the lungs work

Demonstrate the action of the diaphragm by means of the apparatus shown in the accompanying diagram. The rubber balloons re- present the lungs, the tube represents the windpipe and the open bottom jar represents the bony thoracic girdle. Lowering the diaphragm reduces the pressure inside the chest cavity and air flows into the lungs. Raising the diaphragm reverses the flow of air. Try moving the diaphragm with the clamp closed. Rubber tube and clamp



2 What is your lung capacity?

Pupils may be interested in finding the volume of air that the lungs can displace. This can be determined quite easily.

Fill a jar with water and fit a two-hole stopper. Insert a rubber tube through one hole; the other hole serves as an outlet. Invert the jar in a larger vessel and have a pupil make one exhalation through the tube. Place the fingers over the outlet and remove it from the large vessel. Use the graduate to measure the amount of water needed to refill the jug. The amount of water needed will equal the volume of air that was exhaled.

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CHAPTER XVIII

Some useful notes for teachers

1 Cleaning of glassware

Dissolve 100 g of potassium dichromate in a solution of 100 g of concentrated sulphuric acid in 1 litre of water. Glassware can be soaked in the solution, which may be used over and over again.

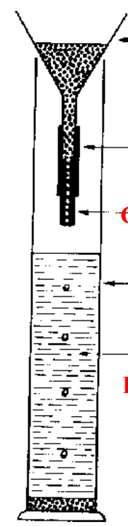
Caution: Great care should be taken to avoid getting this very corrosive solution on skin or clothes. When diluting concentrated sulphuric acid use a stone or earthenware vessel. Pour the acid very slowly into the water as a great amount of heat is given out in the process.

The teacher should use his knowledge of chemistry to remove stains of know origin. If dirty vessels have contained alkalis, or salts with alkaline reactions, then obviously the cleaning effect of a little dilute acid should first be tried; if the stain is due to potassium permanganate, then the effect of sodium sulphite solution, acidified with dilute sulphuric acid, should be tried, etc.

Alkalis slowly attack glass, and bottles which have contained caustic soda, etc., for a long time, will never recover their original transparency.

2 Cleaning of mercury

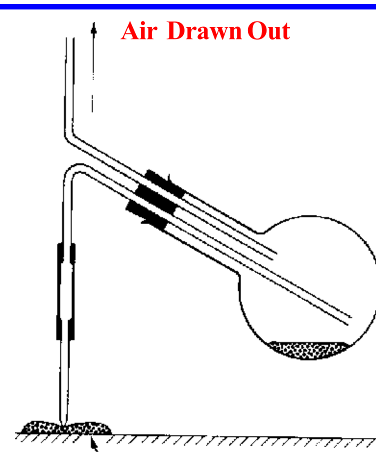
When mercury, flowing over a surface, begins to leave 'tails', it should be cleaned. It is allowed to drip into a tall cylinder containing nitric acid slightly more dilute than the usual bench reagent. If the mercury falls through the acid in a fine stream, as it does when made to pass through a capillary tube attached to the end of a funnel, so much the better. The mercury is then shaken up with water in a strong bottle to wash it free from acid. Finally it is allowed to pass through a pinhole made in the middle of a filter paper, which is folded in a funnel in the usual way. The last drops of mercury remaining in the funnel should be kept for the next occasion when mercury is cleaned. The mercury may be warmed in an air oven before the final filtering, if required particularly dry.



3 Removal of air bubbles from, and the recovery of, spilt mercury

Air bubbles appear in a tube which is being filled with mercury. To remove them the tube is closed with the finger, before it is quite full, and inverted to allow a large air bubble to travel up it. As it moves upwards, the large bubble collects the smaller ones. When the tube is turned up again the large bubble reverses its track, moves upwards and escapes. The small amount of mercury needed to fill the tube is then added.

Mercury spilt on tray, bench or floor, may be recovered by sucking it into a small 'wash- bottle'.



4 Collections of biological materials

These have little value unless they are kept in good condition, and the various kinds require different treatment.

Flowers and plants: A collection of dried specimens is called a herbarium. Its main purpose is to provide a supply of identified plants for general reference and to facilitate the naming of freshly collected specimens. The teacher must always have at hand a supply of material with which to illustrate the various kinds of flowers, leaves, fruit and roots. A specimen is not complete until all the parts of a plant are present. As flowers and fruits do not always appear at the same time, it may be necessary to collect specimens of a plant on more than one occasion.

Plants can be dried by pressing between sheets of newspaper. Special paper can be purchased for the purpose, but newspaper makes a satisfactory substitute if two or three sheets are put on each side of the specimen. A number of layers of specimens can be pressed at the same time. Drying is assisted by inserting sheets of stiff corrugated paper between every few layers. The pressing can be carried out by putting the sheets on a table under a heavily weighted drawing board. But drying is quicker between two wire frames pressed together by spring fasteners, adjust- able screw fasteners, or straps. For the first few days the specimens should be removed and placed between fresh dry paper every day, but as they become drier the changes need be made less frequently.

Specimens are less subject to the growth of mould if brushed over gently with a solution of 0.5 g of mercuric chloride in 100 mi of methylated spirit (methyl alcohol). The specimens should then be gummed, or glued, to sheets of stiff drawing paper, or to cards (about 25 x 45 cm) specially made for the purpose. The gum, or glue, should be made up with a little mercuric chloride, which also helps to repel insects. Alternatively, or in addition, the specimen can be sewn to the card, or fastened to it with transparent adhesive tape.

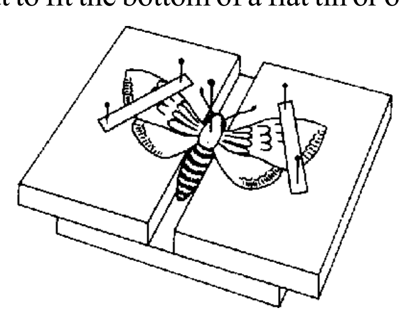
Each specimen should be labelled with at least: (a) the name and family of the species; (b) the name of the person, or group, which has identified the specimen; (c) the place and date of finding; and (d) the name of the finder.

Fruits or other bulky material associated with the specimen may have to be labelled and stored separately, but small seeds can be put in an envelope and attached to the mounting card.

Insects: These are best killed in a wide mouthed bottle containing a suitable poison. A killing bottle is easily made as follows. Some plaster of Paris is stirred to a thin paste with a 20 per cent solution of potassium cyanide (the 'commercial' mixture of pot- assium and sodium cyanides is satisfactory) and quickly poured, to a depth of about 1 cm, into the bottom of the bottle, where it soon sets hard. Cut a piece of blotting paper to place over the cyanide and plaster of Paris. Punch the circle full of holes. The bottle should have a screw-cap or a well-fitting airtight stopper, when it will remain effective for some months.

Caution: The cyanides of potassium and sodium are deadly poisonous and should be handled with the utmost care.

A captured insect becomes merely insensitive when first put into a killing bottle; so it should be left for a few hours until it is dead. It may then be removed to a setting board. A good substitute for the usual 'board' with a half-round groove consists of two sheets of compressed cork, or thick cardboard, with a gap between their edges, fixed on a third sheet, as shown in the figure. The setting board should be just large enough to hold the insect satisfactorily. A long thin pin, of the 'entomological' type, is then pushed through the middle of the insect's thorax, securing it in position in the groove. The wings, legs and antennae are then spread out carefully by means of seekers or fine tweezers, and kept in place by narrow strips of paper. (The strips are held down by pins, which must not touch the insect.) The specimen must now be dried thoroughly—not always an easy matter, in the tropics, unless the setting board can be left in a desiccator for some days. When it is dry the strips of paper are removed, as the various parts of the insect will now remain in place. It tends to be brittle, so no attempt should be made to move the thorax pin. By means of this pin the insect is lifted from the setting board and pinned in a suitable position on the mounting card. This is a sheet of card- board or compressed cork previously cut to fit the bottom of a fiat tin or other suitable box, the lid of which may be replaced by a glass top.



The preservation of specimens in the tropics is somewhat difficult, the chief problem being to prevent the attack of various kinds of ants. Some useful notes for teachers Some minute species seem eager for viscera, fresh or dried, and determined to remove everything except head, thorax and wings. The specimens must be kept, therefore, either in ant-tight cases, or in cases on some support completely surrounded by liquid. (Water requires frequent replacement owing to evaporation, and a layer of oil or disinfectant to prevent mosquitoes from breeding. Used engine oil, from a car sump, needs less attention and is just as effective as water.) Probably the best answer to the problem is to keep the insect boxes on a table with its legs standing in tins of oil or disinfectant. The legs remain clean and dry if they stand on smaller tins inverted in the middle of the liquid. Ants and other harmful insects are unable to cross the liquid surface.

Other biological specimens: Amphibians, reptiles, birds and mammals are killed with chloroform, a pad of cotton wool, soaked in the liquid, being placed in the containing box. Mammals can be preserved in either 70 per cent alcohol or 4 per cent formalin. Amphibians, reptiles, molluscs and crustaceans are most suitably preserved in alcohol.

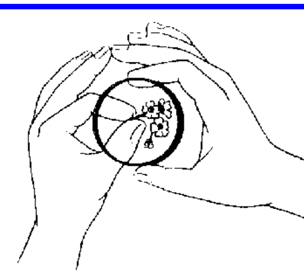
The cleaning of small skeletons, and the removal of viscera from large horny beetles, are jobs which, in the tropics, can be left to ants. The dead creatures are exposed in a suitable place. Their presence is soon detected by various ants, and before long a perfectly cleaned specimen remains. Bones can be scrubbed with an old toothbrush; bleaching powder should first be applied, and then hydrogen peroxide.

5 Botanical specimens

To keep these fresh until there is time to press them, they may be put in a closed tin in a refrigerator, where they readily remain stiff and fresh for a week.

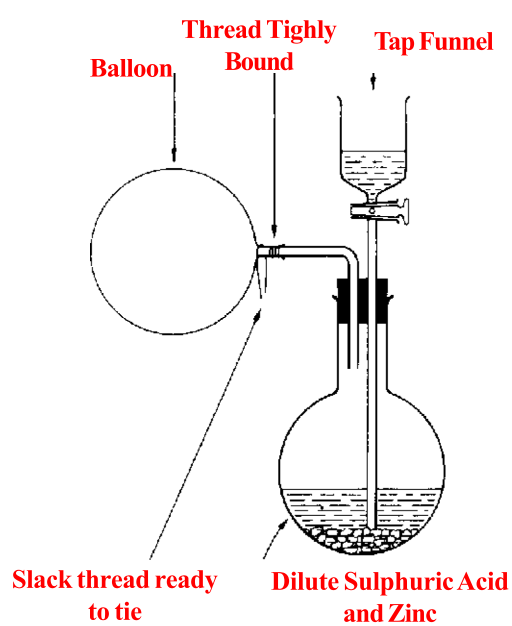
6 Hand lens

Young pupils find difficulty in holding lens and object steady, and so fail to keep the image in focus. Control is much easier if the thumb and forefinger of one hand hold the object, and those of the other hand hold the lens, and the tips of the middle fingers are pressed together.



7 Hydrogen balloons

In filling a toy balloon with hydrogen, the usual thistle funnel can be replaced by a funnel fitted with a tap. The delivery tube should be of as large a diameter as possible. The end of the balloon tube should be tied to the very end of the glass tube. This allows the final tying-off of the balloon to be done without first removing it from the glass tube. The acid is run into the vessel and the tap closed. The vessel should be a stout flask or bottle.



8 Tropical conditions

There are many causes of trouble in a laboratory, especially during a wet season, in the tropics. Materials perish, papers stick together, instruments rust, specimens go mouldy, lenses develop a fungus which quickly renders them useless and ruins their accurately ground surfaces. In addition, ants, termites and other insects continue their endless work of destruction.

Whatever can be kept in an air-tight container should be so kept. Glass jars, such as specimen jars with lids well greased, are ideal. Screw-capped bottles, e.g. those which have contained sweets, are very useful. Metal containers, such as biscuit tins, cake tins, etc., can be rendered fairly air-tight by strap- ping the joint between the lid and container with insulating tape.

Lenses of microscopes should be kept in a desiccator when not in use. A piece of string soaked in creosote and placed with the eyepiece in the lens container has been found useful for retarding the growth of mould.

During the rainy season, microscopes, galvanometers and other sensitive instruments should if possible be stored in an air-tight cupboard with a 50-watt electric bulb continuously burning. Needles can be inserted in a piece of material in which some Vaseline has been rubbed. Metal instruments such as screw gauges, vernier callipers, tuning forks, etc., should be greased. The screws of retort stand bases, rings and clamps should be oiled frequently. Scalpels should be smeared with vaseline and kept in a case. The metal parts of tools should be rubbed over with an oily rag.

Paste, gum and glue should contain some chemical to make them repellant to insects. Such adhesives are sold specially prepared for the tropics. But, if the teacher makes his own, the addition of a very small quantity of a solution of mercuric chloride, during the preparation, is generally effective. (Also, consult a pamphlet on it's Easy to Reduce Humidity, published by the Calcium Chloride Institute, 909 Ring Building, Washington, D.C., U.S.A.)

9 Culture solution (for plants)

The following salts, of purest quality, should be dissolved together in 1 litre of distilled water :

0.70 g potassium nitrate
0.25 g calcium sulphate (hydrated)
0.25 g calcium hydrogen phosphate (hydrated)
0.25 g magnesium sulphate (hydrated)
0.08 g sodium chloride
0.005 g iron (ferric) chloride (hydrated)

To the solution should then be added:

1 ml 0.06 per cent boric acid solution 1 ml 0.04 per cent manganese chloride solution.

10 Stains

In general it is preferable to buy stains ready made up in solution, but the following are useful recipes:

(a) Aniline sulphate. A few drops of dilute sulphuric acid are added to a saturated solution.

(b) Borax carmine. 4 g of borax are dissolved in 100 ml of water; 3 g of carmine are added and the solution warmed until the carmine is dissolved; 100 mi of 70 per cent ethyl alcohol are then added and the solution filtered.

(c) Safranin. 1 g is dissolved in 100 ml of water or 100 mi of 50 per cent aqueous ethyl alcohol.

11 Sea water

A useful substitute for sea water can be obtained by dissolving the following in 2 litres of water:

45.0 g sodium chloride
3.5 g magnesium sulphate
5.0 g magnesium chloride
2.0 g potassium sulphate

12 Lime water

Lime is not very soluble in water, but the solution required for class use is easily made by adding 10 g of slaked lime to 1000 cc distilled water. After shaking, allow it to settle before use.

13 Litmus solution

Litmus decomposes on heating; it should therefore be prepared by extracting the solid litmus with cold distilled water. It should also be stored in bottles which allow access to air, otherwise the colour will disappear.

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14 Accumulator solutions

(a) Lead accumulator. The specific gravity of the sulphuric acid in various conditions of the battery is as follows:

Fully charged 1.28
Half charged 1.21
Discharged 1.15

The above figures are approximate. The recommendations of the makers, usually printed on the battery, should be followed. A rough guide to the making of a solution of sulphuric acid of specific gravity 1.28 is as follows :

Concentrated sulphuric acid is added slowly, with stirring, to a beaker two-thirds full of distilled water, until the solution is almost boiling. The solution is allowed to cool, and more acid is added, with similar precautions, until the solution is again almost boiling. After cooling to room temperature, the specific gravity is adjusted by the addition of more acid or more water, according to the hydro- meter reading.

(b) Nickel-iron (Nife) accumulator.

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15 Pole finding paper

Blotting paper is soaked in a solution of sodium sulphate to which a few drops of phenolphthalein has been added. Damp the paper before use, and apply the wires to it a short distance apart. The paper touched by the negative pole becomes red.

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16 Electroplating solutions 17 Silvering solution (for depositing a bright silver mirror on glass)

First, 12.5 g of silver nitrate are dissolved in 100 mi of water, and 32.5 g of sodium potassium tartrate are dissolved separately in 100 mi of water. The two solutions are mixed, warmed to 55^0 C, and kept at that temperature for 5 minutes. The mixture is then cooled and the clear liquid poured off from the precipitate and made up to 200 ml for solution A. Second, 1.5 g of silver nitrate are dissolved in 12 ml of water. Dilute ammonium hydroxide solution is added until the precipitate first formed is almost entirely redissolved. The liquid is made up to 200 ml for solution B. The solutions A and B are then mixed. (The surface to be silvered, having been cleaned very carefully to free it from all traces of grease, should be suspended upside down in the solution, just below the surface. The solution can be put into a clean test-tube, or small flask, and a mirror deposited on the inside of the vessel. The solution can be slightly warmed to hasten the deposition of the silver.)

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18 Heat sensitive paper

A solution of cobalt chloride in water is added to a solution of ammonium chloride in water. (The proportions do not matter.) The solution is diluted until it is pale pink. Filter paper soaked in the solution and allowed to dry appears to be almost colourless, but on heating it will turn a bright green colour.

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19 Cements for general purposes

Many special cements are now available on the market. Where they are not available the following can easily be made up in the laboratory:

Acid-proof cement

1 part rubber solution

2 parts linseed oil

3 parts powdered pipeclay

Aquarium cement

(a) Equal parts of powdered sulphur, ammonium chloride, and iron filings are mixed. Boiled linseed oil is then added and all are mixed thoroughly. White lead is added to form a thick paste. The cement should be applied while fluid.

(b) Mix red lead with sufficient gold size to make a smooth paste and apply immediately. Allow a few days to set and rinse the aquarium before using. Celluloid cement

Celluloid scraps can be dissolved in acetone or amyl acetate. This cement is useful when making up small accumulators.

Cement for iron

90 parts fine iron filings

1 part flowers of sulphur

1 part ammonium chloride

Mix to a paste with water immediately before use.

Waxes

Chatterton's compound

1 part Archangel pitch

1 part resin

Melt these together and add three parts of crepe rubber in small pieces.

Faraday's cement

5 parts resin

1 part beeswax

1 part yellow ochre

Melt the resin and wax together in a tin and stir in the ochre.

Wood's alloy (melting point 70^0 C)

2 parts lead

4 parts tin

8 parts bismuth

2 parts cadmium

Darcet's alloy (melting point 70^0C)

5 parts lead

3 parts tin

8 parts bismuth

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20 Commercial adhesives

Many glues are now available for special purposes and it is worth selecting them carefully. China, glass and metal can all be stuck by china cements. But if the mended articles are likely to be put into hot water the only completely satisfactory results are from the new epoxy resins such as araldite. Paper and card can be stuck with almost anything. Cleanest and easiest to use are the vegetable glues, such as Croid No.22; Gripfix; Ste-fix; and Gloy. Textiles, leather and carpets are best stuck by the rubber lattice glues including Copydex; Fabrex; and Jiffytex.

To stick plastics is very difficult, or even, as in the case of polythene, impossible. Best results are normally obtained with a cement of the same base as the plastic, e.g. PVC sheeting with a PVC cement such as Pac or Plastitex. The impact adhesives are very suitable for sticking laminated plastics to other materials.

Evostick and Formica Adhesive are rubber solutions, and can be removed from the hands by petrol. Most other domestic adhesives yield to soap and water. There are many types of adhesive suitable for wood, of which the following are good examples :

Hot animal glues: Cake Glue, Pearl Glue, Croid Aero.

Cold animal and fish glues: Croid Universal, Duroglue, Seccotine, Le Page's Fish Glue.

Casein cold water glues: Casco, Croid Insol, Neverpart.

Urea Resins: Aerolite, Cascamite. PVA Emulsions: Casco PVA, Croid Polystic, Le Page's Suregrip, Unibond.

Animal glue and the emulsions are not resistant to cold water; resin glues are, and—for a time—to hot water. Casein glues are less strong, have a fair resistance to heat and damp, but stain some woods. Sticking things takes time. The more trouble taken in preparing and applying the glue the better the result

21 Insulating material for electrostatics experiments

Melt some paraffin wax in a can surrounded by a water bath. Add flowers of sulphur and stir until a pasty mass is formed. This can then be moulded to fit the neck of a flask or cast into slabs as required.

22 Replacing eyepiece cross-wires

Drawn out glass tubing, monofilament nylon (obtained by unravelling a piece of nylon material) or spider web can all be used for this purpose. Remove the supporting ring from the instrument. To make a frame for holding the fibre, bend a U-piece of copper wire so that the arms are about 1 cm further apart than the diameter of the ring. Place the arms under the fibre and stick it to them with a strong adhesive before breaking off the ends. Now lift the frame and place the fibre in position over the supporting ring. Fix it down with adhesive, and allow it to dry before trimming the ends.

If spider web is to be used, it is better to apply the adhesive to the frame before taking the filament from the web, and to the supporting ring before placing it in position.

Satisfactory threads can also be made from Durofix, Centofix and Seccotine by making a blob on a piece of paper and allowing it to dry partially. Very fine filaments of glue can then be drawn from the blob by touching it with a pin or the nozzle of the tube. These can then be fitted as before, though with some practice the operation can be carried out in the supporting ring, and the cross-wires fitted directly.

23 Soldering

Solder is an alloy of 66 per cent tin and 34 per cent lead which is used for making mechanical and electrical joints between two metals. It is generally obtained in the form of rods or sticks. It is applied in the molten state from a pointed block of copper known as a 'bit'. This may be heated electrically (in which case a 75 watt heater is sufficient for general purposes) or it may be heated in a Bunsen flame.

Whatever method of heating is used, the surface of the bit must be cleaned by scraping or dipping in a liquid flux, or the solder will not stick to it. When the right temperature has been reached, a little solder applied from the stick will flow all over the bit. This process, a preliminary to the actual making of the joint, is known as 'tinning'.

The surfaces to be joined must also be cleaned and tinned. In this case the heat is supplied by holding the hot copper bit on the object. When the solder begins to flow, it can be spread over the required area by rubbing gently with the tip of the bit.

When both surfaces have been timed, they should be brought together and heat applied again by the bit while they are held in the required position. The solder from the two surfaces runs together, and on cooling makes a strong joint. Naturally large surfaces require more heat, and it may be necessary to use a flame to bring the object to the required temperature.

The three essentials to successful soldering are cleanliness, flux and heat.

Fluxes Rosin is the most useful flux, especially for copper, brass, and tinplate, but it is not satisfactory for iron and steel.

'Dead' zinc chloride or 'killed spirits' is the easiest flux to use, but it is corrosive, and it is best to avoid it in electrical work. It is easily made by pouring hydrochloric acid on scraps of zinc and waiting until all action has ceased. The liquid can then be filtered off into a wide-necked container.

There are many commercial fluxes for special purposes. Flwite is perhaps the best for all general purposes.

Soldering paste is now obtainable. A combination of solder and flux, it is applied with a brush and only needs the heat of a soldering iron to make a satisfactory joint.

Tallow is used for joining lead to lead, or brass to lead, and rosin or killed spirits for joints in brass, copper, tinplate, zinc; killed spirits are suitable for iron and silver. After soldering, killed spirits should be washed off with water, and rosin or Flwite with methylated spirit.

24 Blackboard dressing

A satisfactory dressing can be made using:
100 g shellac
1000 ml alcohol
100 g powdered pumice
100 g crushed lamp black

The alcohol and shellac should be mixed first, as the shellac takes some time to dissolve. Some of the alcohol should be set aside for mixing with the lamp black. This mixture should be added later through a muslin strainer, and the whole should be well shaken before use.

25 'Dead black'

This is useful for painting the inside of 'light' apparatus, so that unwanted reflected light may be eliminated, rays made less diffused, and images made sharper. Lamp black is mixed with gold size, and turpentine added, with constant stirring, until the mixture is sufficiently thin for use as a paint.

26 Fluorescin solution (This is useful because the track of a ray of light travelling through a dilute solution of fluorescin can be seen very clearly.) One gram of fluorescin is dissolved in 100 ml of industrial, or methylated, spirit.

27 Cutting glass

(a) Sheet glass. First prepare a firm, hat surface on which to lay the glass: a table with a blanket or felt thrown over it is satisfactory.

Using a rule and with a firm grip on the diamond or glass cutter, make a scratch along the required line. Turn the sheet over and tap gently along the line of the scratch with the wooden end of the cutter. If this does not result in a crack spreading along the line, turn the sheet over again and grasp it with one hand on each side of the scratch and boldly bend it about, using this line as a hinge.

(b) Glass tubing. Tubing is best cut with a glass knife, and 'everlasting' knives are now available. A file, though often used, makes a rounded valley in the glass instead of a crevice.

Make a scratch at the required point and holding between the thumb and finger each side of the cut, pull the tubing apart, flexing slightly upwards.

To cut off a very short piece, hold in one hand and place the scratch over some ~m pivot such as a gas tap. Strike the short end a smart blow with some hard object.

Wide tubing must be scratched all round to make a neat cut. A molten piece of glass rod placed carefully on one part of the scratch will cause a crack to run round the circumference in each direction. If the two cracks do not exactly join, the tube should be bent about the uncracked part as hinge in order to separate the two pieces.

(c) To cut the bottom off a bottle. Make a scratch round the bottle at the required level. Wrap strips of damp blotting paper on either side of this scratch. Play a fine gas flame on the cut, rotating slowly as the glass begins to crack at this point.

If no gas flame is available the crack can be made in another way. See that the bottle is dry and well corked. Then tie a length of very absorbent cotton around it horizontally, keeping the knot as flat as possible and cutting off the loose ends. Level off carefully, so that the thread is exactly the same height up the bottle all round. Turn the bottle on its side and soak the thread with kerosene from an eye-dropper. See that no kerosene runs on the glass; if any does, wipe it off with cotton wool or filter paper. With the bottle still on its side and resting on two wood blocks with a gap between them, set fire to the thread and rotate the bottle on its axis with both hands until the whole thread is burning uniformly. Set the bottle upright on the table until the thread is burnt out, at which stage the bottle may split in two of its own accord along the line of the burn. If this does not happen as the flame goes out, gently lower the bottle upside down and vertically into cold water. It must be kept absolutely vertical and must not be immersed beyond the line of the thread.

Smooth off the raw edge with a file, or by rubbing on a flat ground-glass plate on which has been smeared a paste of carborundum powder.

(These bottles are useful for electrolysis experiments and as bell jars. In the latter case, a ring of soft rubber can be used to make an air-tight seal.)

(d) For (a) and (c), if electricity, either AC or DC, is available, it is also possible to place a round of wire, german silver or nichrome on the scratch. Switch on the current; the red hot wire will crack the glass along the scratch. This method is also found useful in cutting used electric bulbs.

28 Extinguisher

Materials for putting out a fire must be kept handy in definite places. Teacher and pupils should know how to use them quickly and correctly.

First-aid kit

A first-aid kit should be kept in each laboratory or adjoining preparation room, prefer- ably in a separate cupboard. It must be kept in good condition, and the teacher must know how to use its contents.

29 Blueprinting

Solution I: potassium ferricyanide 10 g; water 50 mi.

Solution 2: ferric ammonium citrate 10 g; water 50 ml.

The solutions are prepared separately and kept in a dark room or in subdued light. For use, mix equal quantities in subdued light and place in a shallow glass or enamelled tray. The paper is sensitized by brushing the mixed solution over it with a soft, wide brush, or the paper may be placed on the surface of the solution and allowed to float there for a few seconds. After sensitizing, the paper should be hung to dry in the dark room.

An opaque object, a drawing in black ink on tracing paper or any material to be printed is placed and fixed (on frame) on the paper. It should be exposed to sunlight (or artificial light) for several minutes and then washed thoroughly in running water.

30 Shellac coating Dissolve 1 part of shellac in 5 parts of alcohol, and apply with a soft brush.

31 Preparation of common alloys

Lower melting alloys

These may, in general, be produced by using a bunsen burner as a source of heat. The bismuth and lead are melted together, and then the other ingredients added. The temperature should not be higher than necessary to prevent excess oxidation. The parts indicated are by weight.

Alloy	Lead	Tin	Bismuth	Cadmium
Wood's metal	4	2	7	1
Solder	1	1	0	0
Electric fuse alloy	8.5	2.5	1.3	0

Higher melting alloys

These may be produced using a furnace. The copper should be melted first, and the other metals added to it.

Alloy	Copper	Tin	Zinc
Bronze	80	5	15

Brass, malleable	58	0	42
Brass, casting	72	4	24

32 Dyeing

(a) Direct. The dyeing of cotton should be preceded by removing the sizing from the fabric. This is accomplished by boiling it for 5 minutes in a dilute solution of HCI (hydrochloric acid). This solution is made by adding 1 part of concentrated HCI to 10 parts of water. The following formula makes a satisfactory dye:

Congo red 0.5 g

NaHCO, (sodium bicarbonate) 2.0 g

Na2SO, (sodium sulphate) 1.0 g

H,O (distilled) 200.0 mi

The fabric should be boiled for 4 to 5 minutes and then rinsed in cold water and dried.

Instead of the congo red, methylene blue or primuline brown may be used. The dye and salts should be mixed together ~st and then added slowly, with stirring, to the water. White silk, rayon or wool may be dyed in the same way.

(b) Use of a mordant. Show the use of a mordant by heating a piece of white cotton fabric for 10 minutes in a dilute solution of (NH,),SO, (ammonium sulphate). It should stand for a few minutes in dilute NH,OH (ammonium hydroxide), after which it is rinsed. White silk may be mordanted by boiling for 5 minutes in a tannic acid solution. It should then stand for a few minutes in a solution of tartar emetic. The effect of the mordant may be studied by boiling the mordanted and unmordanted pieces of cotton and silk in alizarin solution for a few minutes, after which they are rinsed and dried.

(c) Basic dyes. Show the use of basic dyes using malachite green. Boil samples of mordanted and unmordanted cotton and mordanted and unmordanted silk in a solution of malachite green (or methylene blue) for 5 minutes. They are then rinsed and dried. The malachite green solution is made by dis- solving 1 g of dye in 200 g of water. Two hundred grams of water are acidified with acetic acid. Forty grams of the dye solution are added to the acidified water.

(d) Ingrain or developed dyes. The development in the fibres of colours known as ingrain or developed dyes requires the use of three solutions. The first consists of 0.1 g of primuline and O.lg of NaHCO, (sodium bicarbonate) dissolved in 100 mi of water. Boil a strip of unsized cotton in this solution for 1 minute, then transfer it to the second solution. This solution is made by adding 0.5 g of NaNO, (sodium nitrite) and 3 mi of HCI to 100 mi of water. The strip is permitted to remain in this bath for 15 minutes and is then transferred to the developing bath. The developing bath is made by dissolving 0.05 g of NaOH (sodium hydroxide) and 0.05 g of phenol in 100 mi of water. Onstead of phenol, alpha naphthol or resorcinol may be used.) The solution should be kept warm and the cloth allowed to remain in it for 20 minutes, after which it is rinsed and dried. The results of various types of dyeing may be studied for quality.

33 Making matches

Make small splints of wood or use match- sticks from which the heads have been cut before they are used. The ends of these sticks are dipped in melted paraffin wax. A mixture of 2 g of powdered KCIO, (potassium chlorate) and 1 g of red Sb,S, (antimony trisulphide) is made. Do not grind. The two solids should be mixed with the fingers. A thin mucilage is added to make a paste. The paraffined end of the matchstick is dipped in this mixture, and it is hung head down to harden for a day. A surface for igniting the matches is prepared by adding mucilage to equal volumes of red phosphorus and fine white sand. This is spread on a cardboard or wooden surface and permitted to dry. The matches ignite when rubbed on this surface.

The matches so prepared should be com- pared with commercially-made safety matches and with those that are not of the safety variety.

34 Chemical ‘flower gardens’

Chemical ‘flower gardens’ are the result of osmotic action. A water glass (sodium silicate) solution of specific gravity of 1.1 is desirable. Into 400 mi of this solution in a beaker are dropped pieces of the sulphates of copper, iron, nickel and aluminium; the chlorides of copper and iron; and the nitrates of copper, iron, cobalt, nickel and calcium. From these pieces the ‘flowers’ grow rapidly. The silicates form membranous sacs which have a high concentration on the inside, thus promoting the rapid growth of the sac.

35 Winding a spiral spring

Phosphor bronze or steel wire (SWG 26) is suitable for an average spring. Choose a nail 15 cm long and clamp the point in the jaws of a hand drill. Trap the end of the wire in the jaws also. Fix the drill horizontally in a vice. Turn the handle of the drill, and pull hard on the free wire, using a piece of cloth or a leather glove to protect your hand. When you have made the spring as long as you need, use a pair of pliers to bend the free end round the nail, and cut the wire. The wire will uncoil a little, but this does not matter. Release the wire from the jaws of the drill, cut off the ends of the spring so formed and remove the nail. Using pliers, grip the two end turns of the spring together and bend them at right angles to form a loop. Repeat this at the other end of the spring.

CHAPTER XIX

Some new tendencies in science teaching Science has been taught in schools for approximately a hundred years. It began as natural philosophy, and by about fifty years ago had settled down to become a course of scientific knowledge which was mainly factual and descriptive. During the last few years the science programmes of many countries have been under scrutiny. The rapid progress of scientific knowledge during this century has brought with it many new concepts, and a new unity of ideas. The manner as well as the matter of science has changed: individual research has been replaced by team work; new techniques have appeared, and the apparatus in use has become much more elaborate. The science taught in schools has become divorced from everyday life, and many teachers have begun to feel that it is no longer sufficient to teach the science of even a generation ago, but that matter should be included in the courses which is more relevant to a modern age. There is nothing essentially new in this—sooner or later the skills and achievements of society have always been reflected in the curriculum of the schools. But the great advances that have been made in science and mathematics, and in the associated technology, seem to have out- stripped the progress of educational theory and practice.

For this reason, many countries are rethinking their educational programmes, and because physics is the most advanced of the sciences, and possibly produces the most far- reaching effects on human life, it is this subject which has received first consideration. The conclusions reached bear equally on the other science subjects, but in what follows physics will be stressed because in this subject some complete syllabuses and schemes have been worked out and tried as pilot schemes. In a short survey it is not possible to give in detail the educational schemes of different countries, and in what follows the emphasis is on the principles involved in the construction of the courses. Mention will be made of the work done by the Physical Sciences Study Committee in the United States of America, by the Science Masters' Association in the United Kingdom, and by the International Union of Pure and Applied Physics, and a brief note is added on physics teaching in the Union of Soviet Socialist Republics. The work of the Physical Sciences Study Committee

The Physical Sciences Study Committee is a group of university and secondary school physics teachers, who undertook in 1956 the task of developing an improved physics course for American secondary schools. Its work has been administered by Educational Services Incorporated, a non-profit making corporation. It has stimulated a general movement in the United States to improve secondary school science education; similar groups are now working in the areas of biology, chemistry and mathematics.

A critical examination of school textbooks, apparatus, visual aids and library material revealed the following deficiencies:

1 Textbooks in general reflected a scientific outlook which dated back half a century, and was no longer representative of the views of the scientific community.

2 Genuine attempts to remain abreast of scientific developments had given even the best textbooks a patchwork quality in which the unity of the subject had disappeared. The sheer mass of the material had become unreasonably great.

3 With the increasing application of science to everyday life the books had become further overloaded by more and more attention to technology.

4 The laboratory manuals suffered the same defects.

5 The potentialities of audio-visual aids were not being adequately exploited.

It was then decided to formulate a new physics course in which the unity of the subject would be preserved, and modern ideas would fall naturally into place. This has now been embodied in a textbook entitled PSSC Physics. Naturally, this book is designed to fit the educational schemes of the United States, and in fact is intended to be a one-year course for the last year of the secondary school. But the outline of the syllabus, the ingenious Some new tendencies in science leaching experiments which have been incorporated in the laboratory manual, and the supporting films and library books are of interest to teachers in all countries.

The syllabus divides naturally into four parts. The first is an introduction to time, space, matter and motion. The second includes optics and waves. A particle model of light is developed to explain wave behaviour. When the particle model is found inadequate, a kinematic picture of wave behaviour is introduced as an alternative. In the third part, mechanics is presented through the dynamics of Galileo and Newton, leading to a study of momentum, energy, and the conservation laws. The fourth part begins with an introduction to electricity and magnetism, and the behaviour of particles in fields. Discovery of the photo- electric effect leads back once more to a more subtle consideration of the nature of light. The synthesis of wave behaviour and particle mechanics in a description of the atom bring the course to a conclusion.

In close relation to the ideas developed in the textbook, a laboratory programme was then conceived; in this the following considerations were used as a guide:

1 Experiments should be true experiments, and not routine accumulation of data to agree with a result well known in advance.

2 They should be performed with simple apparatus that can be quickly assembled by the student.

3 They should encourage further work along suggested lines, and should lead to the consideration of theoretical ideas growing from the experiment, and be guided by those already mentioned in the textbook.

It was originally the intention of the committee to develop laboratory apparatus of a type which could be constructed by the teachers and students themselves, but it was soon discovered that although there would be obvious advantages in this, the burden on the teachers would be too great. The apparatus described in the laboratory manual is now manufactured commercially to designs which have made it possible to set the commercial price at a minimum.

Visual aids were then considered, and an examination of the many educational films available showed that there were few which in manner and content furthered the ideas outlined in the textbook. Accordingly, a new set of about sixty films was planned. The intention of these films is: (a) to ease the load on the teacher; (b) to provide visual presentation of operations too difficult to carry out in the laboratory or to show by demonstration experiments; (c) to present a new subject, or to summarize and integrate a field of study; (d) to show, where possible, real scientists at work in real situations, and speaking directly to the students.

A further activity of the committee has been the production of a set of paperback books about science and scientists. Their primary purpose is to take the load off the textbook, leaving it free for the elucidation of general principles. Sixty books are at present envisaged, which will provide a survey of physics within the grasp of those following the main course. Some tell of the role of physics in the service of man, others are biographical in nature and tell the stories of discoverers and their great discoveries. It is hoped, too, that besides supplementing the course, they may be comprehensible to the layman, and perhaps help to bridge the gap between the science and arts student.

Trials of the course outlined above showed that some teachers would find a guide to the textbook helpful. The final effort of the committee was therefore to produce a set of teachers' notes for this purpose, including solutions to the problems in the text, and suggestions for teaching the subject. This comprehensive guide is now available, and will prove invaluable to all attempting to adopt the course, or to adapt it to their own special needs.

The Physical Science Study Committee is interested in rendering whatever services may be of use to those individuals and schools who wish to know exactly what the new course is, and how it has come into being in its present form. Such information, as well as advice on the present status of foreign translations and adaptations, may be obtained from: Physical Science Study Committee, Educational Services Incorporated, 164 Main Street, Watertown 72, Mass.

The work of the Science Masters' Association and the Association of Women Science Teachers in the United Kingdom In 1957, motivated by the considerations mentioned earlier, the above associations issued a policy statement on science teaching in schools. Subject panels later compiled syllabuses for the biological, chemical and physical parts of the science course below the sixth forms, as well as for the specialist teaching which follows.

The general recommendations were that science should be the 'core' subject in gram- mar schools in much the same way for example as English and mathematics are at present, and as classics used to be. Believing that all students should study science up to the fifth form years, and that all specialists should study some science, the authors of the statement laid down the following principles. Teaching should be divided into three phases: an introductory phase covering the first two years, an intermediate phase up to about sixteen years of age, and an advanced phase to include some specialization.

In 1960 the committee issued syllabuses for physics, chemistry and biology covering these three phases. To make it possible to include material more closely connected with modern life, difficult concepts, ideas and numerical problems on energy, magnetism, and certain aspects of heat and light were omitted from the early and intermediate phases of the physics course. The criterion for the inclusion of any item at the advanced phase was, 'Is it fundamental to physics today?' Subjects more properly included under the heading of applied physics or technology have also been excluded. These have been replaced by substantive sections on mechanics, the under- standing of which is so essential and fundamental to an appreciation of modern physics.

The same general principles have been applied to chemistry. Although it can be claimed that the teaching of chemistry in British schools has at its best been as good as any in the world, some modifications are necessary to meet the new situation. The past syllabuses have been too heavily weighted with facts, preparation, and details of procedure.

The general plan of the early stages in chemistry, it is suggested, should be visualized as a series of empirical investigations, with the emphasis on experimentation and observation. Speculations in the light of ascertained facts will then arise, and opportunities will be provided for the invention of simple theories. These in turn will lead to new theories and the discovery of new facts. In the second phase, it is suggested that the pupil should learn to appreciate the nature of scientific laws, the inter-relationship between facts and theories, and the intimate relation between matter and electricity. Some ideas, too, should be formed concerning the need to assume a particle structure of atoms when considering the reactions in which matter takes part, as well as the factors which can affect chemical reactions in general. On the sound basis of the first two phases of teaching, it should now be possible to discuss the material basis of chemistry, types of materials and changes, and their full explanation in terms of molecules and ions.

The committee, reviewing the teaching of biology, emphasized that this term implies not a single science, but a whole group of sciences. It was further realized that biology can be used to unite all the sciences, and to link them with psychology, the social sciences, and with history and the arts. To achieve this linking effect, biology should be centred on the study of whole organisms, and not on anatomical, physiological, cytological or biochemical abstractions.

In the introductory and intermediate phases biology should be part of an introduction to science as a whole. Personal observations on Some new tendencies in science reaching live organisms should be made, and prominence given to practical work. The organisms studied should be selected from easily available local flora and fauna, and simple habitat studies are eminently suitable. Nutrition and respiration can be studied as parts of wider science topics with physical, chemical and biological aspects. At the intermediate phase an advance should be made in greater depth and on a narrower front than at the introductory phase. A further suggestion was that a syllabus based on that of the level of the Cambridge Local Examinations Syndicate meets the above requirements, and contains more useful suggestions to teachers than many of the other syllabuses. The syllabus at the advanced stage grows out of that of the earlier phases. Sixth formers approach the subject with more mature minds: more advanced practical work is possible. Individual dissections of animals can take the place of the previous demonstrations. The staining and mounting of some microscopical preparations can also be undertaken. Teachers can develop particular sections according to their own outlook and interests, and to the local conditions, especially as regards field work. The syllabus would therefore include further study of the mammal and of flowering plants; a variety of patterns of life; elementary ecology, and a number of general biological topics under the general title of 'The nature, continuance and diversification of life'.

The work of all these planning committees is not complete, but the suggestions outlined have been embodied in detailed syllabuses published by the associations. The great freedom allowed to British teachers allows them to be interpreted in many different ways. Pilot schemes are in operation in the schools, and in the next few years much will be learnt of how best to achieve the desired objectives.

Publications

The following publications of the Science Masters' Association and the Association of Women Science Teachers are obtainable at 2s. each from the Librarian, Science Masters' Association, 52 Bateman Street, Cambridge: A policy statement on science education.

Physics for grammar schools.

Chemistry for grammar schools.

Biology for grammar schools.

The work of the International Union of Pure and Applied Physics

In July 1960 an international conference on physics teaching took place in Paris. It was sponsored by the Organization for European Economic Go-operation (now OECD), Unesco and the International Union of Pure and Applied Physics, and was part of a wider study of the teaching of science, mathematics and chemistry being undertaken by OEEC. Delegates from the Netherlands, Switzerland, Italy, Denmark, France, the United States of America, Japan, Poland, Germany and the United Kingdom considered topics including examinations, laboratory work, the training of teachers, and the use of films and television in science teaching. They further considered the defects of the present systems, the approach to the teaching of physics and the supply of physics teachers.

The diversity of conditions and facilities in the various countries made it very difficult to arrive at general conclusions. Some countries were inevitably criticised for over-emphasizing the theoretical aspects of the subject, and others for the inclusion of too much practical work. But all were agreed that drastic changes in the method and content of physics teaching were necessary. General agreement was however found in an agreed syllabus, and suggestions were made for its implementation. These are to be found in a full report of the conference. This is now published under the title International Education in Physics, John Wiley and Sons Inc., 440 Park Avenue S., New York 16, N.Y. Science teaching in the Union of Soviet Socialist Republics

The revision of the science teaching programme in the Soviet Union began as early as 1919, when a State Council was set up to provide, amongst other things, general and methodological guidance and curricula for the higher schools. In 1921 a further special commission declared the aim of the Soviet high schools, and set up schemes for the training of scientists and teachers.

But the greatest step forward was made in 1957, when the regulations of the Ministry of Education required all scientists in post- graduate training to study pedagogics, psychology, logic, and methods of teaching special subjects, as well as the skill of conducting classes. This resulted in a great increase in the numbers of scientists available for teaching.

The Academy of Pedagogical Science set up in 1943 has rendered great help to the teachers. It provides information on new teaching methods, and promotes constructive co-operation between teachers and educational Some new tendencies in science leaching authorities, and furthers the production of textbooks. It is also responsible for the syllabuses and supply of apparatus, as well as for the textbooks to be used. The syllabus thus includes a full list of the demonstration experiments to be shown, the topics to be discussed, the films to be shown, and the expeditions and factory visits to be made. Regional training institutes set up in all areas supplement the work in the academy by organizing courses, lectures and seminars.

Education is now compulsory from 7 to 18 years of age, and all pupils have the same basic course for the first eight years. The schools are co-educational, and classes must not exceed 30 in number, though more usually they do not exceed 24. There is no 'streaming'; all pupils go through this same basic course. For the last three years the pupils proceed to a type of school suited to their abilities.

Biology is the first science to be taught, but in the last three years gives way to physics. The syllabus here includes advanced work on atomic structure; nuclear energy; isotopes; the physics of light; supersonics; the photo- electric effect, semi-conductors, as well as work on three-phase alternating current. There is a great emphasis on practical work by the students, and also on good demonstration experiments. Most schools possess an oscilloscope and the necessary apparatus for teaching alternating current. As mentioned, the apparatus is supplied by the academy, and is thus of a type most suitable for the purpose.

The syllabus outlined is only a minimum; sufficient time is allowed for individual teachers to follow their own ideas. The intention of the syllabus, the suggestions and the provision of apparatus is merely to ensure that all pupils are adequately taught, even by the less gifted teachers.

This brief outline shows what consistent effort, immense energy and resources have been directed towards science teaching during the last 40 years. The result is seen in the outstanding position of Soviet science today. References

The training of scientists in the Soviet Union, by G. Galkin. Education in the USSR, by M. I. Kondakov.

end of book