Section 5

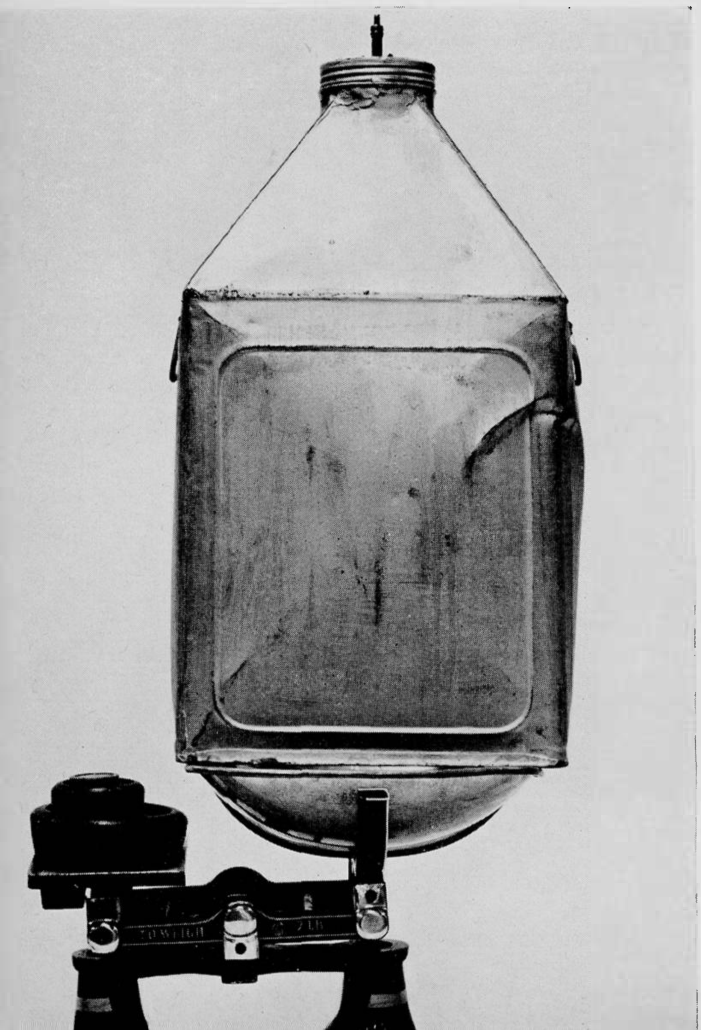
Air

Introduction

The three great environments of living things are air, earth, and water. No study of life is complete without some consideration in detail of each of these environments. Earth is the easiest of all to study as it is a tangible concrete material which can be easily handled and examined by young children. Water is tangible too, and although it introduces new qualities such as fluidity and a lack of form, a child can see that it is there and it is real. Air, on the other hand, is invisible, is less easy to believe in than soil and water. So, from the outset, the teacher will be preoccupied with putting in the child's way practical experiences which will help him appreciate the reality of air. It will be most significant if these experiences are the natural outcome of other scientific enquiries. Parallel with this work will go the need to provide an expanding vocabulary which will be the natural accompaniment of new ideas. Older children may be ready for the need for more precision to enter their work, and for the expression of quantities in terms of measurement. Work on the composition of air can be approached from a genuinely empirical point of view. This may be done by an examination of the differences between various samples of air and so lead to a study of 'airs', rather than a premature use of terms like oxygen, nitrogen, and carbon dioxide. No doubt there may be a place at the upper end of the age scale to introduce these names to identify certain undeniable situations. However, they should follow a study of airs rather than precede it. In some ways this treading of the ground of the historical development of scientific investigation gives teachers a significant insight into the possible ways in which the complexity of a subject may be built up.

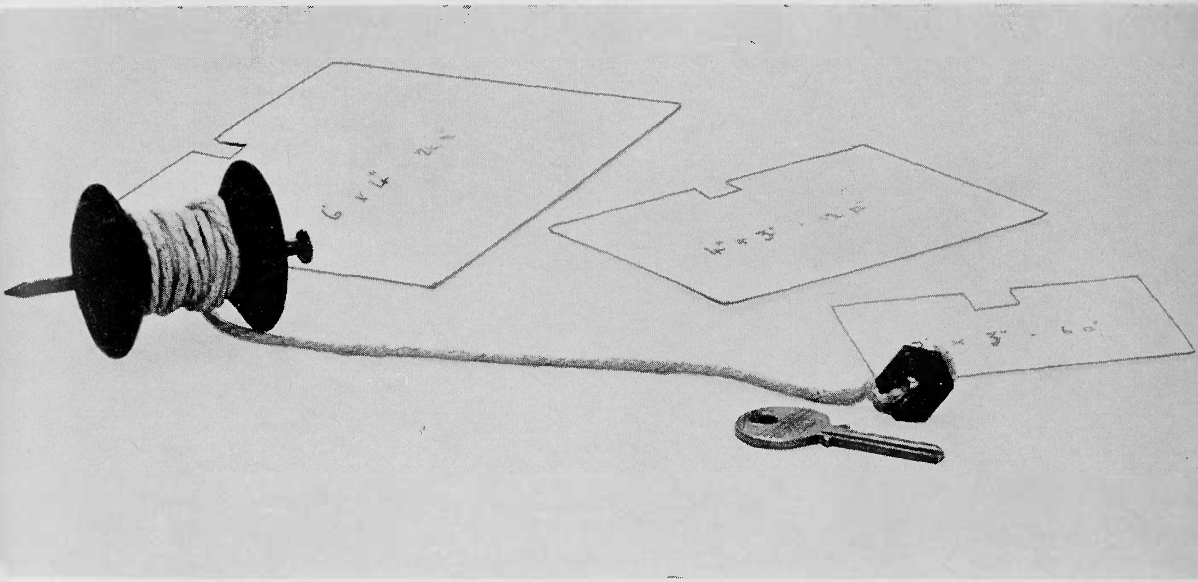
1. Air

If air is a real substance, it should have weight, and this should be discernible by the ordinary means of weighing. The apparatus shown is a means of demonstrating that this is so. It provides a way of overcoming some of the difficulties which arise when the traditional beam balance with balloons or football bladders inflated or deflated is used. This latter piece of apparatus is open to many objections both from a mechanical and a scientific point of view. It should be stressed, though, that the alternative suggested here is merely a way of seeing that air has weight. It is not a way of finding out how much weight a given amount of air has. In essence the apparatus consists of a five-gallon can with a bicycle valve inserted into the screw top. Rubber washers should be placed on either side of the valve base, and a layer of rubber solution or Evo-Stik put generously between them. The cap is then screwed on and soldered into place. All this should produce an airtight joint. The can is placed upon ordinary domestic scales and put into balance. The weights are not important; what is important is that the two shall be in exact balance. Pen nibs or pieces of chalk form good materials to trim the scales into final balance. Then, if one hundred pumps, or thereabouts, of air, are put into the can from a bicycle pump, and the can is replaced on the scales, the balance will be upset and the pan will be depressed on the side of the load, thus indicating that the air which had been put into the can has weight, just like any other substance which is put on the scales. A check can be made by undoing the valve, placing it in the scale pan, and letting the air out, thus bringing the scales back into balance.



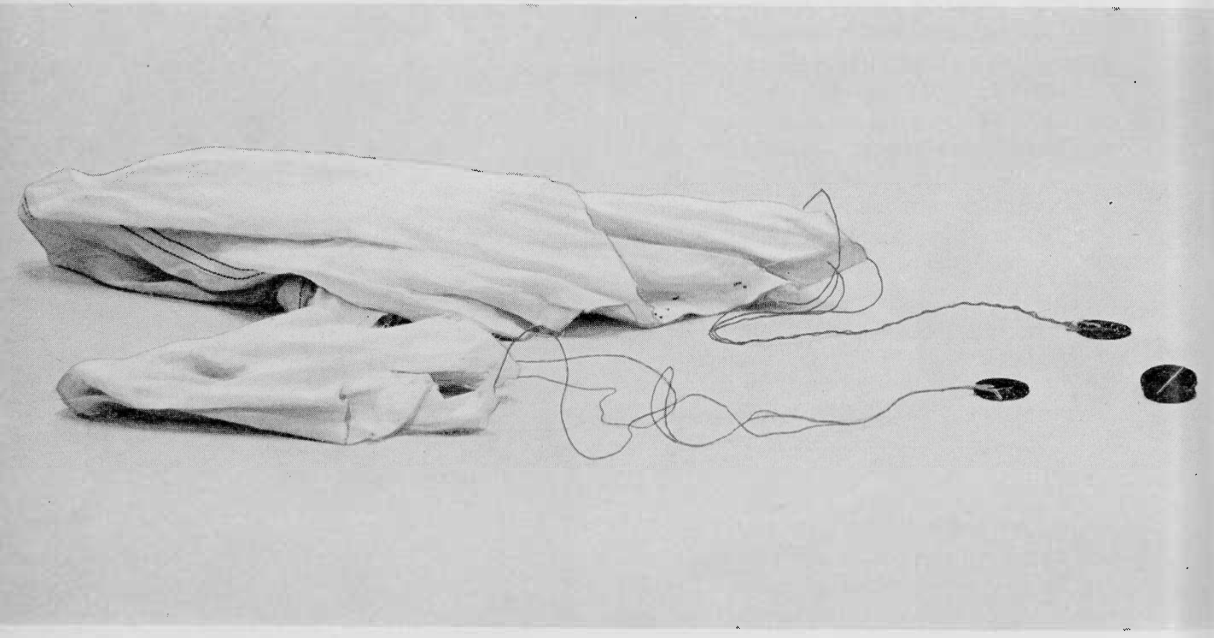
2. Air resistance A

The simple apparatus illustrated shows how children may discover that because air is real it resists movement, and, if it is so desired, it is possible to record this resistance in numerical terms. The cotton reel is free to revolve on the nail as an axle. A large nut or key forms a weight on the end of a metre of string. A $\frac{1}{4}$ in. deep saw-cut is made across one end of the cotton reel and into this vanes of different areas can be inserted. The thread is wound round the reel, a vane is inserted, and the time in seconds is counted for the weight to descend the full length of the thread. Simple areas for the vanes should be chosen, such as 2 in. by 3 in., 3 in. by 4 in., and 6 in. by 4 in., and then the recording and tabulation of results become easy.



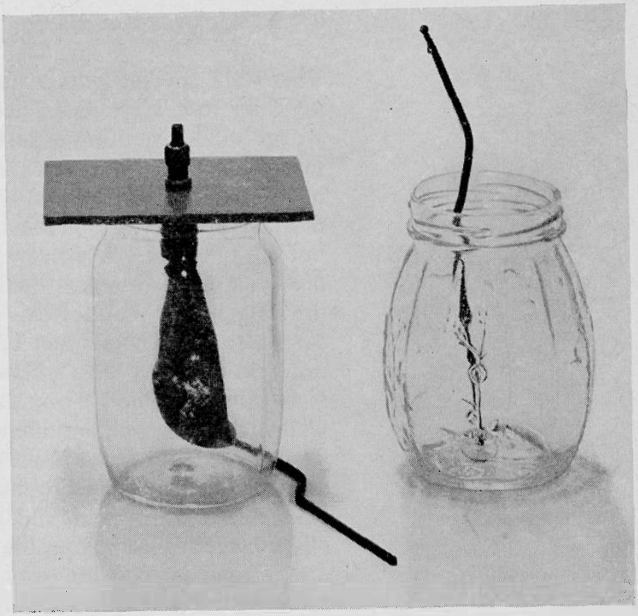
3. Air resistance B

The resistance of this real substance, air, is put to good use in the parachute. Children can investigate this quite easily at different levels of difficulty. They may simply make parachutes of different sizes and observe their behaviour generally, or the situation can be sharpened when different specific areas of material are made into parachutes, each having the same length of cord, and each being weighted with the same denomination of weight. This illustration shows two parachutes, one with an area of 1 sq ft, and the other with an area of 4 sq ft. Each has the same length of cord and is weighted with a halfpenny. Both were thrown to the same approximate height, and their times of descent were measured. Halfpennies with $\frac{1}{8}$ in. holes drilled in them, or washers, form useful weights for this kind of experiment. Many problems can be posed, such as, 'What weight is required to make the larger parachute descend at the same rate as the smaller? What sort of weight would a parachute support which was double the area of another whose maximum load we know?' and so on.



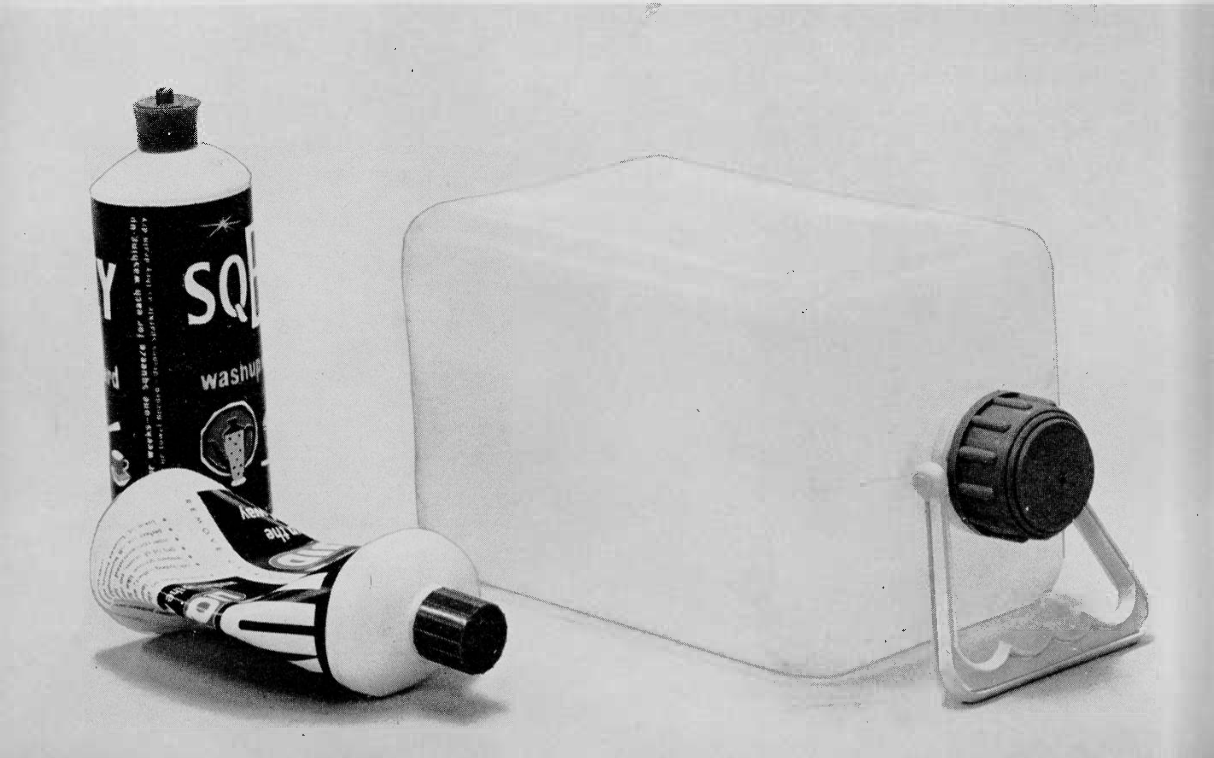
4. Fluidity of air

A difficult fact for children to appreciate is that air occupies all the space available to it. It is easy to state that air is everywhere, but far less easy for children to grasp. The apparatus illustrated was an attempt at investigating this situation. The bicycle valve inserted through the piece of hardboard carries a balloon at the other end. This is used to imprison a sample of air. The bent piece of umbrella rib, which is of hollow section, serves to allow an escape route for pockets of air which will collect at the bottom of irregularly shaped jars. The balloon can be inflated via the valve, and if a series of irregularly shaped jars is available, it will be seen that the volume of air imprisoned in the balloon with its flexible sides will adjust itself to the shapes available, whatever they are. Beside the conventional cylindrical jam jar it is useful to have a triangular one and a hexagonal one. This same sort of device can be used in many other circumstances for children to investigate this fluid property of air.



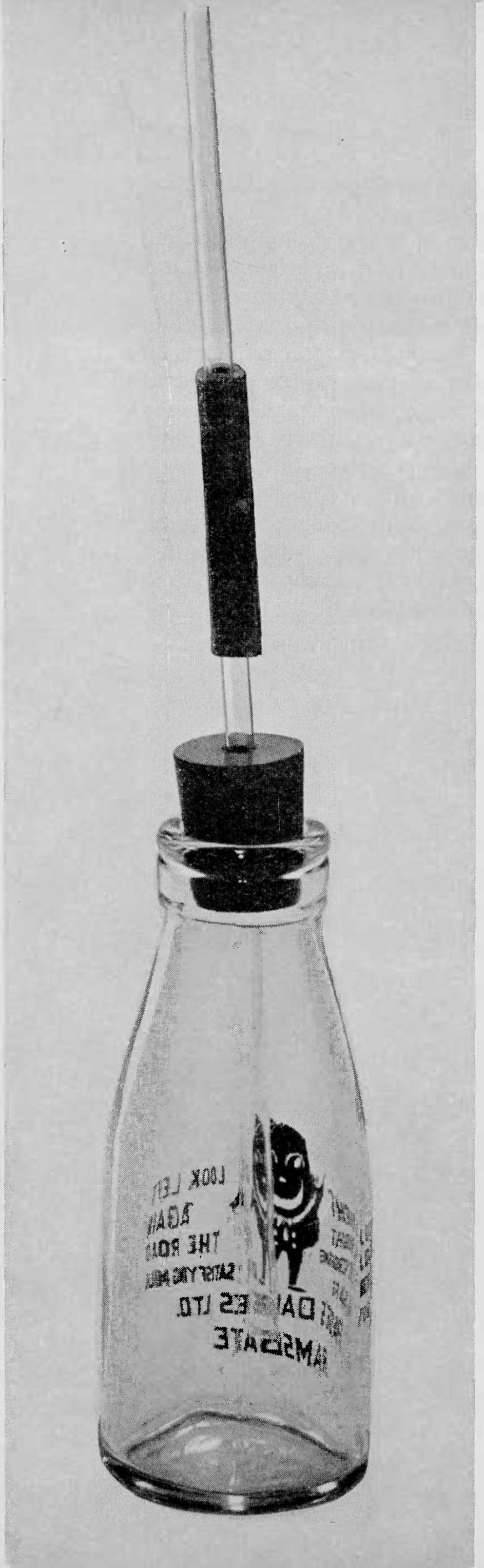
5. Air pressure A

There are several pitfalls in the conventional experiments on air pressure, not least those designed to collapse cans by condensing steam and so creating a partial vacuum. Not only is a question of safety involved but also a barrier in understanding. The significance of putting water in the can to create the steam, and then creating the partial vacuum by condensing it, is something many children are not ready to grasp. However, they will readily appreciate the forces involved if they remove the air from a plastic container, by simply drawing it out themselves. (It is a good thing to avoid the word 'suck', so that the teacher can seek to build up an idea of pressure differential rather than a concept of a spurious force called suction.) It is now possible to buy gallon-sized plastic vessels with flexible walls, and these make quite a dramatic device for enabling children to appreciate the force of air pressure. If a $\frac{1}{8}$ in. hole is drilled in the stopper of one of these containers, the air can readily be removed from the vessel by the child, and furthermore, because he is physically engaged in removing the air, he will be aware of what has gone on. This is all difficult work, and the teacher's presence and active participation in the conversations and discussions around this topic will be vital if understanding is to be built up at all. The whole concept of pressure is difficult, and is not likely to be formed by younger children.



6. Air pressure B

The dramatic effect of air pressure can be experienced by children in several ways. A large rubber force cup, used for drain cleaning, illustrates this well. Children are amazed at the strength required to remove it from a highly polished floor. An experiment of this sort can well be used to start children thinking and talking about the situation. While younger children will do this fairly loosely, older ones may be ready to particularize, using more precise terms of measurement. They will find smaller section rubber or plastic stickers useful. If a wire hook is fixed to them then the pull required to detach them can be measured by a spring balance. Children can also measure the area of the sticker surface, and calculate roughly the pull per square inch required. In the foreground of the illustration there is a miniature version of the Magdeburg Hemispheres experiment, this time using two small rubber stickers with a surface area of approximately 1 sq in. With this apparatus children can make a physical appreciation of the situation.

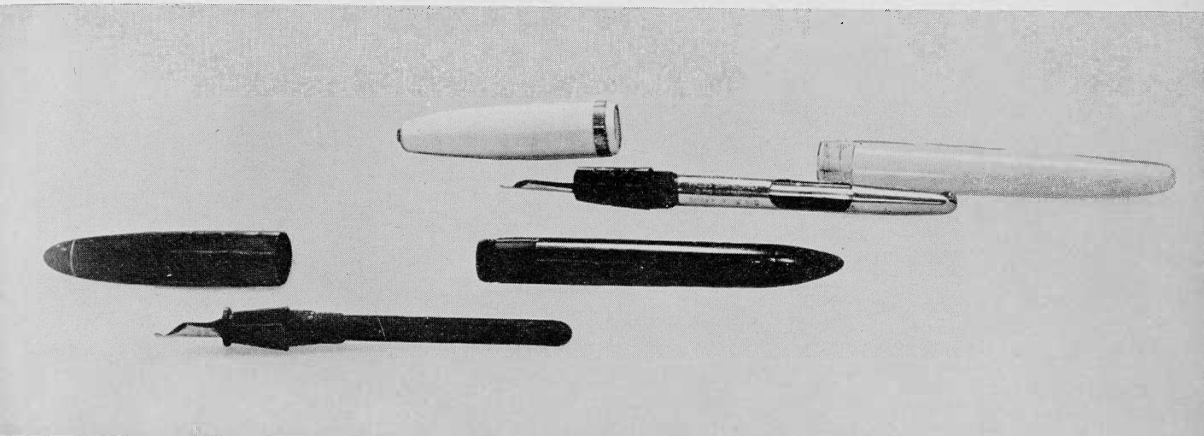


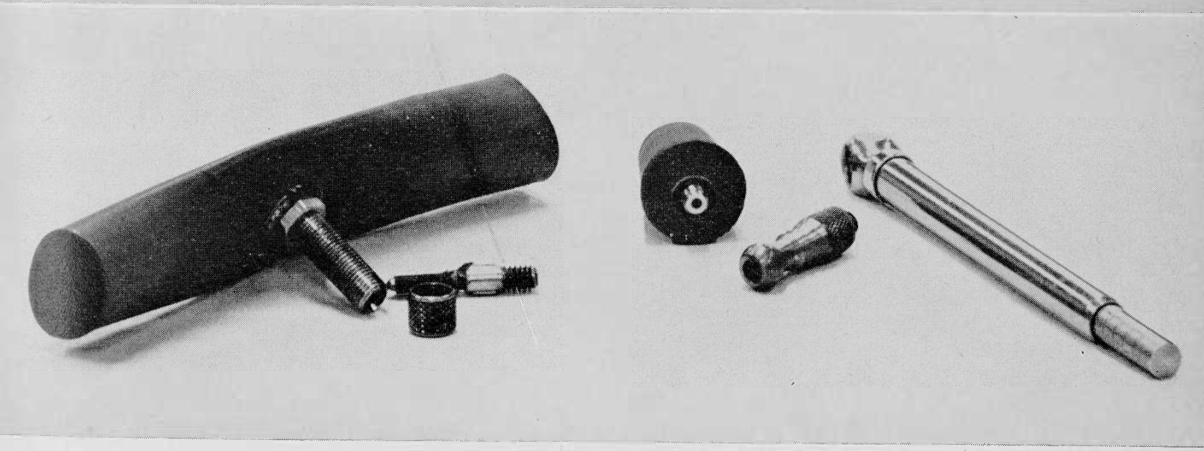
7. Air pressure C

Investigations into particular aspects of the subject can sometimes be touched off merely by leaving on display in the classroom a situation that invites a question. This single-holed stopper inserted into a milk bottle poses the question, 'Do we really draw milk out of a bottle when we drink?' The rubber connection allows a variety of mouthpieces to be used with this apparatus, so that each child can have a clean glass insert to experiment with. This experiment may start much discussion, and give the teacher many opportunities for helping children's thinking in this difficult zone of work.

8. Air pressure D

These illustrations show, respectively, means of using air pressure in the fountain pen and means of controlling air pressure. Among the latter are a bicycle valve, and a football-inflator valve which has been inserted into a rubber bung and so forms a very useful method of pressurizing plastic containers. A pressure gauge is also shown. Children will need to do considerable practical work and have opportunities for thinking aloud in their efforts to discover how these various devices work and the purposes that they serve.



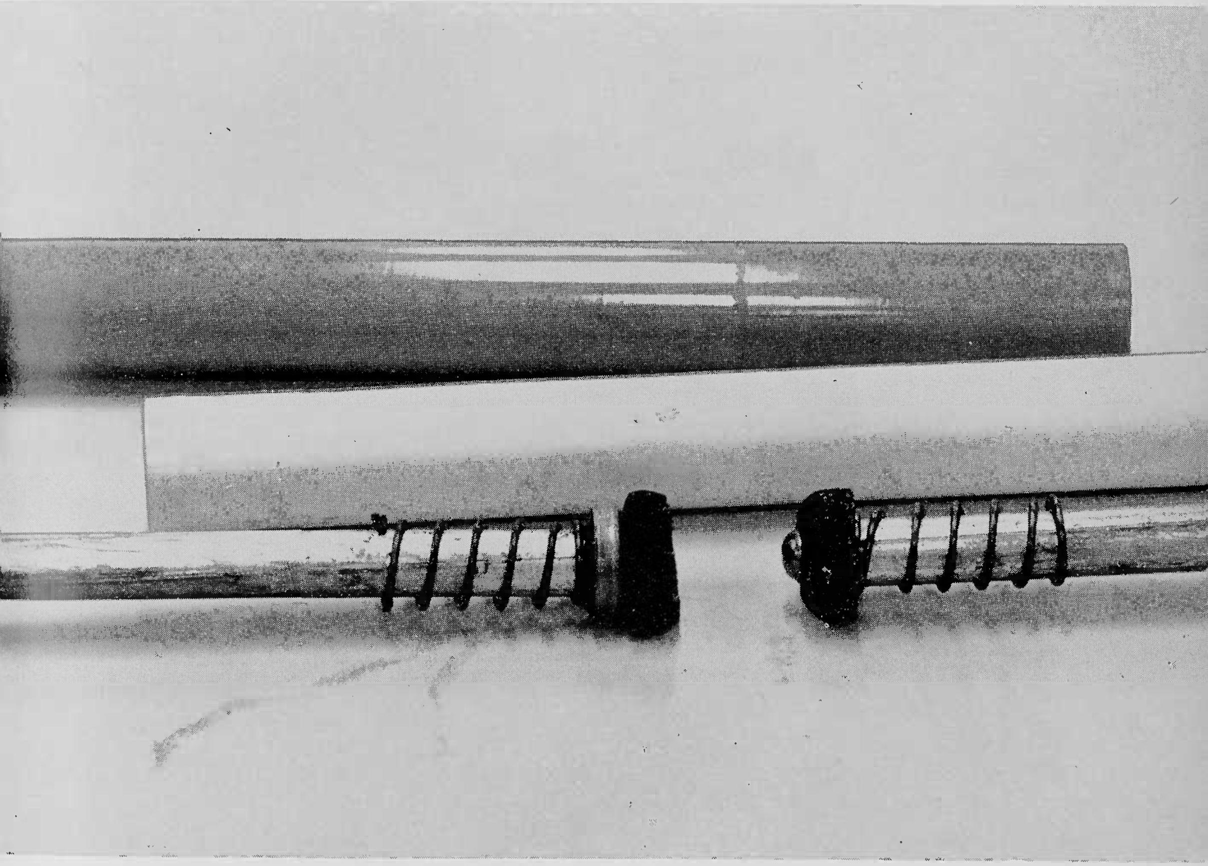


9. Compressed air

The subject of compressibility will open up new lines of thought for the child. It is well to recall that it is a comparatively short time ago that Boyle was preoccupied with it and called it 'the spring of air'. Today compressed air is used in so many ways that this study will have values in many directions. The illustration shows a simple pump for inflating balloons and a bicycle pump which children can probably experiment with first, to feel the spring of air. In the middle a football bladder is used as a simple pneumatic lift, another exploitation of compressed air.

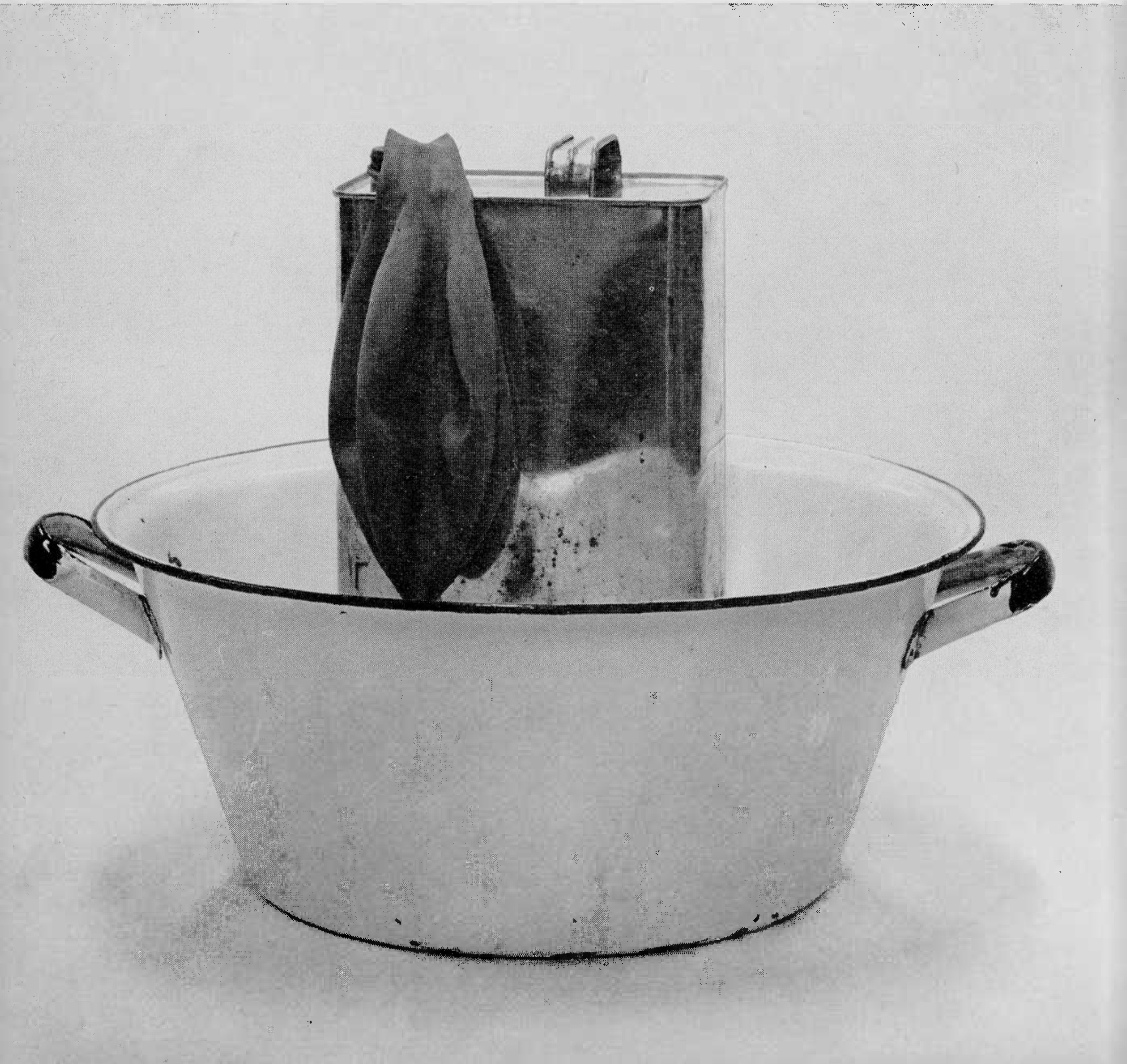
10. Air pumps

In a study of air, the bicycle pump will provide one of the most useful pieces of apparatus. In this illustration the washer in one pump is in the normal direction and in the other it is reversed. In the latter arrangement the pump can be used for withdrawing air from vessels and so reducing pressure. If the washer is a well fitting one and the barrel of the pump is suitably greased, a sufficiently air-tight joint can be made to make it possible to test the extent of pressure reduction. This can be measured by attaching a scale pan to the handle of the pump and loading it with weights. This is the kind of equipment which may be left out on the discovery table.



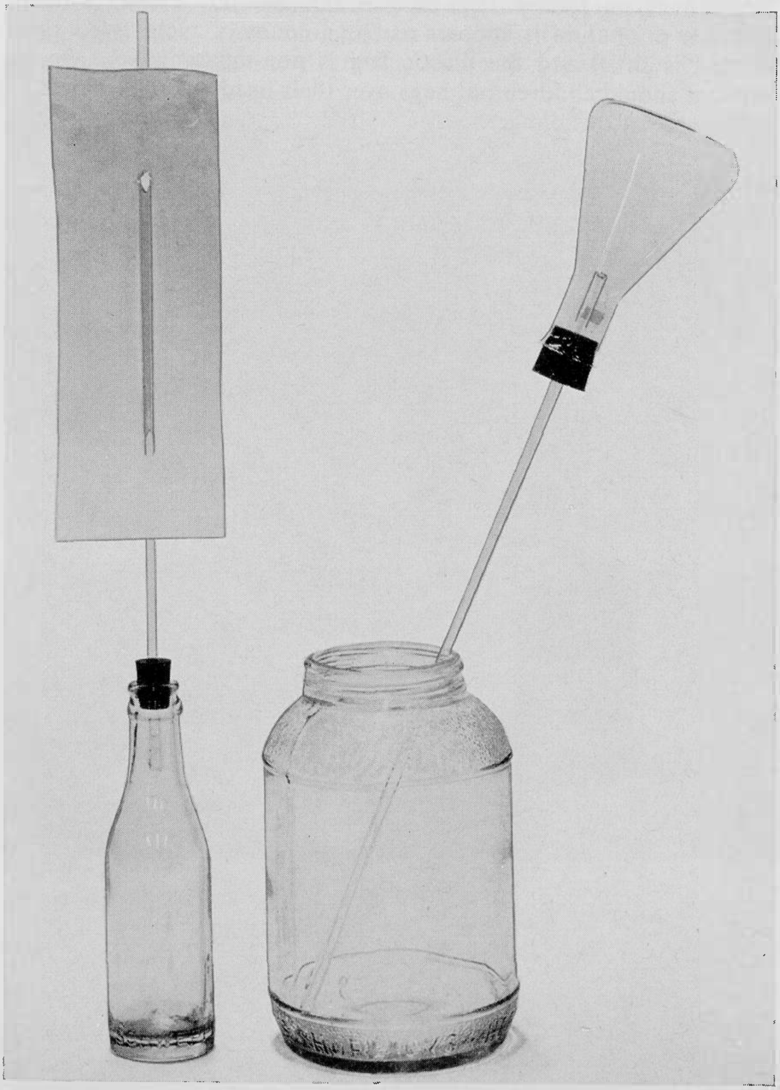
11. Warm air A

Quite young children can begin to appreciate the effect of heat on air if the experiments are large scale ones. The illustration shows a simple apparatus for this work, and is also intended to remind teachers of a safe source of heat to use. Warm water will produce quite enough expansion to inflate the balloon. The reverse effect of cooling can then be experimented with in the same apparatus by pouring away the hot water and refilling the bowl with cold. The work, however, need not stop at the simple fact of the experiment, but can be carried on in a discussion between the teacher and the children to help them see what it really means.



12. Warm air B

If children have experienced how air expands when it is heated and contracts when cooled, with the larger scale apparatus already illustrated, they may be ready to refine their ideas by work on a smaller scale. This illustration shows two pieces of apparatus they can use. They are both versions of the simple thermoscope. The conical flask with its thinner walls will be more responsive to temperature changes than the lemonade bottle with its thicker glass. Both will pose many problems for the teacher and the children to investigate during the course of their practical work.

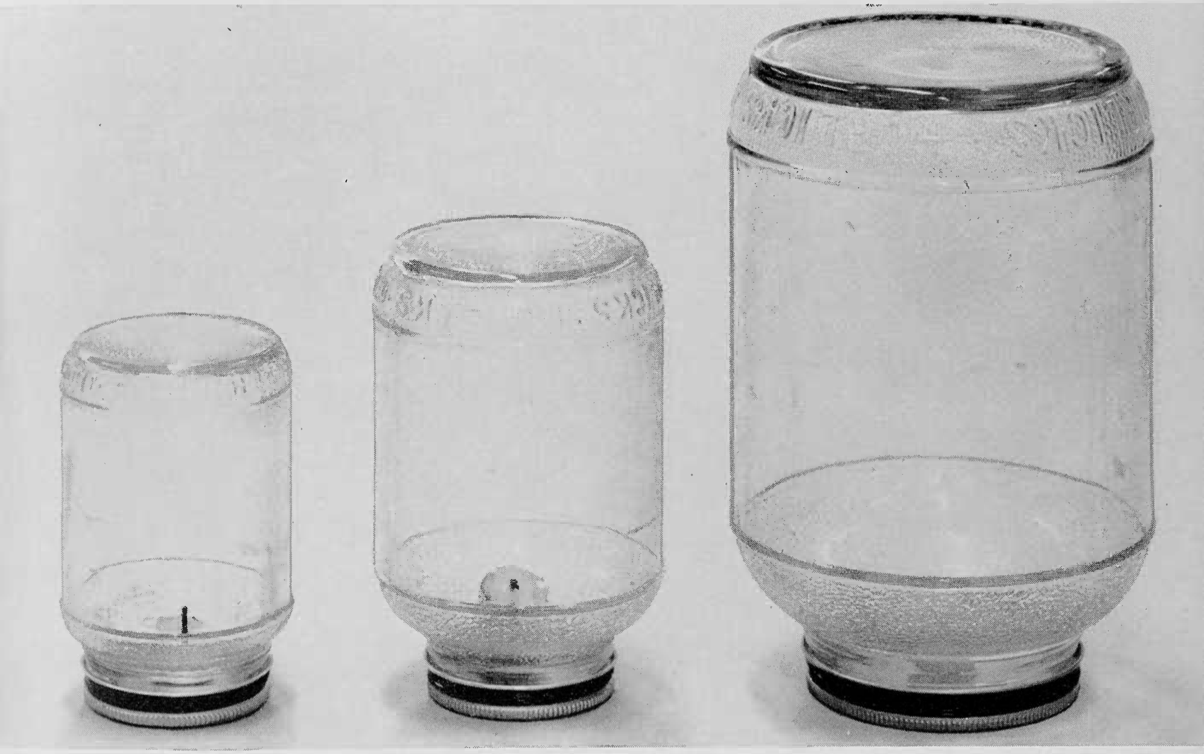


13. Hot air balloon

Perhaps children will have already started thinking about the hot air balloon during their reading or in a history lesson. An effective and exciting one can be made from a large plastic bag, with the mouth held open by a light framework of wire carrying a cross-wire. A small piece of cottonwool soaked in methylated spirit is attached to the cross-wire. The bag is held open about a foot from the ground, and the soaked cottonwool is lit. As the hot air fills the bag it will become more and more buoyant and will gently rise. A control cord can be made from a thin black thread. Some experiment will be needed to gauge the exact amount of cottonwool and methylated spirit to use to produce good results. Too much flame will cause the bag to melt, too little will not produce sufficient lift. This experiment is much safer than it appears as the amount of methylated spirit needed is small and the plastic bag is non-inflammable. On no account should children put bags over their heads. Teachers will be well aware of this danger.

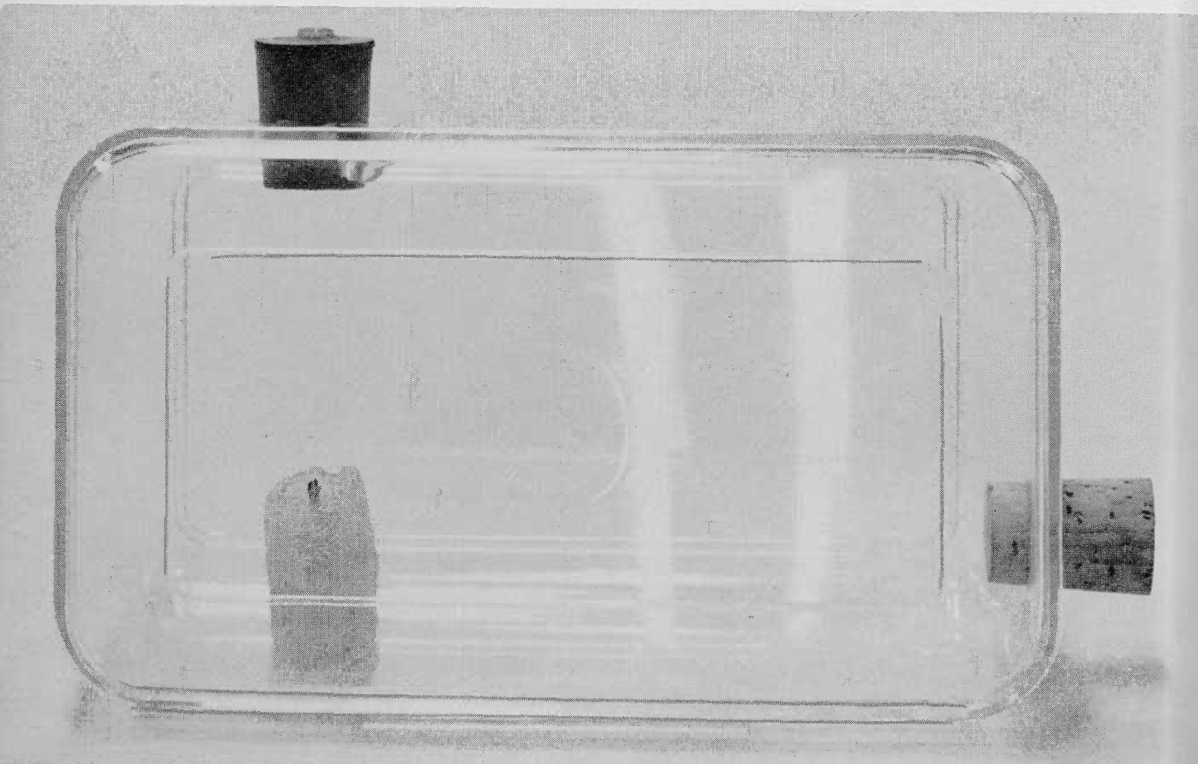
14. Combustion A

The topic of air and burning frequently arises, and this is quite right. However, it is unfortunate if it leads both teacher and child to reproduce the ambiguous experiments of the past by placing lighted candles under bell jars of water, noting the rise in the level of liquid, and relying on this to demonstrate that the air consists of one-fifth combustible material. The hazards in this experiment are so great, and the factors which could cause a variation so many, that it is best left aside. What children can appreciate through experiment is the fact that if the supply of air is limited, combustion will eventually cease. The illustration shows a convenient apparatus for this purpose. The volumes of the three jars can easily be measured by even young children, using a straightforward gauge of their water capacities. Then the children can light the candles and time how long they burn, and relate this to the air capacities.



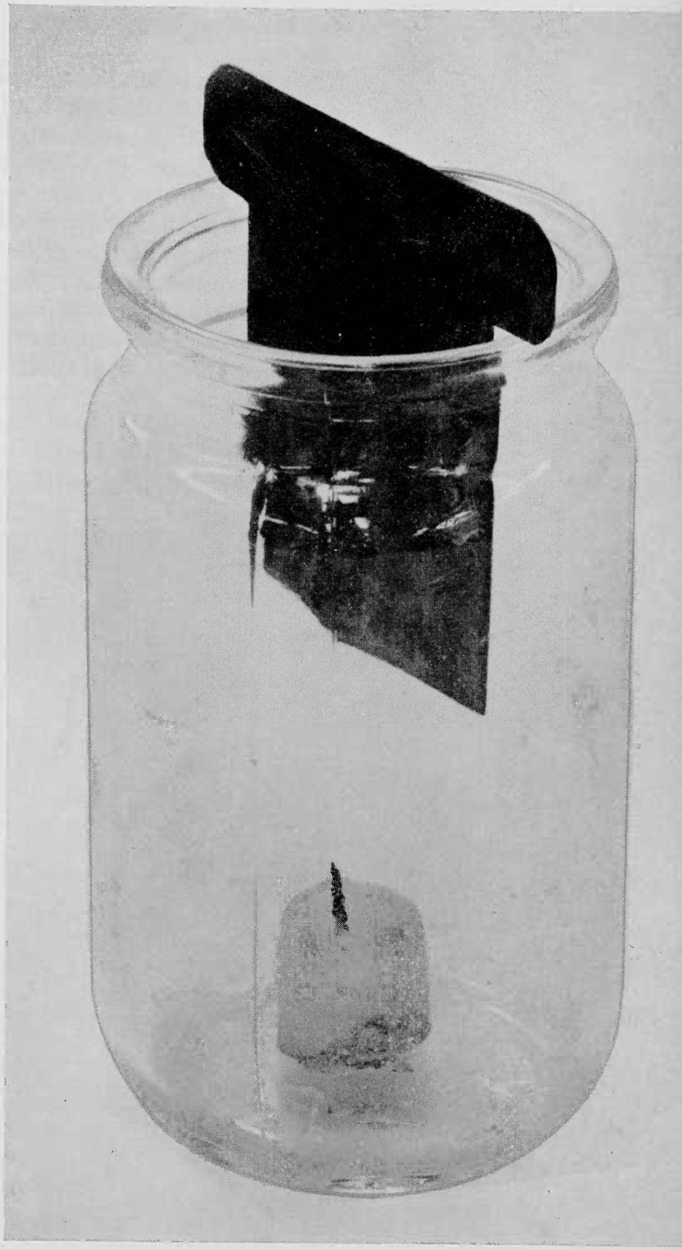
15. Combustion B

Another question which may arise is, 'What happens if there is a continuous supply of air?' The apparatus shown will allow the children to investigate this. A night light can be used quite effectively in place of a candle stump. The box is a clear plastic lunch box or sandwich container. A hole has been made in either side to accommodate the cork and the rubber bung. The rubber bung is single-holed and contains a very short length of glass tubing. Air supply can be regulated by withdrawing the cork from the side. The holes can be made in the container either with a centre bit, or by very carefully burning it with a hot knitting needle. In either case, care is needed to avoid cracking the plastic.



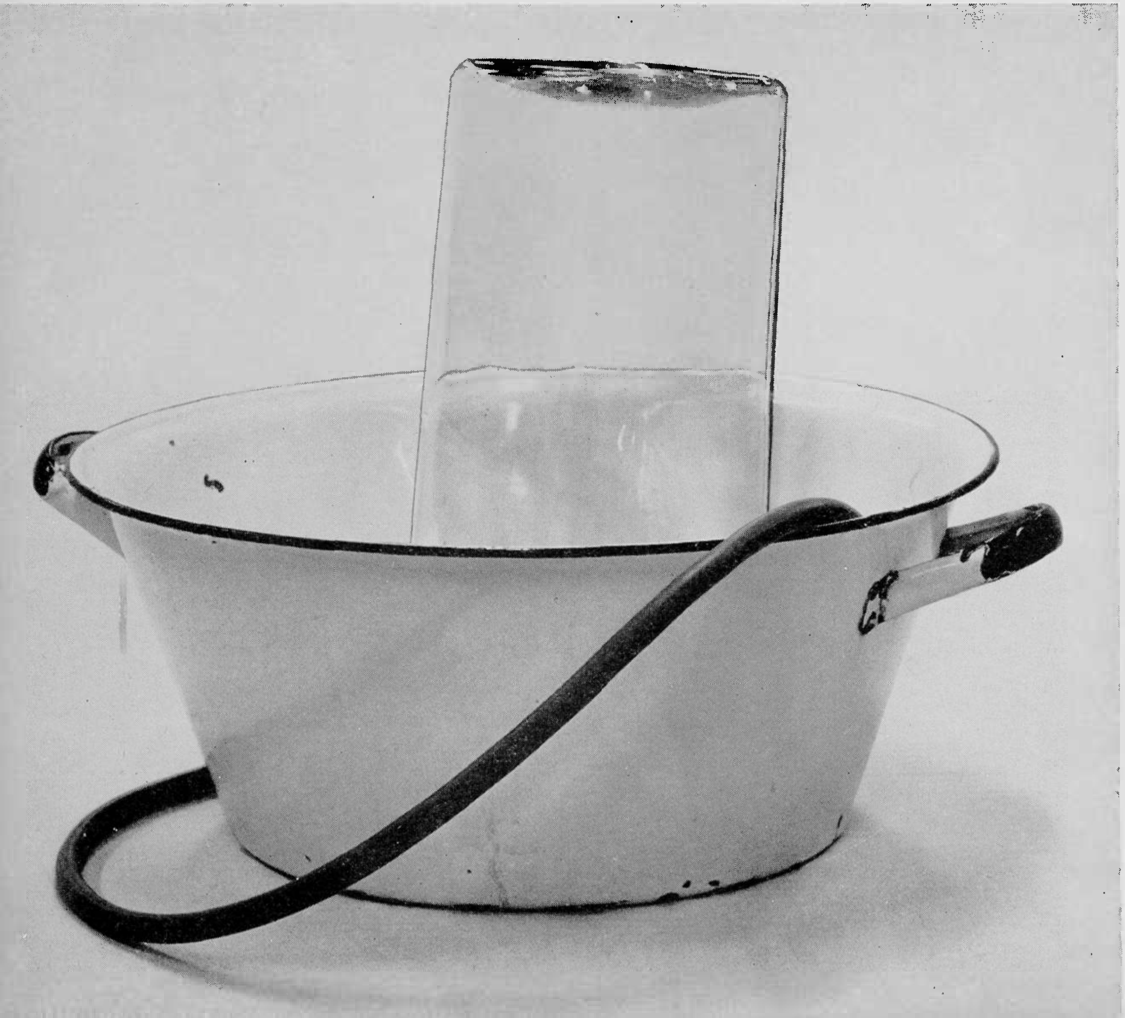
16. Combustion C

This illustration shows a variation on the arrangement for providing a continuous air supply to a burning candle. In this case the metal dividing-tongue is inserted into the jam jar. This divider can easily be cut with tinsmith's snips from an old tin or piece of metal plate. Unless some smoking string or smouldering paper is used to provide a smoke stream to trace the path of the air, this apparatus is not as effective as that shown in the previous illustration. It is, however, simpler to produce.



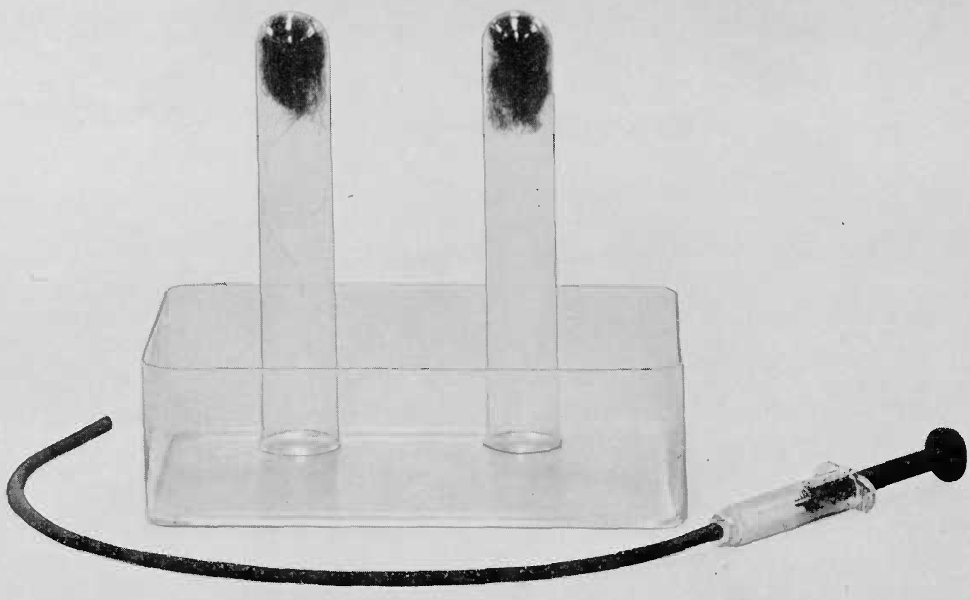
17. Vital lung capacity

The question of vital lung capacity is one which sometimes arises in connection with this topic. A simple apparatus for measuring it is shown here. The large sweet bottle and the bottom of the bowl are filled with water. It is important that the bowl be large enough to accommodate also the water which will be expelled from the bottle as the child exhales into this through the tube. More experienced children will be able to calibrate the bottle and so arrive at a series of comparative results. If several children are to use the same apparatus it is advisable to produce glass mouthpieces, one for each individual to insert into the rubber tubing. Alternatively, the tubing can be dipped into weak disinfectant between each use.



18. Study of airs

The study of the composition of air by purely empirical means is a difficult one at this stage. However, 'airs' can be studied empirically and with great interest. The apparatus illustrated provides some opportunities. It consists of a plastic sandwich box which contains water, and test-tubes which have a known quantity of the finest possible steel wool pushed into them. This wool should be of the sort sold for very fine metal cleaning. The test-tubes are filled with water and inverted over the dish of water. Specimens of the airs to be analysed can be taken from other containers via the small syringe. The samples can then be expelled from the syringe into the test-tubes. Some airs which can be tested in this way are candle air, exhaled breath, air from a jar in which seeds are germinating, air from a jar in which a match has been burnt, and so on. When samples of these have been transferred to the test-tubes, they should be left for at least six hours. Then, the fine-gauge steel wool will have rusted and absorbed the oxygen, so causing the water to rise appropriately. Thus, the different contents of the airs can be compared by the water levels. The aim of this sort of investigation is to bring the children to a realization that there can be different sorts of 'airs'. This may prepare them for the study of gases in more detail later on. It will prepare the way for thinking about the composition of air, and at the same time maintain the empirical spirit of enquiry which is so important at this stage.



Section 6

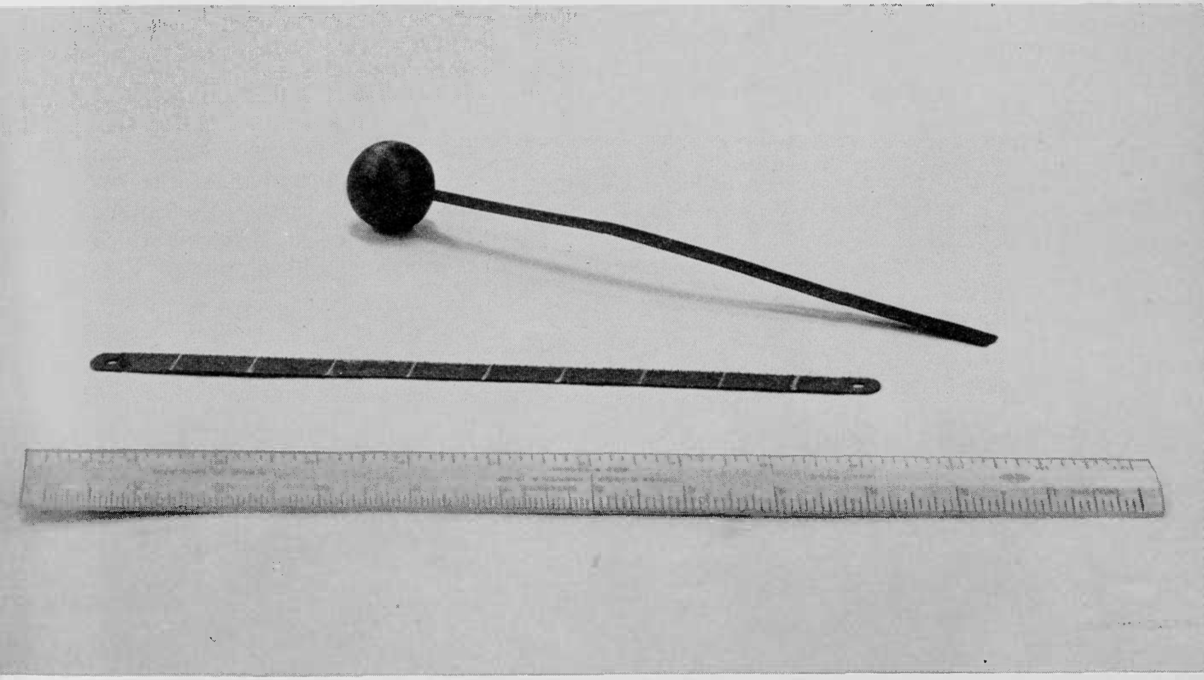
Sound and heat

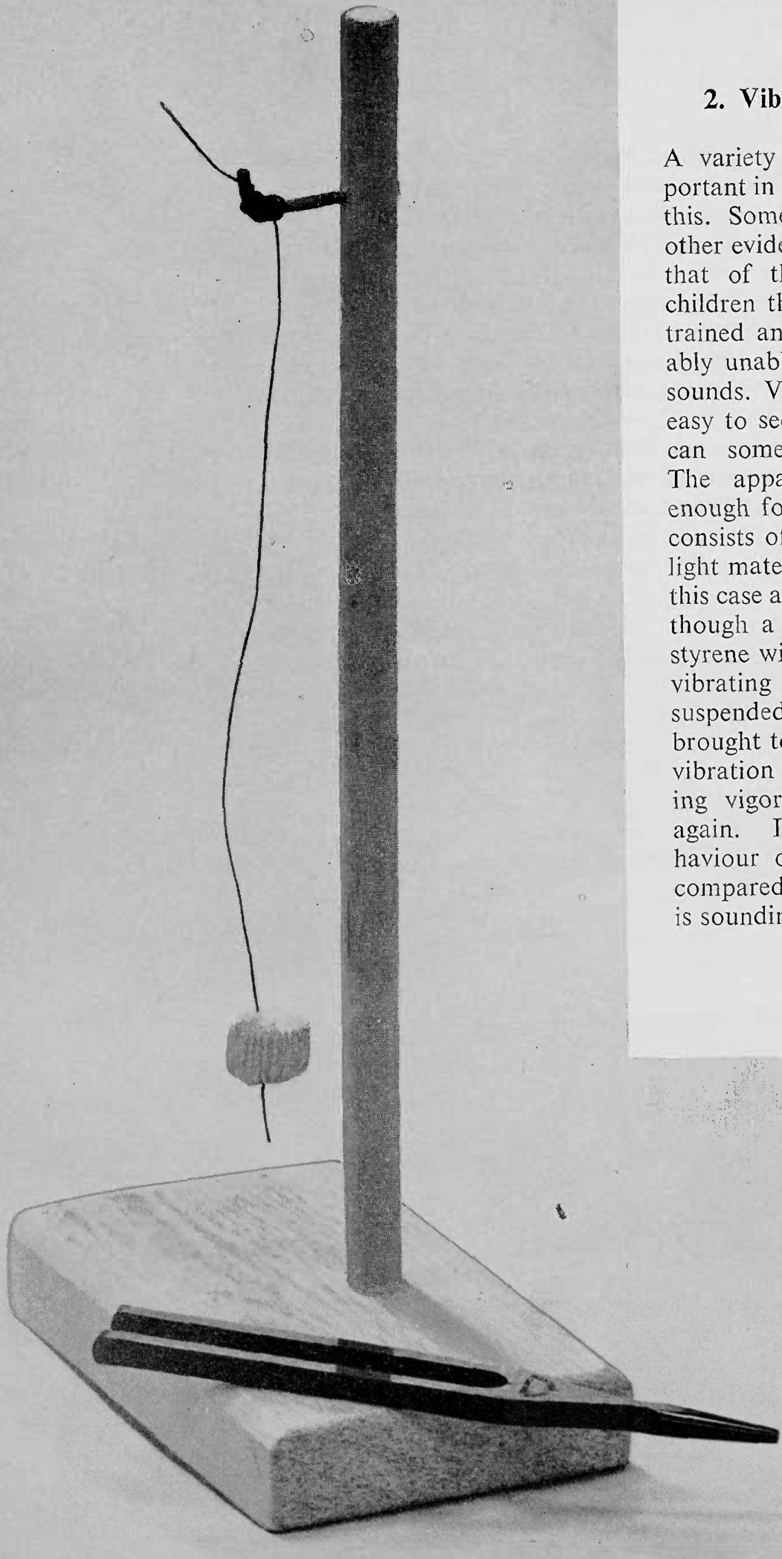
Sound

This is an age of noise and sound. Whatever the children's environment may be, it will be full of its own characteristic sounds. It is quite easy, therefore, to underline their significances and bring them to the children's attention. When this happens, the way opens for a series of investigations. Musical instruments will obviously be useful in these, but most of the essential underlying principles will be best exposed by everyday materials designed for other purposes. The study of living things will obviously provide some starting points. The field is a wide one, whether the approach be sound as a medium for communication, or sound as a by-product of the environment, or sound as a beautiful thing in music and an ugly one in noise.

1. Vibrators A

The essential point to establish at the outset in any study of this subject is the relationship between sound and vibration. The illustration shows some simple sources of vibration which may be used in investigations of sound. The piece of spring steel with the ball on the end makes a good vibrator, if the ball is clamped on firmly. To take the point a step further, the hack-saw blade has been marked off at one-inch intervals. This can be plucked and the effect both be seen and heard. The same can be done with the ruler though with slightly less obvious effect. The important thing in both these experiments is that the vibrator can be calibrated and can prompt the children to relate their results to the lengths used. Younger children may only see the relationships as fortuitous if they see them at all; the teacher should leave it at that.



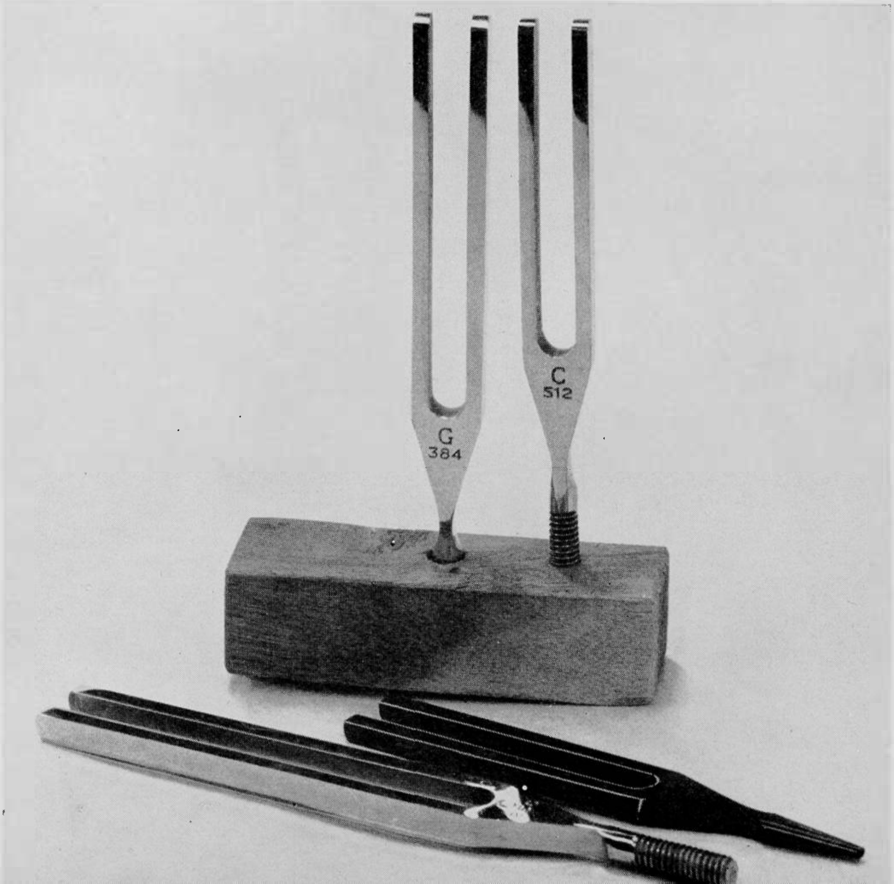


2. Vibrators B

A variety of approaches is important in any subject, not least in this. Some children may demand other evidence of vibration beside that of their ears. In a few children the ears will still be untrained and immature and probably unable to differentiate some sounds. Vibrations are not always easy to see, either, although they can sometimes be well heard. The apparatus here is simple enough for any child to use and consists of a piece of thread with light material at the end of it. In this case a pith-ball has been used, though a piece of cork or polystyrene will do equally well. If a vibrating fork is held near the suspended ball and gradually brought to it until it just touches, vibration will send the ball bouncing vigorously away again and again. In this manner the behaviour of a silent fork can be compared with that of one which is sounding, and so on.

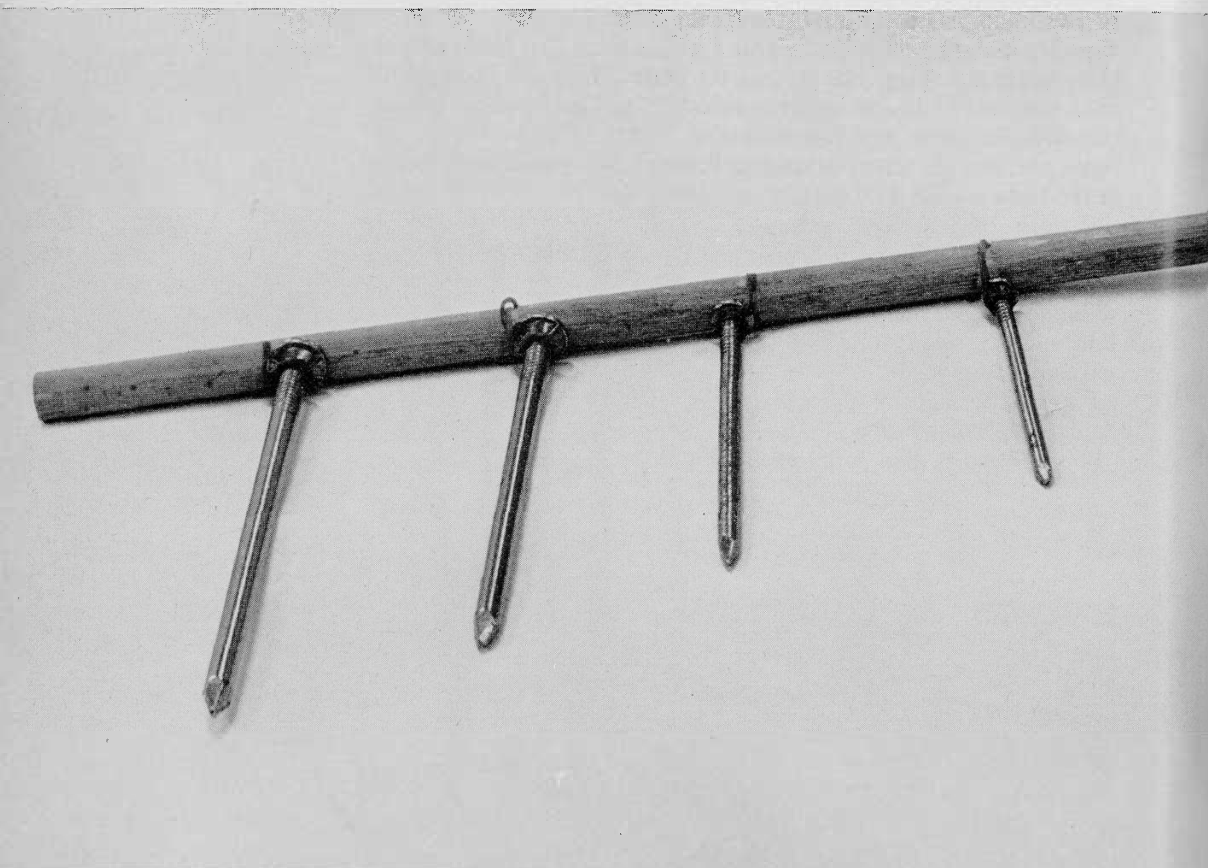
3. Vibrators C

Older children will not only be ready for more exacting work but will be able to tackle it if they are given suitable materials. Now that all schools have access to film strip projectors, a new field opens up for work in sound, particularly in comparing the vibrations of one note from a tuning fork with those from another. Holes of the core sizes of the threaded bases of two tuning forks should be drilled in a block of wood and the tuning forks screwed in. If bristles are fastened with Sellotape to the inner prongs of each fork these will act as markers under suitable circumstances. A piece of glass 35 mm wide and about 6 in. long should be blackened in a candle flame so that it will receive a trace made by the vibrating bristles on the ends of the tuning forks. If both forks are set vibrating and the bristles are wiped quickly, but steadily, across a different part of the blackened glass plate, a trace will be left on the plate. This can be projected onto the screen via a film strip projector, and a visual comparison be made between the two vibrating forks. Children may well begin to compare the relationship between the peaks and troughs in the trace of one with that in the other.



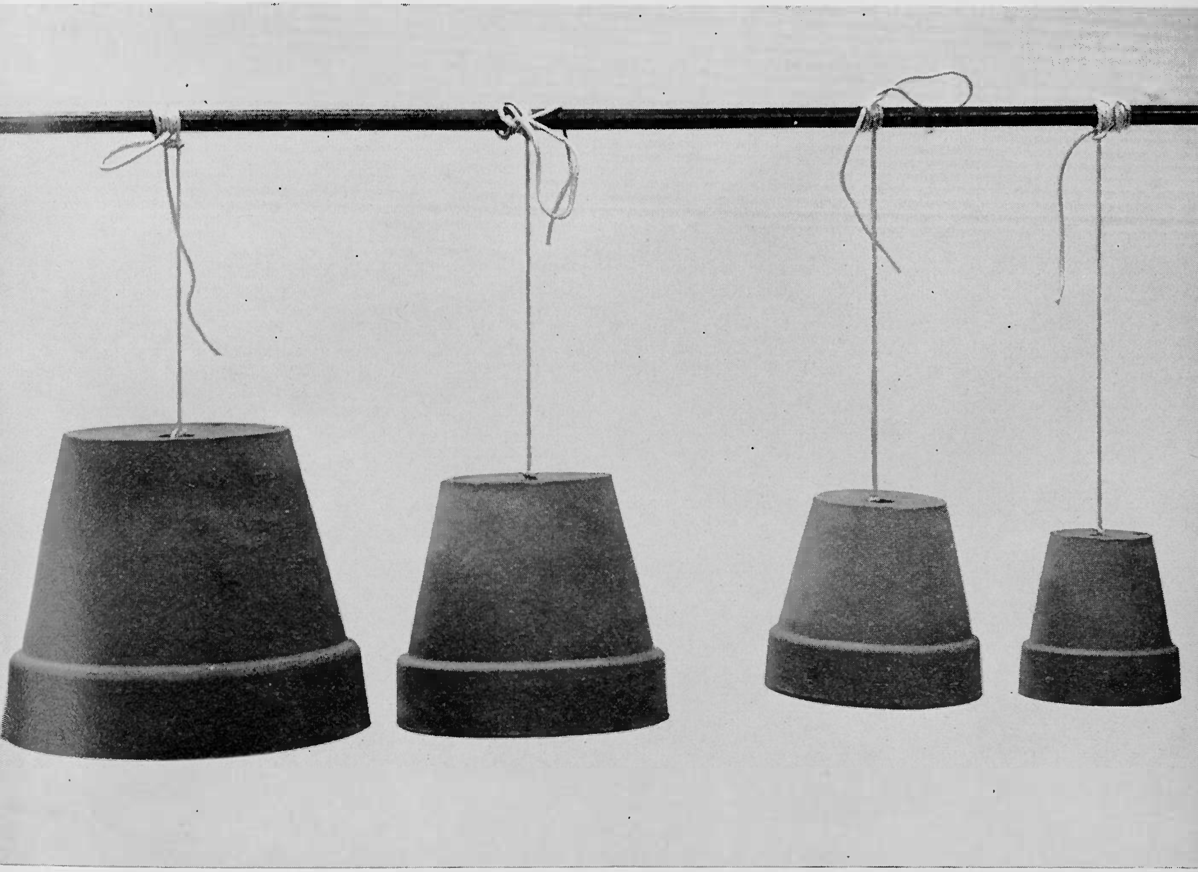
4. Nail chimes

Children who have had a wide variety of experience of vibration may arrive at the conclusion that big bodies vibrate slowly producing low notes, while small bodies vibrate fast producing high notes. However, some children will find it quite difficult to arrange bodies in the sequence in which they would occur in a musical scale. In the illustration, 6 in., 2 in., and 1 in. nails have been suspended from a wooden rod by elastic bands, at intervals designed to produce a regular chime. Another 6 in. nail can be used as a striker.



5. Flower pot chimes

This illustration shows a device similar to the one already shown. The flower pots are suspended from a broomstick by strong strings which end in wooden toggles underneath the holes in the pots. This suspension will allow them to ring when struck. Before the pots are chosen and bought at the ironmonger's they must be tested for their rings. A suitable range will again produce a chime. A drumstick covered in felt will make a suitable striker.

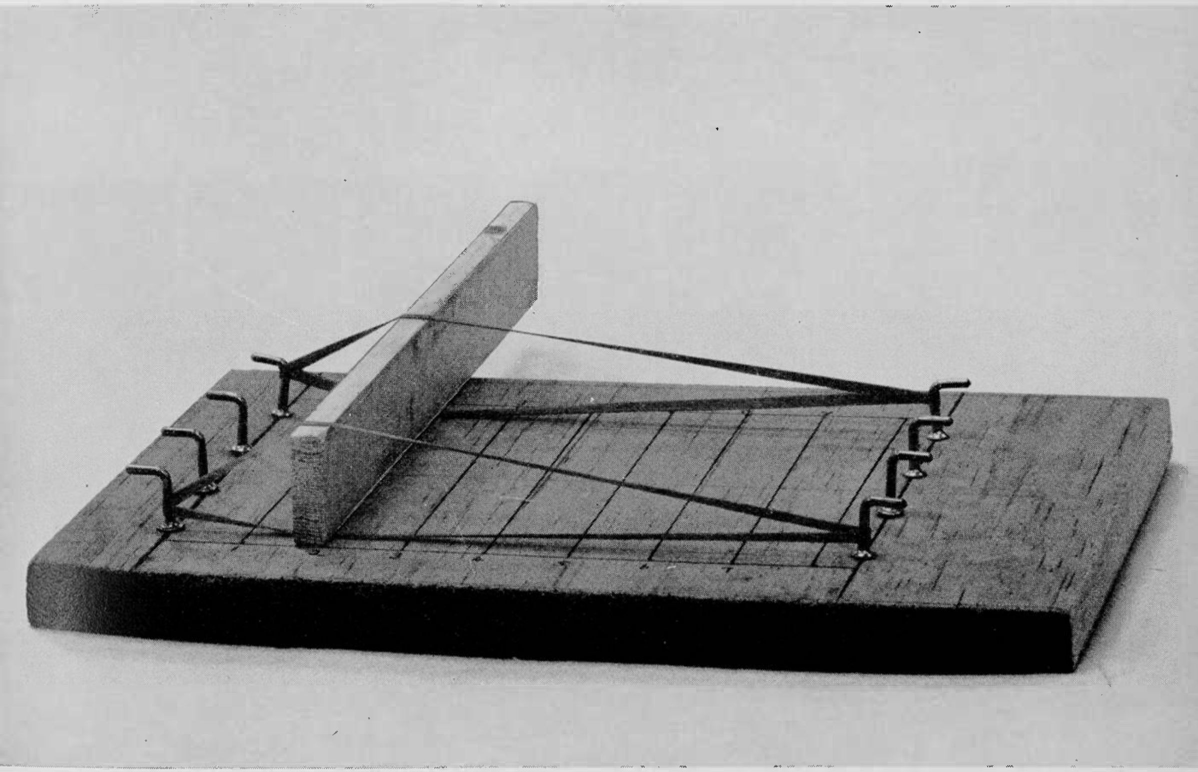


6. Bells

This illustration shows a corollary to the previous two. It is intended to challenge children to think about the relationship between big bodies vibrating slowly and small bodies vibrating quickly, and the kind of sounds that they produce. Any school which is lucky enough to have a set of hand bells obviously has apparatus which can be extremely useful in this kind of work.

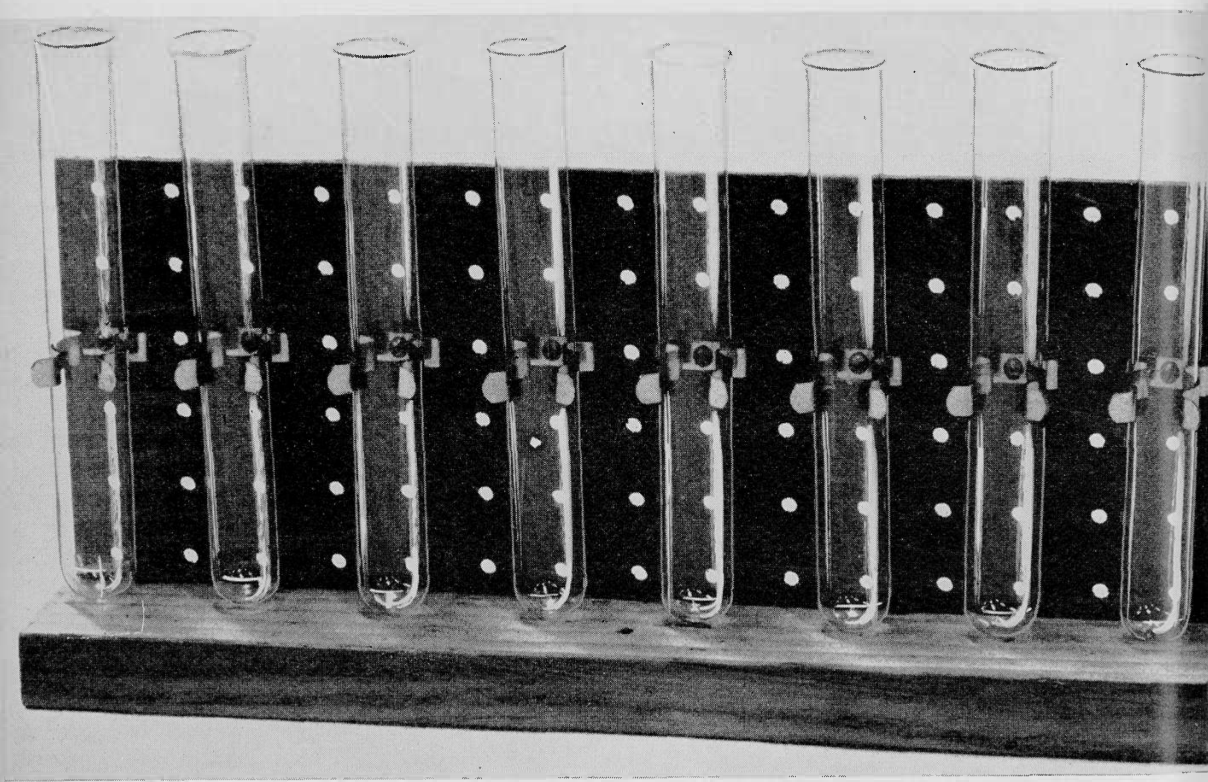
7. Stretched strings

Work with stretched strings is not easy unless certain basic equipment is available. A simple device such as the stretched elastic band will provide an introduction to the subject, but some elaboration soon becomes necessary if work is to be accurate. The apparatus shown will be helpful. Its construction can be seen from the photograph and the method of making the strings, in this case elastic bands, both shorter and more tense is clearly shown. Comparisons can be made, not only between bands of different thicknesses, but also between different tensions. The main function of crude apparatus such as this is to begin raising questions in the child's mind, and to put in his way a practical means of beginning to solve them which will lead on to the use of more refined apparatus.



8. Vibrating air A

Children do not always find it easy to appreciate that adding water to a tube shortens the length of the air available to vibrate in it and so alters the pitch of the sound produced if it is struck or blown across. (It also alters the timbre of the sound.) Thus, it may be necessary for the teacher to establish exactly what is the function of water in such a piece of apparatus as the one illustrated. The eight test-tubes provide a means for the child to produce a tuned scale when air is blown across the rims. The construction of the apparatus can be seen from the illustration. It is merely a piece of pegboard screwed to a piece of battening. The test-tubes are held in place by Terry clips fastened to the pegboard with nuts and bolts.

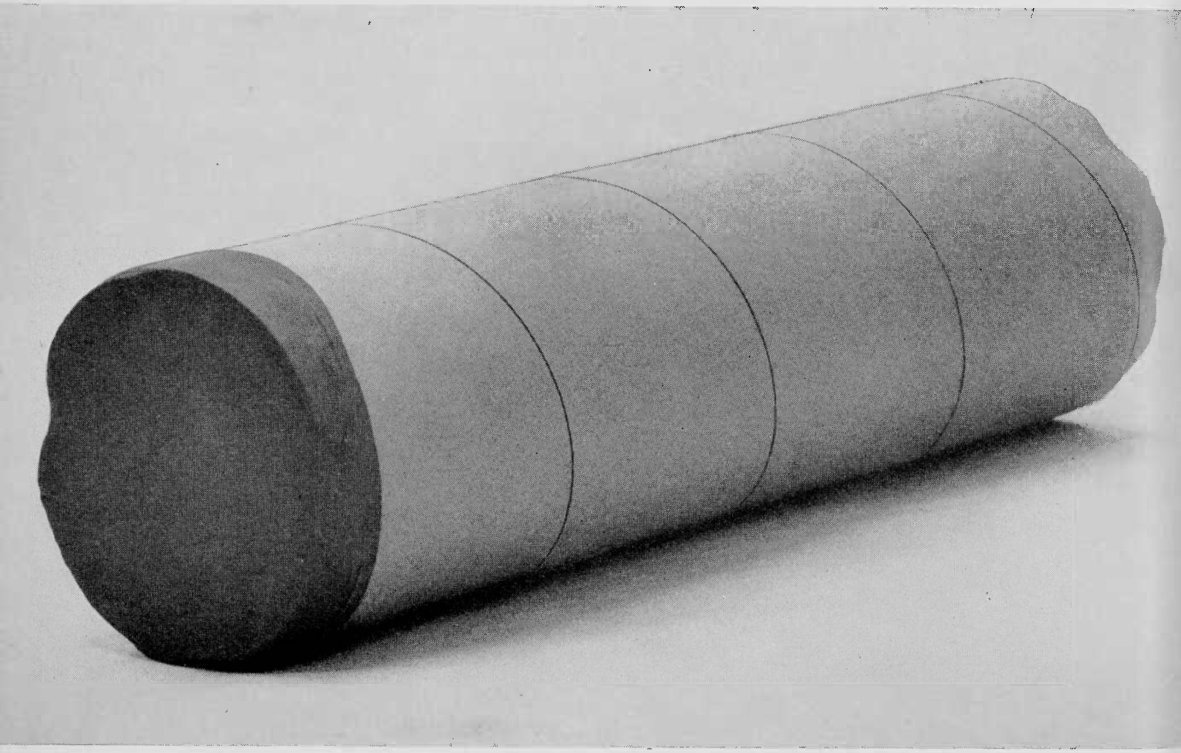


9. Vibrating air B

The method of lengthening and shortening the tube in a wind instrument may be clear to an older person, but it is not always so to children. Many children who are quite proficient recorder players are ignorant of the working principles of their instrument. This is not surprising as the ideas are fairly sophisticated and refined. Very possibly, the child may first come to understand by experimenting with glass tubes of different lengths. After this, he will probably be able to go on and make a simple pipe for himself.

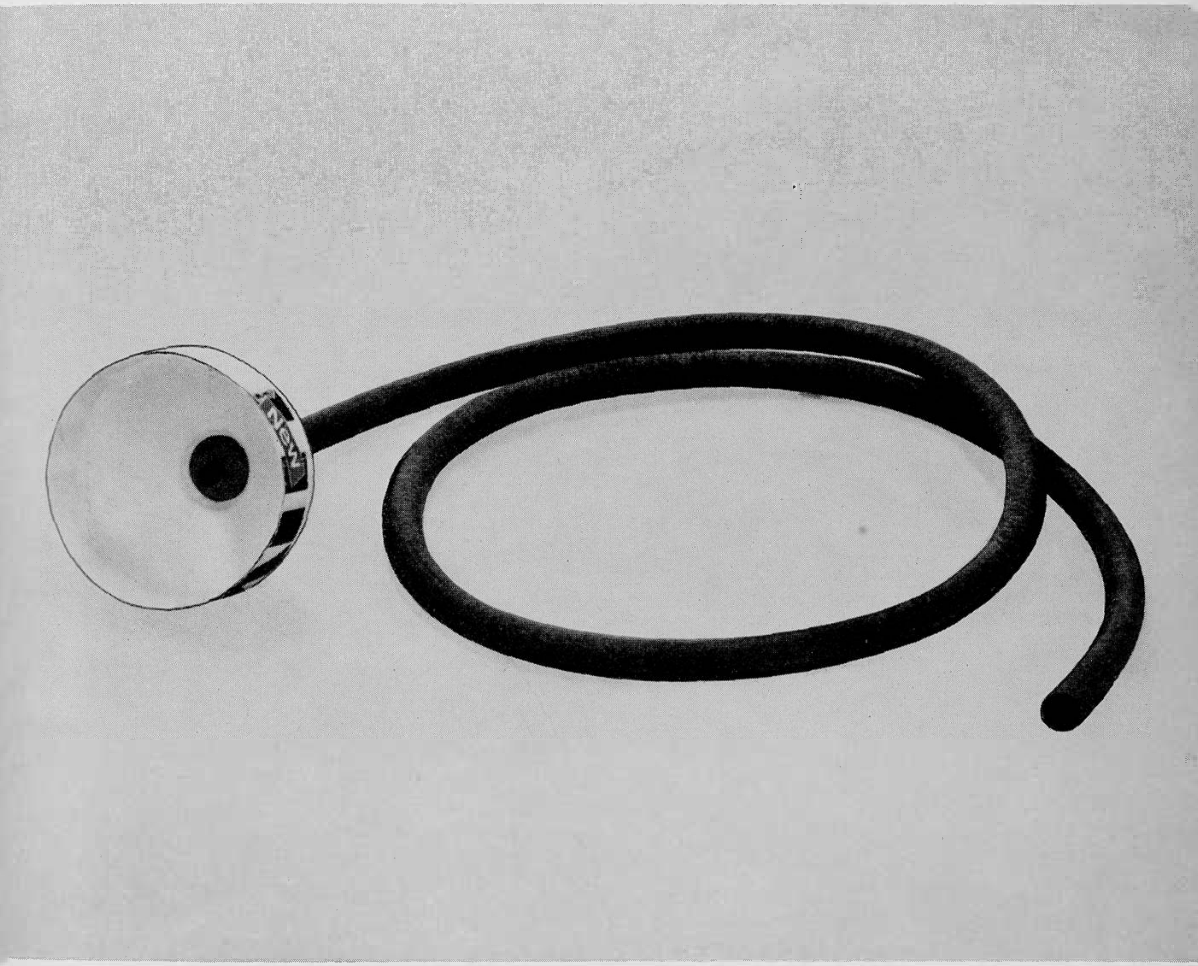
10. Vibrating air C

This illustration shows a simple piece of apparatus for illustrating the fact that most sounds which reach our ears come by the medium of vibrating air. The cardboard tube is the inside of a large roll. The rubber diaphragm is cut from a balloon and fastened tightly across the end of the tube. If the open end of the tube is pointed in the direction of a fairly loud sound, the diaphragm can be felt to vibrate. With softer sounds, it will be necessary to fasten a small piece of thin mirror or highly polished silver paper to the diaphragm. Then, if the child shines a strong light on this, he may detect its movements in the beam. Quite a number of refinements are possible to this basic piece of apparatus. It does provide a starting point for a considerable amount of work, not only connected with the movement of sound, but bearing also on a study of hearing and the ear.



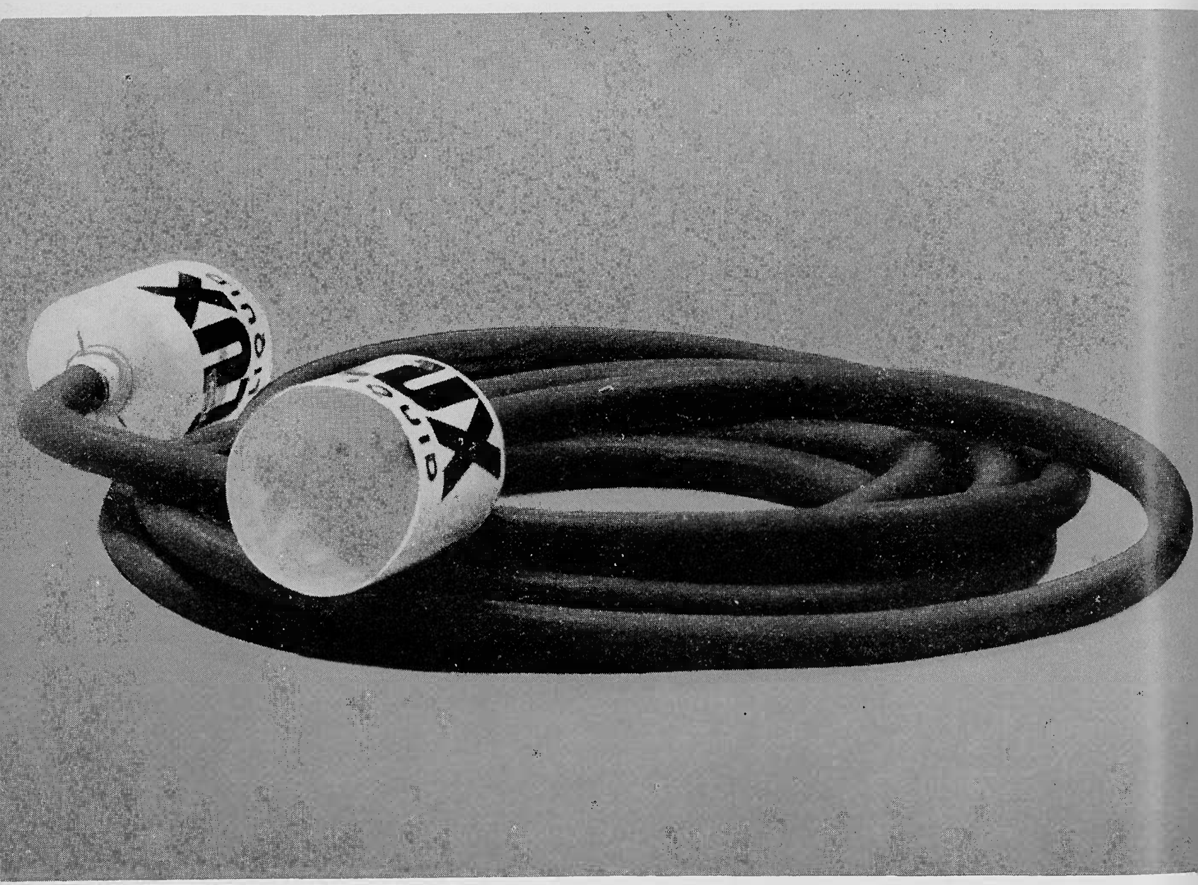
11. Stethoscope

Children seek with profit to improvise, both by applying the principles that they discover and adapting standard pieces of equipment, to their own uses. The illustration shows a child's attempt to make a stethoscope. It was surprisingly efficient considering the simplicity of its construction, which is obvious from the illustration.



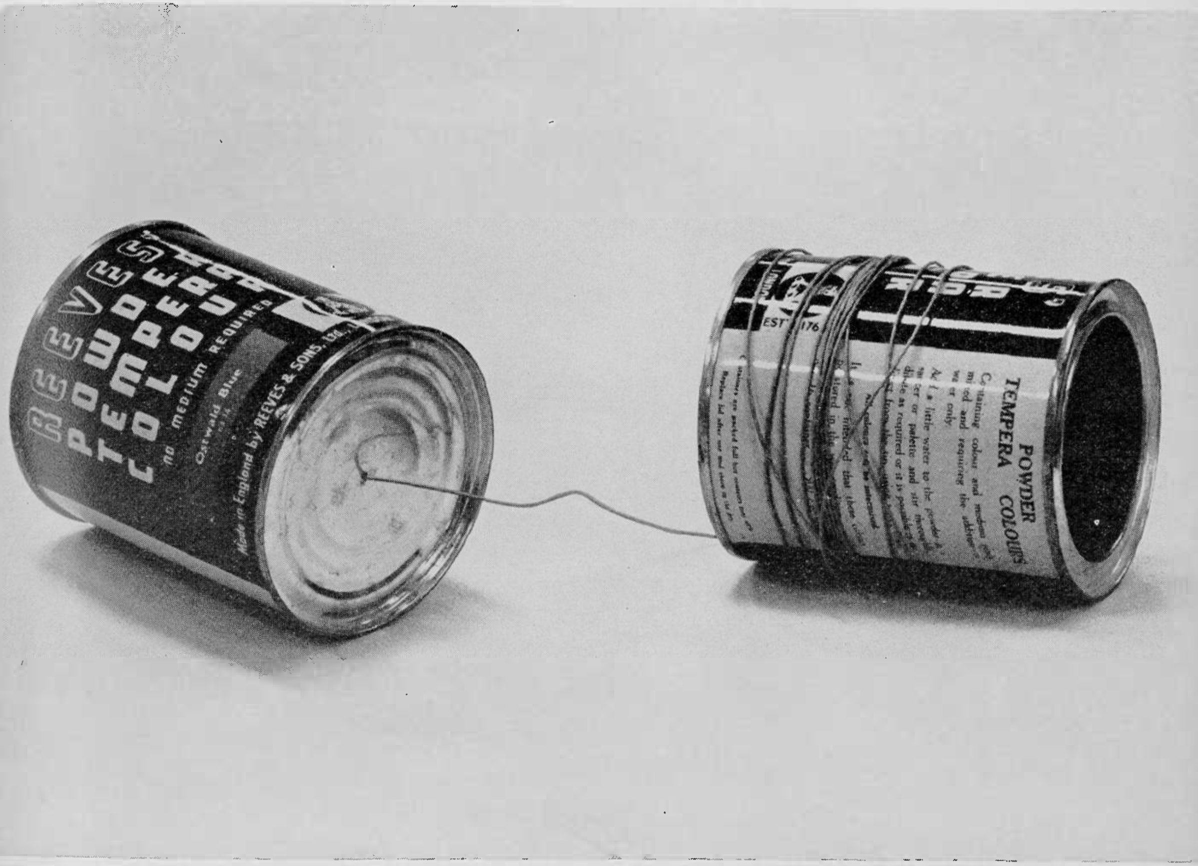
12. Speaking-tube

Another group of children had been tackling the problem of transmitting sound between rooms which had apparently a soundproof barrier. They did in fact invent for themselves the speaking-tube, the early Victorian device which preceded the telephone and still has its uses today. The apparatus can clearly be seen from the illustration.



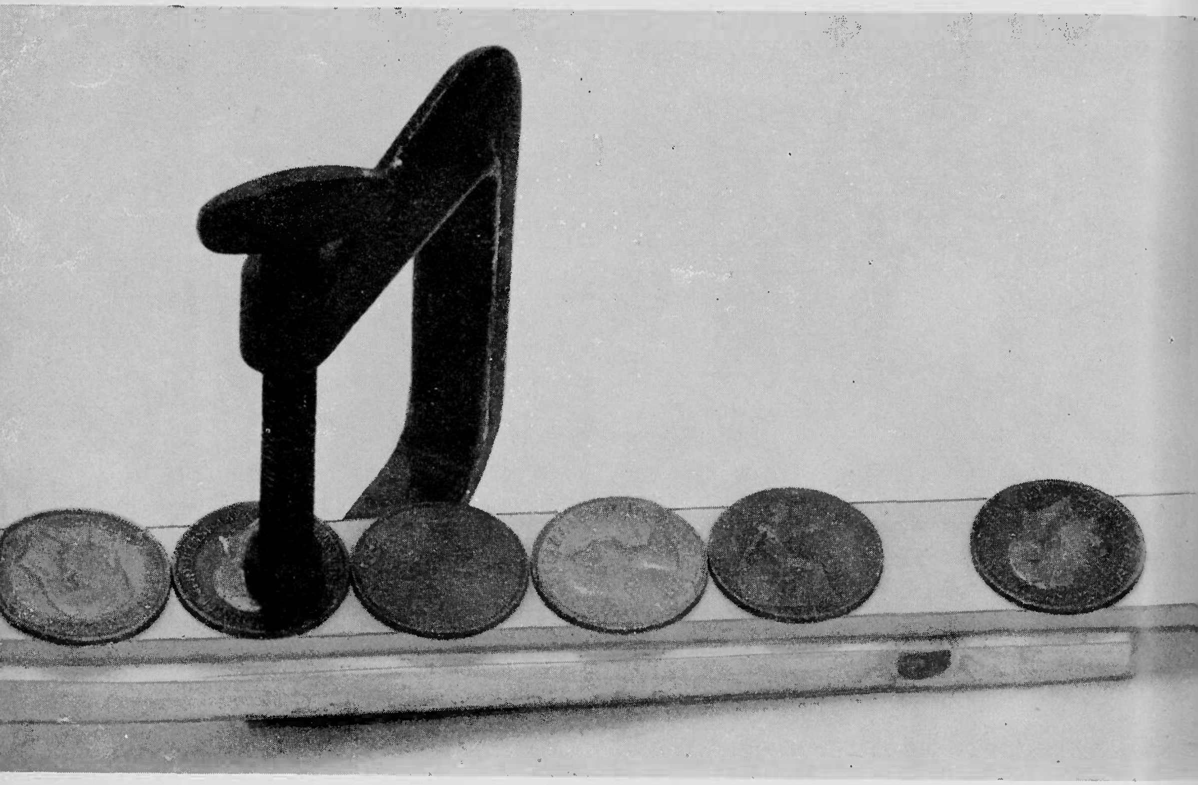
13. String telephone

The string telephone is well known in most schools. Sometimes, however, it is used as an isolated practical example of the phenomenon of the transmission of sound. It is included here among illustrations of others to remind teachers that it needs to be seen in perspective and be part of related practical work.



14. Particles in motion

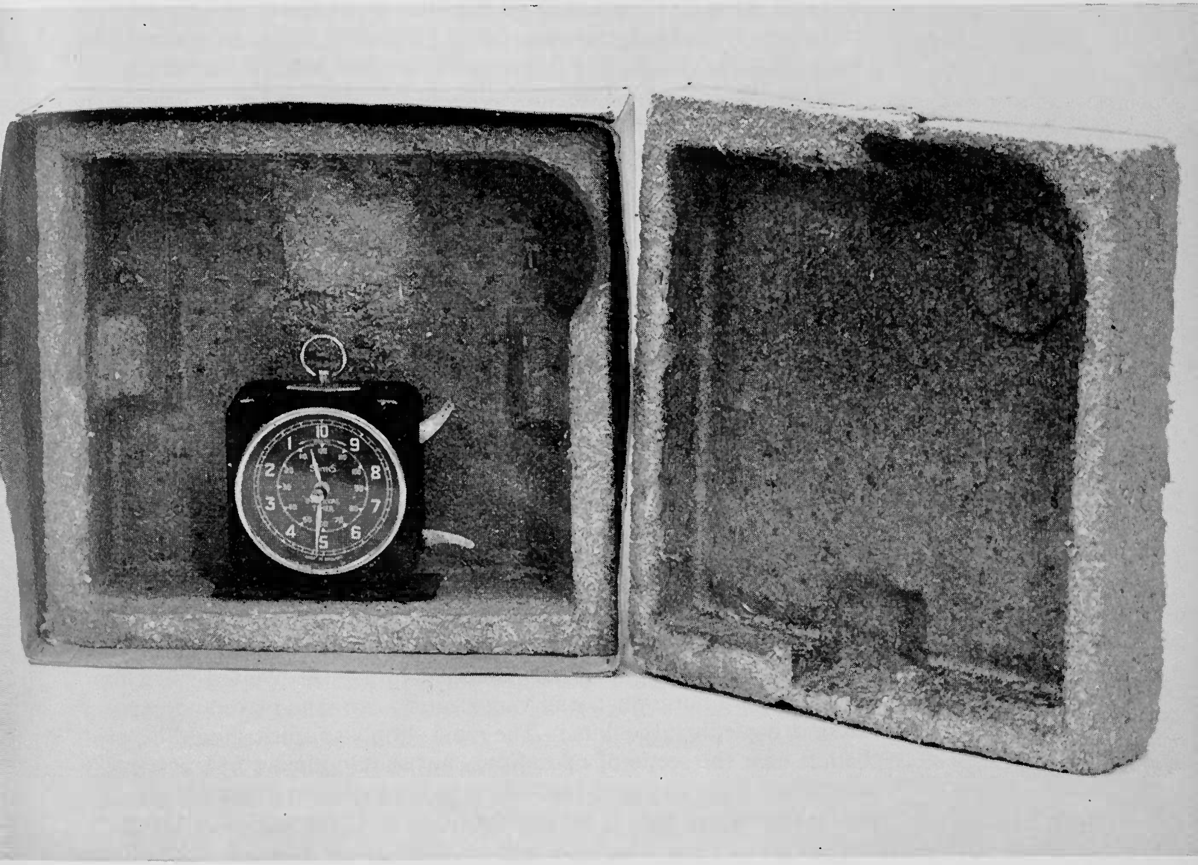
Some children may well begin to raise questions about the transmission of sound through solid bodies. The simple device shown here can follow up some of this questioning by setting new problems to think about. The clamp holds one coin immovable against the board. The free coin on the left is pushed vigorously to strike the fixed coin. A wave of motion results which passes through the particles of the fixed coin and onto the others until it comes to the free coin at the end which is pushed forward. Variations on this situation can be invented by the children using large glass marbles in the groove of a metal curtain rail, or billiard balls along a piece of grooved hardwood.



15. Sound insulation

Sound insulation and noise reduction form a very rewarding theme for children to investigate. A starting point is illustrated here. The moulded wood-shaving package unit makes an excellent sound insulator. Various experiments were, in fact, done with this particular one to provide a numerical basis upon which work was planned.

This simple equipment was part of a child's attempt to measure the efficiency of various forms of insulator and study the modern applications of the principles.



Heat

One of the topics that teachers discuss most vigorously when they are talking about science in the junior field is sources of heat.

Let us say at once that you can never use heat without any danger at all. Teachers who feel very strongly that the risk is extreme will obviously use only the warmth from water, the sun, and the classroom radiators, and not attempt anything that cannot be done with these. Other teachers preparing to use any form of heat should use some kind of protection on the desk or table, not only to prevent immediate damage, but also in order to begin at the very outset to build up the right attitude to the equipment and procedures necessary. Pieces of asbestos sheet are the best to use, though large tin lids will serve to some extent as substitutes. If warm or very warm things are to be held, children should be trained to use some kind of tongs or metal-holder for the containers. This kind of training will prevent accidents not only immediately but also later on. A golden rule is not to give children things to do in school which you do not feel they could repeat with perfect safety by themselves at home. Furthermore, those girls who have long hair should be encouraged to tie it back when doing practical work. Boys should remove jackets which could fall loosely over their apparatus. Plenty of working space is essential when direct heat is being used. Some comments follow on some of the simple sources of heat which schools have employed.

Night lights form one of the safest kinds of heat which can be used. The flame is gentle and the base of the night light is broad so that it does not overturn. It can be easily extinguished. On the other hand, it has the disadvantage of giving a sooty flame and only a small amount of heat.

The candle has most of the advantages of the night light, but the serious drawback of being unstable unless it is held firmly in some form of candle holder. (This can easily be made from the top of a detergent container.)

The methylated spirit burner is probably the most useful source of heat. However, two points need to be noted: the flame is invisible unless a small amount of salt is added to the methylated spirit to make it more luminous; and vaporization can take place and cause an unexpectedly large flame. The main supply of spirit should never be left near the scene of operations, but should always be put away after the burner has been refilled. It is advisable never completely to fill a burner, so that if an accident occurs there will be a limited amount of spirit to burn. Home-made methylated spirit lamps serve excellently. They should however be of a design that will prevent vaporization of spirit and the large flames it causes. Usually, the design will do this by having a seal of solder filling the space between the metal wick guide and the container itself. Some schools have used methylated spirit picnic stoves as a source of heat. These give a much bigger flame and a stronger heat source. If a design which has a broad base is chosen, these can usually be operated with safety and success, but because the source of heat is stronger, precautions will be needed in case of accident. The school's fire blanket should be to hand, most particularly if several picnic stoves of the larger type are in use.

Some schools have used butane gas stoves of various kinds for their work in the classroom. It will be for the teacher to decide what it is wise to use. However, some hazards of butane gas stoves should be pointed out. This is a heavy gas, and if there is an escape it will fall to the bottom of a cupboard or remain as a layer of gas towards the floor of a room, so that a source of danger has been created that no one knows about. This might happen if a stove is not turned off satisfactorily, or if a leak develops without the teacher knowing. The cartridge type of refill which is used for some stoves may well have dangers in the school, even though it is excellent for adult use. If the cartridges are pierced, there is a strong risk. If a cartridge should accidentally be heated, a serious explosion could occur. This form of heat should never be used by younger children unless the teacher is actively supervising them.

Paraffin pressure stoves are inappropriate for use with younger children. Petrol pressure stoves should never be used in schools.

In deciding whether a piece of apparatus is suitable for use with younger children, the teacher might well ask: 'Is this essentially safe? Is this absolutely simple? Can this be used merely by observing basic procedures, and not after special instructions? Am I happy that if a mishap occurs, the situation will be brought easily under control?' The more explosive and volatile fuels are undoubtedly more efficient sources of heat, but it is doubtful whether they are worth while, because of the risks. Freedom should lie at the heart of junior science, but it cannot if the work is hemmed about by precautions. Dangerous procedures have no place in education at this level. There is so much other work to do that teachers may never feel obliged to enter any limiting situation.

Some schools will have Bunsen burners fitted in the room in which children are working. Naturally, teachers will need to give explicit instructions on their use. The teacher should know, not only where the individual gas taps are, but also where the main tap is situated, in case there is an accident. Indeed, if this kind of gas supply is used, it is advisable to have an isolating tap fitted into the individual classrooms concerned. In this way, the teacher can have immediate control over the whole situation should a mishap occur.

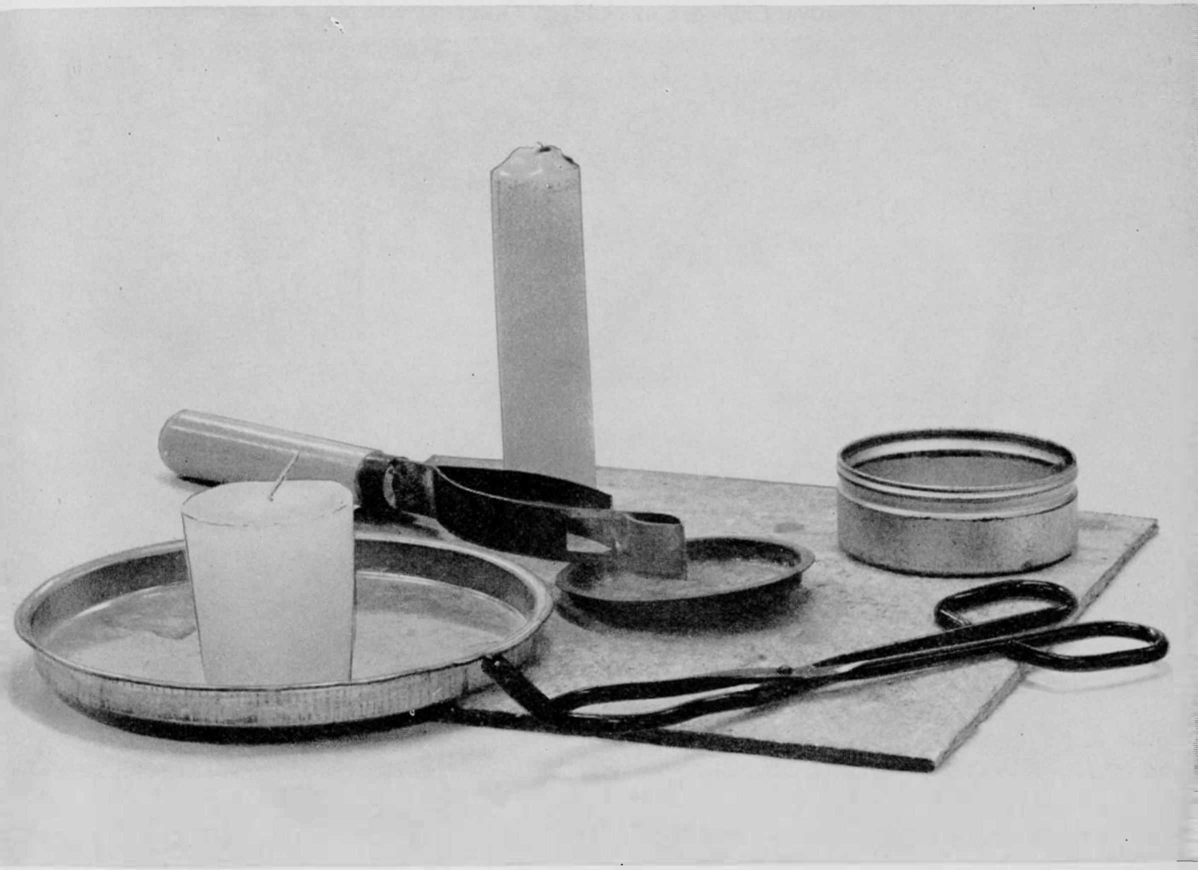
Whenever and wherever sources of heat are in use, the teacher must ensure that there is adequate space for the child to work, and that the other children respect this need for space and so avoid the possibility of accidents due to overcrowding.

On the whole, electricity is not a satisfactory source of heat for use in the classroom, though teachers may well use an electric kettle to produce hot water, which in turn can be cooled to a suitable temperature for classroom use. Electric hotplates, unless they can be controlled to low temperatures, present difficulties which teachers may well wish to avoid in the classroom. Also electrical equipment which is not designed for operation under damp conditions may be exposed to spills of liquid, and thus become defective, causing shocks or short circuits.

In all schools standard firefighting equipment is provided. This should include a fire blanket and a bucket of sand, located where members of staff can reach them easily. It is important that teachers should be aware not only where such equipment is but also how to use it. If simple precautions are taken it is most unlikely that accidents will occur, with the sort of work that it is appropriate for children in the age range five to thirteen to do. Danger is much more likely when the work is inappropriate. Thus, if the teacher makes a wise choice of materials and wisely encourages the relevant interests, he is helping to lessen the risk of accident and injury.

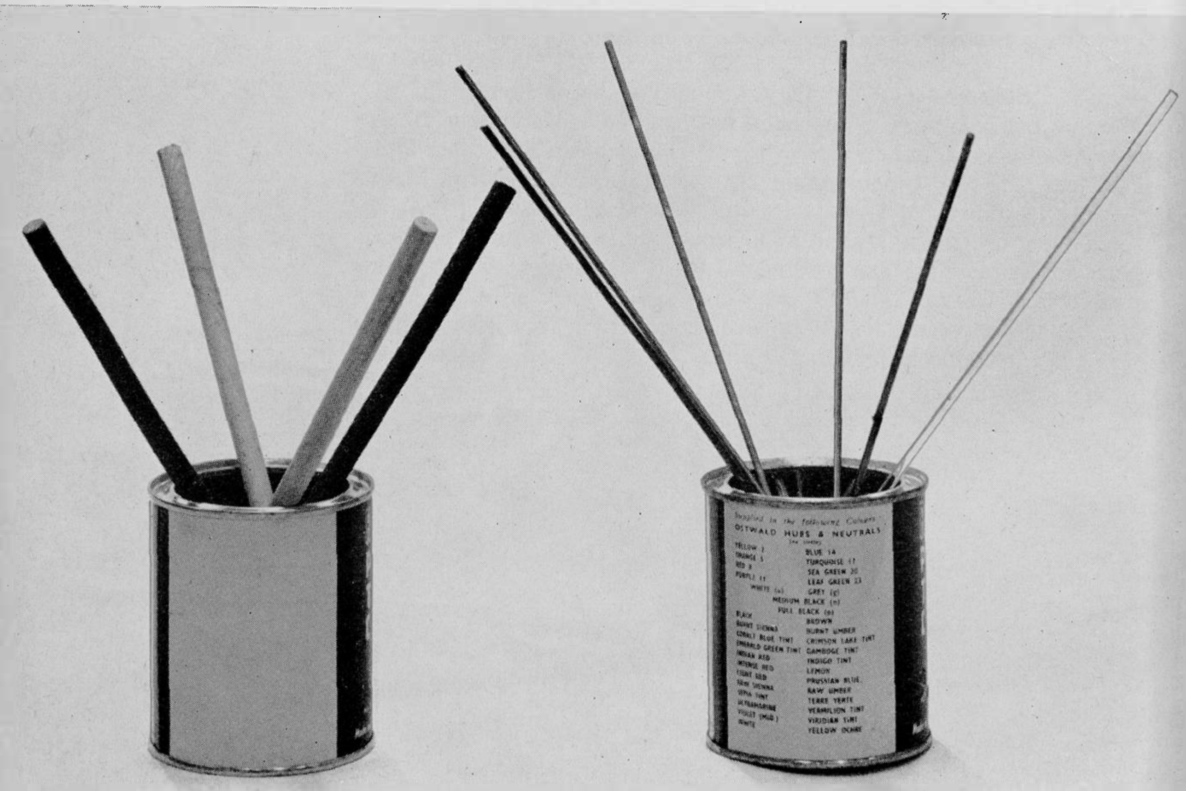
16. Simple sources of heat

This illustration shows a group of simple sources of heat, and associated equipment. Important features to notice are the asbestos sheet, the large tin lid to contain the night light, the tongs and holder for dealing with objects which are being heated. The tin and tin lids not only make containers in which to heat things, but can also be used as snuffers in a case of emergency.



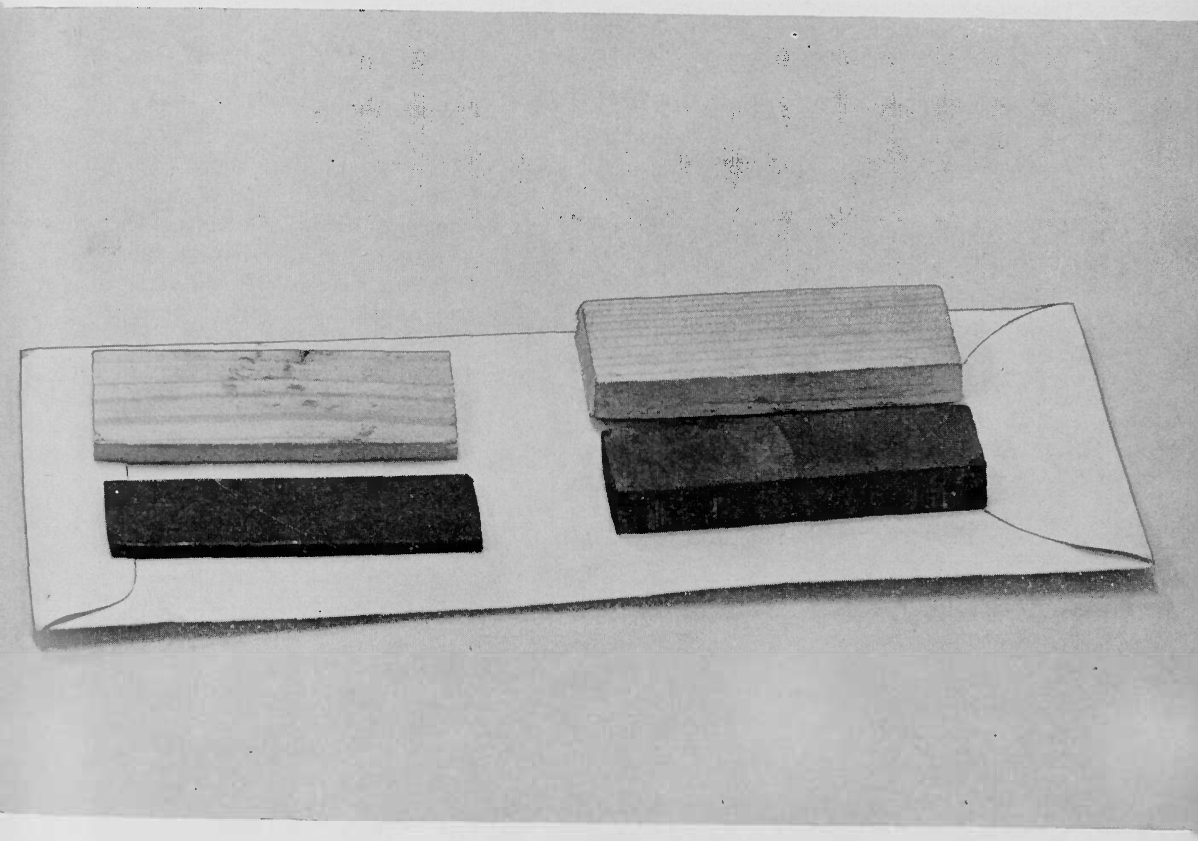
17. Conduction A

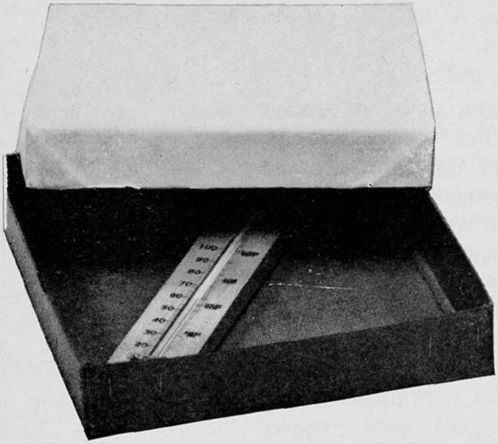
An apparatus for investigating conduction in metal is illustrated here. The tin on the left of the photograph contains pieces of $\frac{1}{4}$ in. wooden dowelling and $\frac{1}{4}$ in. steel rod, all 9 in. long. When the tin is filled with hot water, children can compare the effect of the heat transference in the two materials by feeling them. The manner in which children record these results will depend upon their ages. Older children may well time how long heat takes to reach the exposed ends of the rods, whilst younger ones will just say when they first feel it and leave it at that. The tin on the right of the photograph contains a series of 8 in. rods of various substances—glass, copper, iron, zinc, and lead. These offer possibilities for more advanced work as children's interests and abilities expand.

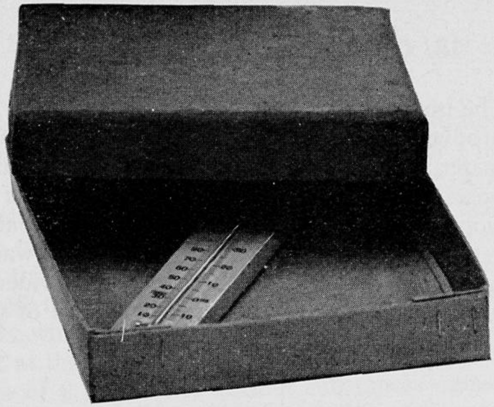


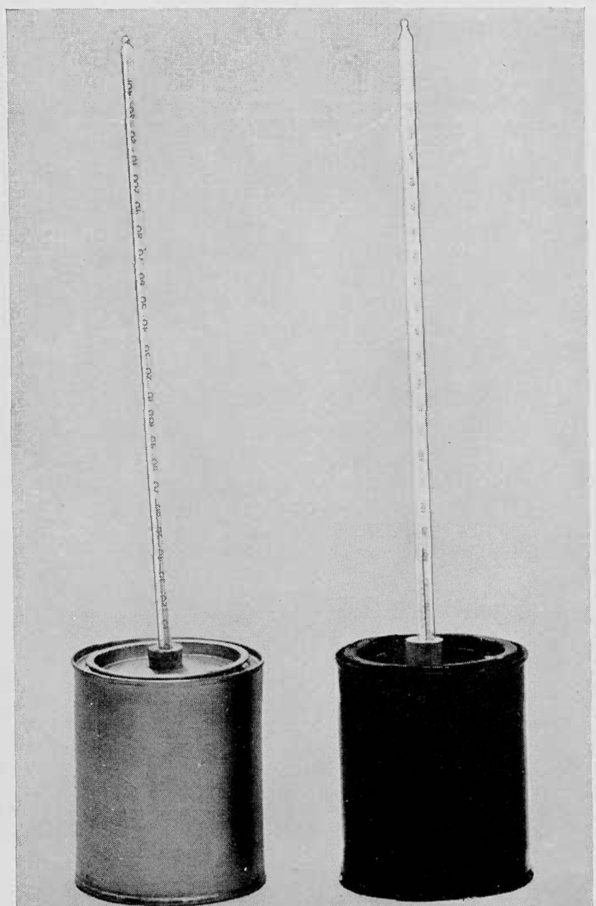
18. Conduction B

The impression of heat or cold we get from materials is not always produced by the materials giving out heat, but more often by materials absorbing it from our hands. The simple device shown here poses this problem. Both the wood and the metal, in this case soft wood and copper, hardwood and zinc, are all at room temperature, yet the wooden samples will feel distinctly warmer than the metal. A range of such materials should be provided to enlarge children's understanding of the questions this sort of work raises.









19. Radiant heat

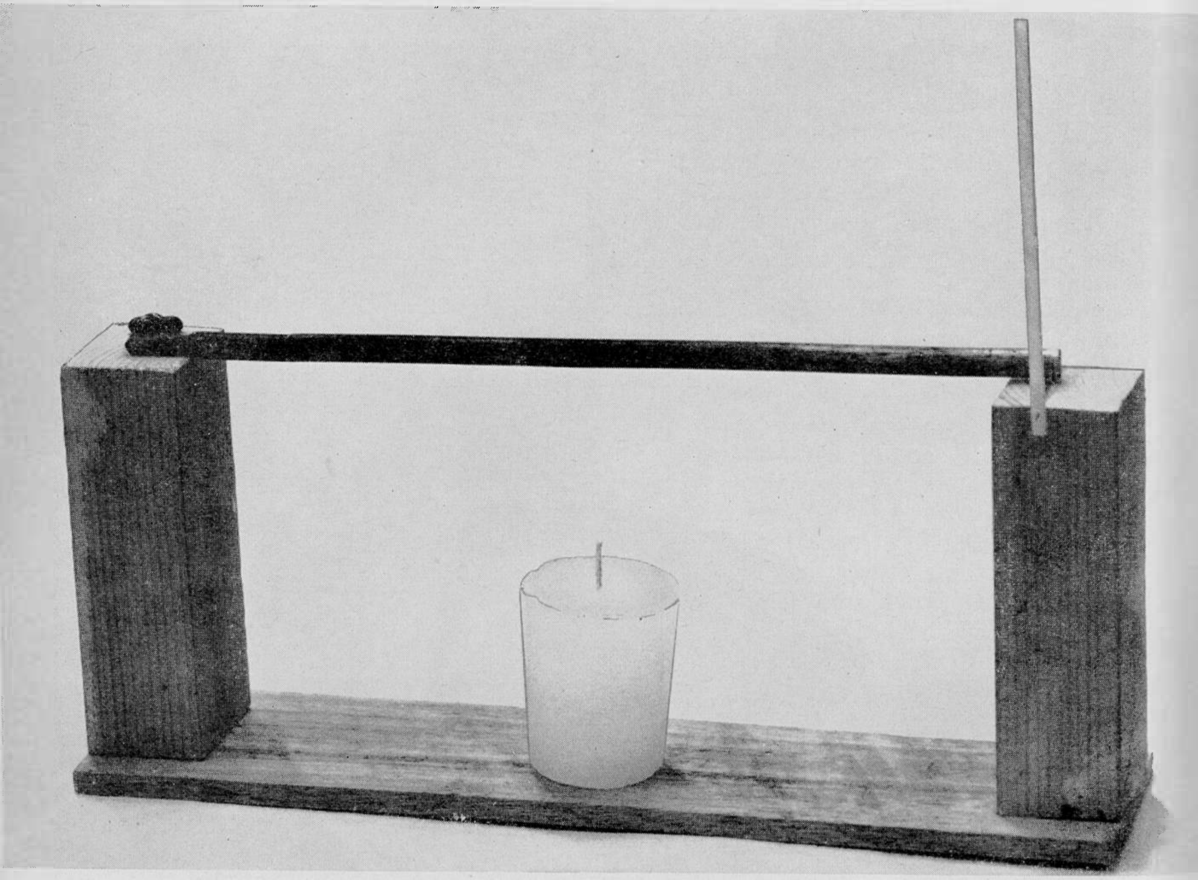
The relation of colour to heat absorption or loss is a topic which it is customary to include in traditional investigations of heat transference. The illustrations show two simple pieces of equipment which may be used. The boxes shown above contain classroom thermometers. The lids are covered with materials of different colours. The boxes are placed in the sun for given lengths of time, and the temperature readings are taken and compared with those of readings made before the experiment began. On the left is shown a variation on this situation. A tin painted silver and a tin painted black have been filled with water at the same temperature, and the rates of heat loss are being compared. These experiments provide interesting opportunities for children to record not only temperatures but also time taken to gain and lose heat.

20. Insulation

There are many questions which lead to experiments with heat insulation. The need in all experiments for a control cannot be stressed too strongly. In the one illustrated, two identical tins are filled with water at the same temperature, various forms of heat insulation are wrapped round one tin, and suitable records are made of temperature variation in both. Some forms of lagging are shown in the picture. These include metal cooking-foil, Polythene plastic material, woollen stuff, and cotton stuff. Children will no doubt invent many variations themselves.

21. Expansion

Some children find it difficult to appreciate that a metal rod really does expand when it is heated, as the expansion is too small to be seen. The apparatus illustrated shows an effective way of making it obvious. The wooden framework supports a metal rod, in this case the arm taken from a water cistern. The rod is anchored securely at one end by a screw and a staple into the wooden block. Under the free end is a needle to which a piece of drinking-straw has been attached. As the rod moves, the needle will roll and the straw will move like a pointer.



22. Reflectors

Heat reflectors are commonly used in domestic appliances. The reflector from a car headlamp will provide a means of reflecting heat most effectively. In fact, if one is held about 6 in. from the face, the heat from the body can be felt quite strongly. If two such reflectors can be obtained and a thermometer is located in place of the lamp in one and the lamp inserted in the other, the points of focus can be found by suitable experimentation and the thermometer will show dramatically that heat rays as well as light rays are reflected. Other forms of reflectors can be made from metal sheeting and aluminium cooking-foil. More experienced children may be able to devise curvatures which will narrow the point of focus sufficiently to make it possible to measure the concentration of heat rays with an ordinary thermometer.