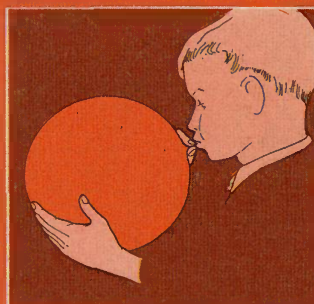
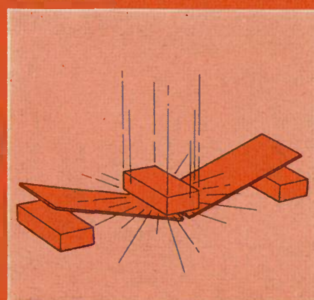
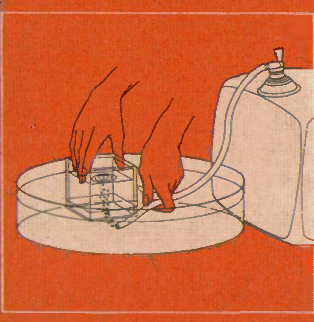
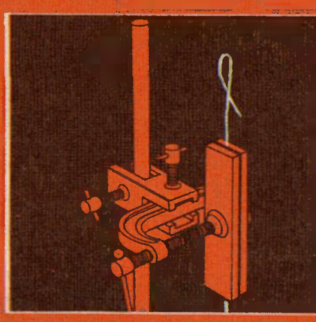
PHYSICS

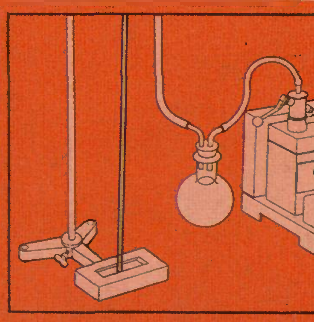
Guide to experiments I











Nuffield Physics Guide to Experiments 1

Nuffield Physics
Guide to Experiments
1

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Foreword

This volume is one of the first to be produced by the Nuffield Science Teaching Project, whose work began early in 1962. At that time many individual schoolteachers and a number of organizations in Britain (among whom the Scottish Education Department and the Association for Science Education, as it now is, were conspicuous) had drawn attention to the need for a renewal of the science curriculum and for a wider study of imaginative ways of teaching scientific subjects. The Trustees of the Nuffield Foundation considered that there were great opportunities here. They therefore set up a science teaching project and allocated large resources to its work.

The first problems to be tackled were concerned with the teaching of O-Level physics, chemistry, and biology in secondary schools. The programme has since been extended to the teaching of science in sixth forms, in primary schools, and in secondary school classes which are not studying for O-Level examinations. In all these programmes the principal aim is to develop materials that will help teachers to present science in a lively, exciting, and intelligible way. Since the work has been done by teachers, this volume and its companions belong to the teaching profession as a whole.

The production of the materials would not have been possible without the wholehearted and unstinting collaboration of the team members (mostly teachers on secondment from schools); the consultative committees who helped to give the work direction and purpose; the teachers in the 170 schools who participated in the trials of these and other materials; the headmasters, local authorities, and boards of governors who agreed that their schools should accept extra burdens in order to further the work of the project; and the many other people and organizations that have contributed good advice, practical assistance, or generous gifts of material and money.

To the extent that this initiative in curriculum development is already the common property of the science teaching profession, it is important that the current volumes should be thought of as contributions to a continuing process. The revision and renewal that will be necessary in the future, will be greatly helped by the interest and the comments of those who use the full Nuffield programme and of those who follow only some of its suggestions. By their interest in the project, the trustees of the Nuffield Foundation have sought to demonstrate that the continuing renewal of the curriculum – in all subjects – should be a major educational objective.

Brian Young
Director of the Nuffield Foundation

Introduction

This guide is a supplement to the *Teachers' Guide*, giving details of the class experiments and demonstrations to be done during the first year of the Nuffield O-level physics programme. It is of course written for the assistance of teachers and is not intended for pupil use. It should be read in conjunction with the *Teachers' Guide*.

Reference is made in each experiment to the apparatus required. The item numbers refer to the numbers given to each piece of equipment needed for the Nuffield physics programme, full details of which are given in the *Nuffield Guide to Physics Apparatus*.

In this volume the illustrations are, for a variety of reasons, more numerous and more explicit than they will be in later volumes.

Experiments in Year 1

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1 *Exhibition*

Samples of a wide variety of natural and man-made materials, solid, liquid and gas

Apparatus

The items should be available as an exhibition for the pupils to look at and handle over several weeks.

It is suggested the exhibition might include most of the following, though teachers will doubtless want to include additional items of their own.

1. Items included in the materials kit (item 1):
Blocks of iron, aluminium, brass, lead, soft wood, hard wood, paraffin wax, foamed polystyrene, Perspex, glass, slate, marble.

2. Items included in the elastic materials kit (item 2):
Rubber, latex foam block, steel spring, bare copper wire.

3. Items included in the crystals kit (item 3):
Alum, hypo, common salt, washing soda, copper sulphate, calcite, cast bismuth.

4. Other items:
Lead shot, bakelite, granite, basalt, limestone, sandstone, schist, mica, flowers of sulphur, asbestos, silk, cotton, wool, Formica, plywood, paper, glass camphor, Milton (chlorine bleach), curry powder, kitchen soap, vinegar, olive oil, gelatine, pitch, chalk, concrete, brick, ceramic, plaster of Paris, greaseproof paper, tungsten carbide drill, wheat, flour.

A bottle containing air and one from which the air has been evacuated. These should be labelled AIR and VACUUM respectively (for details see Experiment 2b).

5. Items available for first day or two only:
A balloon full of air, a balloon of coal gas or hydrogen, a balloon of carbon dioxide. (For details on filling the ballons, see below.)

Additional apparatus

Some of the following should be available near the exhibition for the optional use of those pupils that wish.

several lever-arm balances	– item 42
hand lenses	– item 24
plastic measuring rules	– item 25

The lever-arm balances should *not* be equal arm or chemical balances. They must be the single pan lever type. These are needed later in the year and it is desirable to leave some near the exhibition of materials. Some pupils will certainly try samples on the balances; some may use the lenses to examine specimens; some may use the rules.

Purpose

The exhibition should provide the children with opportunities to grow familiar with a wide variety of materials contained in it by seeing and handling samples. Some items must necessarily be in bottles, but most should be open so that the pupils can have easy access to them.

Notes

1. No specifications have been given as to the precise size of the samples, but obviously these should be as large as possible, for convenient viewing and handling.

2. As far as possible, the substances exhibited should be common ones, of a domestic nature, as suggested above, rather than special chemicals outside the pupils' experience.

3. The sense of smell is important and the list includes some items with strong smells.

4. It would be helpful if manufacturers supplied a printed set of labels, sticky or otherwise, to assist the teacher when he feels the need to label the samples.

Instructions for filling balloons

Apparatus

3 small balloons, preferably of different colours
1 aspirator (10-litre) – item 523
3 rubber bungs (diameters of ends to take balloon necks stretched over them)
2 rubber bungs fitted with glass tubes
1 CO_2 cylinder – item 19/1
rubber tubing for connection to water tap

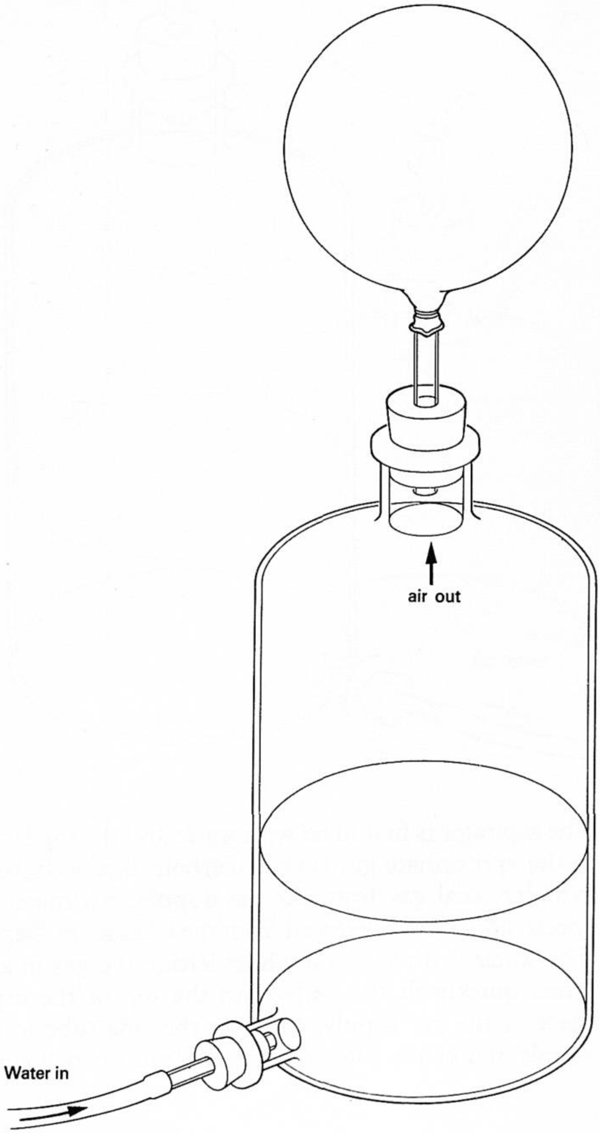
Notes

1. The balloons should be filled immediately before display. Hydrogen in particular will diffuse quite quickly through the rubber of the balloon.
2. It is helpful to work a balloon first before inflating it. This is done by blowing some air into it and stretching the material between the fingers so that all parts of the balloon are equally stretched. This softens the rubber and ensures that the balloon blows up symmetrically.

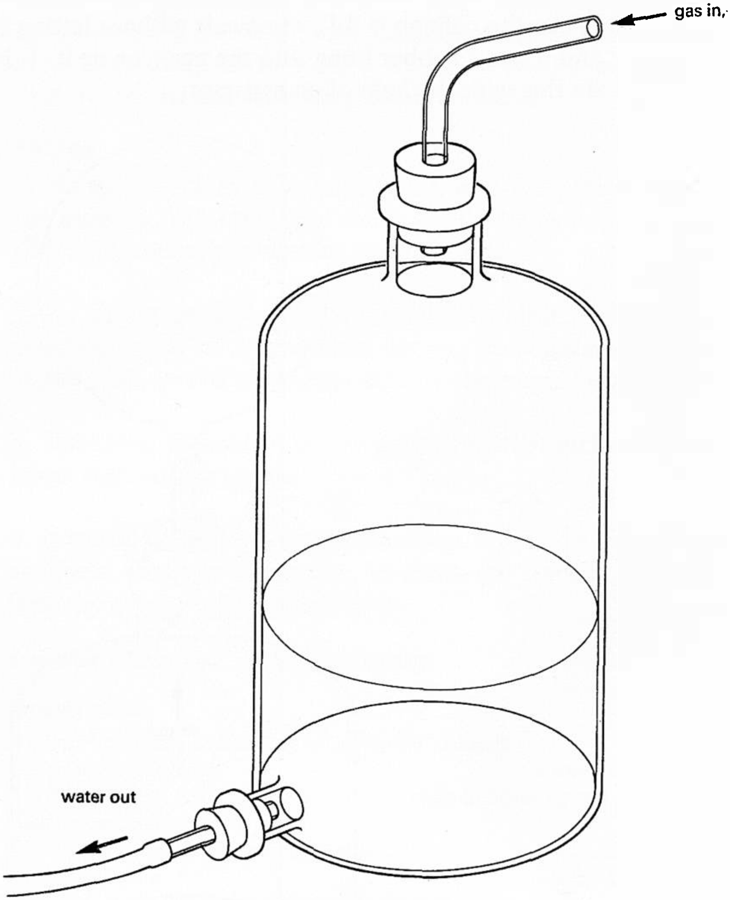
Procedure

1. Air

Connect the balloon to the top of the aspirator. Fill the aspirator with water by connecting the lower end to the water tap. The water displaces the air which fills the balloon. When the balloon is full, remove it without letting the air out and insert a rubber bung into the neck, or tie it. It is easier to do this with the help of an assistant.

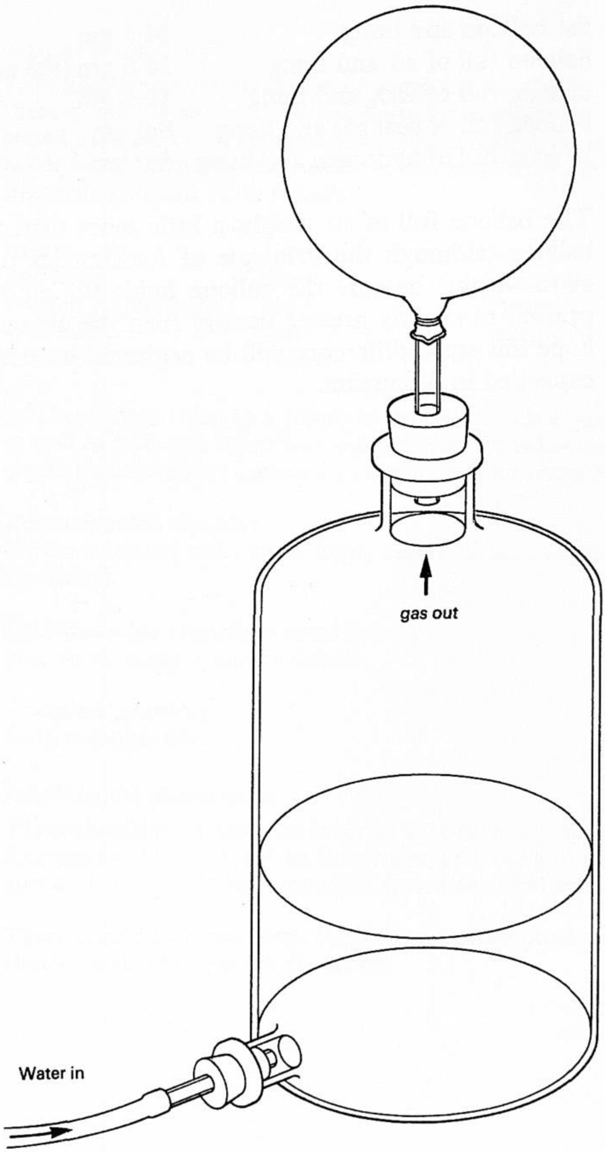


2. Carbon dioxide and coal gas or hydrogen
The procedure for filling the balloon is the same as for air, but first the aspirator must be filled with carbon dioxide, or with the coal gas or hydrogen.



The aspirator is first filled with water and the top is connected to the appropriate gas supply (carbon dioxide from the CO_2 cylinder, coal gas from the gas supply, hydrogen from the special apparatus borrowed from the Chemistry Department). The water is drained out whilst letting the gas in at the top. Then quickly fit the balloon to the top of the aspirator in place of the gas supply. Connect the side tube to the water supply and gently force the gas out into the balloon.

Hydrogen is lighter than coal gas and should be used if the apparatus is available.



Weights of balloons

The following weights are typical:

flat balloon and bung	14·5 gm
balloon full of air and bung	14·8 gm (see note below)
balloon full of CO_2 and bung	19·3 gm
balloon full of coal gas and bung	8·0 gm
balloon full of hydrogen and bung	5·0 gm

The balloon full of air weighs a little more than the empty balloon (although the Principle of Archimedes predicts *no* extra weight) because the balloon holds the air in it compressed to slightly greater density than the air outside. We hope this small difference will be neglected here rather than expanded in discussion.

2a *Class experiment*

Simple classification of materials

Apparatus

1. In addition to the exhibition of materials (see Experiment 1), there should be some further duplicate items which can be passed round in quantity for class examination. Certain items can be taken from the materials kit (item 1) and some from the elastic materials kit (item 2), as follows:

hard wood	wax	iron
soft wood	glass	brass
foamed polystyrene	slate	Perspex
aluminium	lead	marble
latex foam	rubber	

2. There should also be a supply of crystals for class examination, as well as sufficient crystalline and 'formless' powders for circulation. Some are included in the crystals kit (item 3).

Recommended crystals:
copper sulphate, soda, alum, hypo, calcite, quartz, sugar (crystals for coffee).

Recommended crystalline powders:
salt, castor sugar, copper sulphate.

'Formless' powders:
flour, sulphur, talc.

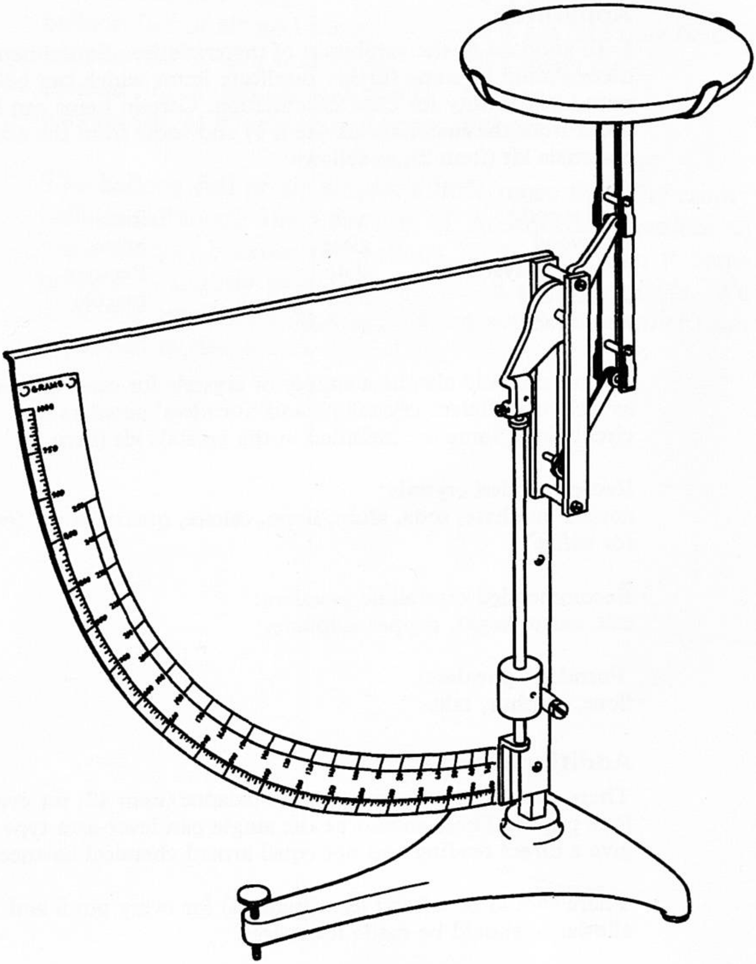
Additional apparatus

There should be at least one lever balance (item 42) for every four pupils. These should be the single pan lever-arm type which give a direct reading and not equal armed chemical balances.

There should be a hand lens (item 24) for every pupil and allowance should be made for spares.

Procedure

Samples should be passed round the class for simple classification.



2b *Demonstration*

Investigation of an evacuated bottle labelled 'vacuum'

Apparatus

1. The bottle must have a well-fitting rubber stopper in the top with a glass tube through it to which is attached a short rubber tube with a screw clip. An ordinary bottle, such as a lemon squash one should be used and not a special 'laboratory' flask.

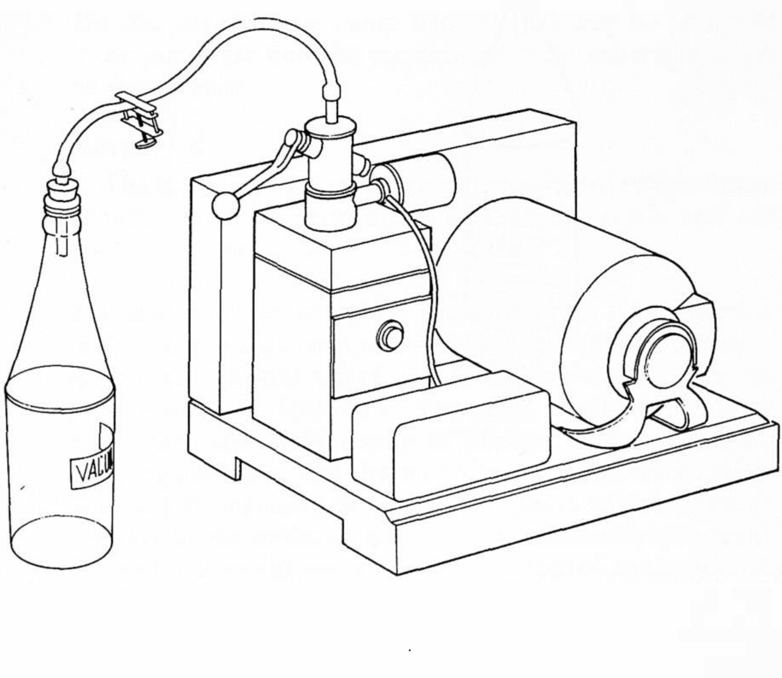
2. A motor-driven rotary vacuum pump – item 13

3. A 4 ft length of pressure tubing to fit the tube on the bottle – item 10DD

4. A large transparent trough – item 532

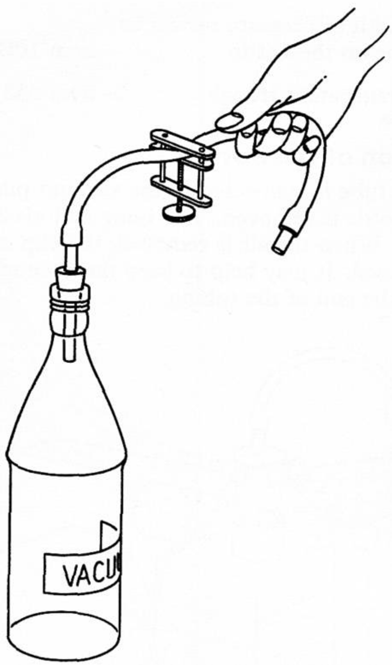
Preparation of the bottle

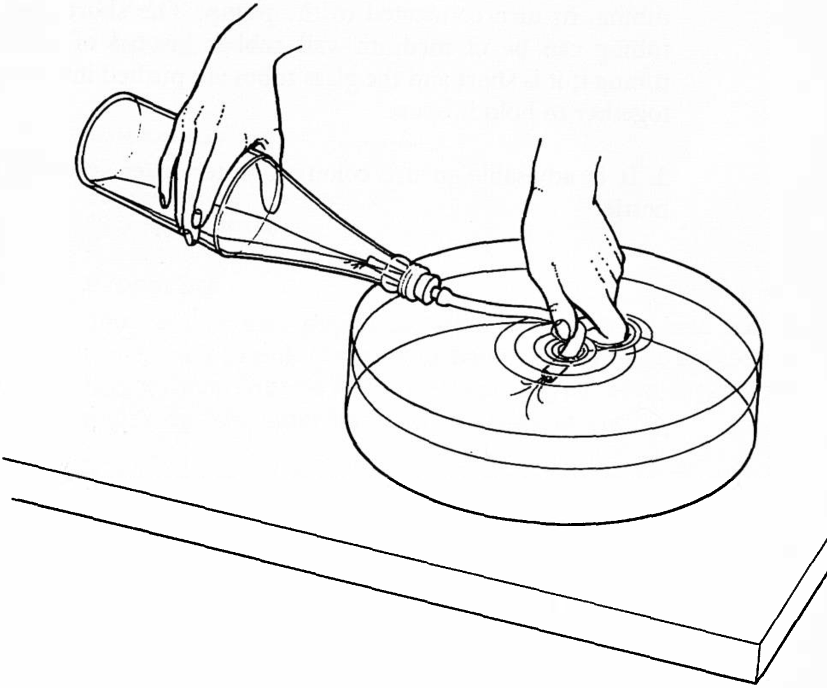
The rubber tube is connected to the vacuum pump and the air inside the bottle is removed. The bung and glass tube must be tight fitting. When the air is removed, the clip on the rubber tubing is closed. It may help to keep the vacuum if a glass rod is inserted in the end of the tubing.



Procedure

The bottle labelled 'vacuum' should be put with the other exhibits and it is hoped the children will ask about it. When this is discussed, the teacher shows there is nothing in the bottle by immersing the neck of the bottle in water and removing the clip. Water will rush in to fill the space. If the vacuum was a good one there should be little or no air inside the bottle. If the pump was not very effective or if there was a leak, then the water will not completely fill the bottle and some air will be seen in it. There will always be a small bubble left, however well the bottle is evacuated, due to air that was dissolved in the water.





On this occasion the pump itself should only be produced if the pupils ask how the vacuum got there: otherwise it will be shown later.

Notes

1. The teacher should reject any old or perished rubber bungs or tubes for this experiment, as they develop cracks and will not hold the vacuum.

2. It is essential to use rubber pressure tubing for connection to the pump otherwise it is liable to collapse (plastic tubing is not advised). A long tail of pressure tubing would be inconvenient when the bottle is opened under water; on the other hand there should be plenty of pressure tubing, say 4 ft, between the bottle and the pump to make the work easier. The best arrangement is to have two pieces of glass tubing: the first in the outlet to the bottle is connected by a short piece of rubber tubing with the clip attached to the second (which is replaced afterwards by a rod as a stopper) and this second piece of glass tube takes the long length of pressure

tubing, in turn connected to the pump. The short piece of tubing can be of medium-wall rubber instead of pressure tubing if it is short and the glass tubes are pushed into it close together to hold it open.

3. It is advisable to use coloured water when opening the bottle.

2c *Class experiment*

Feeling forces

Apparatus

64 rubber bands
32 steel springs – item 2D
32 pieces of string

Procedure

The teacher asks pupils to pull a rubber band and feel a force; then to pull two rubber bands side by side and feel a bigger force. (At this stage, we do not say, or even suggest, to pupils that the latter force may be twice as big.)

Pupils also try pulling a spring and a piece of string.

2d *Class experiment*

Feeling forces between magnets

Apparatus

32 pairs of cylindrical magnets – item 50/1

Procedure

Pupils hold magnets and feel the forces between them, repulsions as well as attractions.

(At this stage poles are *not* mentioned and iron filings are *not* provided as this experiment is intended simply to give a feeling for repulsions as well as attractions, and to show that there are forces that operate without 'contact'.)

Note on experiments 2c and 2d

Both these experiments, 2c and 2d, should take very little time. They are needed to emphasize the view of forces as pushes and pulls that we shall use. Instead of being done now, they may be postponed till just after Experiment 33 or just before Experiment 70.

3 *Class and home experiments*

Handling crystals

Apparatus

large alum crystal	– item 3C
calcite crystals	– item 3A
hypo	– item 3K
castor sugar	
sugar crystals (type used for coffee)	

Procedure

The pupils should handle the large crystals for themselves and examine the smaller ones.

4 *Class experiment*

Watching crystals form quickly

Apparatus

40 small test-tubes	– item 546
1 bottle of hypo crystals	– item F3K

The quantity allows one test-tube per pupil with some spares. Any small tubes will do, but the wider they are the more hypo is needed.

Preparation

Some hours before the class, preferably the day before, put a few cc of photographic hypo crystals in each test-tube (to a depth of about 2 inches) and melt them by gentle warming. The crystals will melt in their own water of crystallization. If they do not do that easily, add a drop of water to the stock of crystals so that they are damp.

Allow the tubes of melted hypo to cool down to room temperature. If the tubes are left a long time after cooling, the hypo may recrystallize in some. A few spares should therefore be prepared.

The recrystallization might be started by dust, so it is advisable to cover the mouths of the tubes with a sheet of paper until they are taken to the class. It is advisable to avoid jarring the tubes as that may start recrystallization.

Procedure

Each pupil should be given a test-tube with the cool liquid hypo in it. Ask him to drop one crystal of hypo into the liquid. Watch very carefully what happens.

Note

The teacher should not suggest looking for the rise of temperature on crystallization. Some pupils will feel it, but others who miss it can meet it at a much later stage.

5 Class and home experiments

Growing crystals of alum or copper sulphate

Apparatus

32 small jars	
32 beakers (400 ml)	– item 512/2
alum or copper sulphate	– items 3J, 3N
1 bucket (plastic with lid)	– item 533

There should be one jar for each pupil. Jam-jars are quite suitable.

Procedure

1 The saturated solution

Before the class experiment is attempted, the teacher must prepare a solution of the salt which is saturated at room temperature. This is best achieved by allowing a supersaturated solution to deposit its excess solid, as explained below.

To prepare the working solution, dissolve the salt in warm water (about 50°C.) at a rate of 40 gm per 100 cc for copper sulphate and 30 gm per 100 cc for potassium alum. Seven litres is sufficient for a class of thirty-two using jam-jars. Pour this solution into the bucket, close the lid, and allow it to cool to room temperature. This solution is now supersaturated.

Seed this solution with a pinch of tiny crystals and leave it in the closed vessel for two or three days, shaking occasionally, to become saturated at room temperature. Pour off the clear saturated solution into another glass vessel which is closed with a lid.

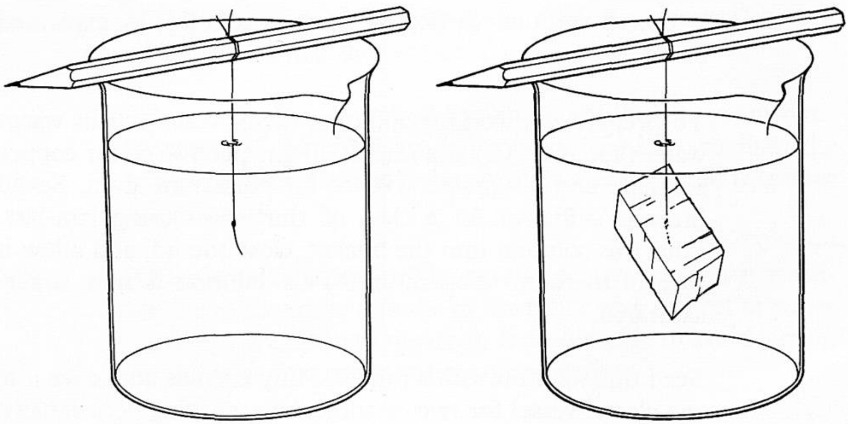
2 Seed crystals

One method of producing the seed crystals is to dip a length of thread into the saturated solution and then to hang it up to dry. Small crystals will appear on it and the whole thread is then hung in the solution. After one or two days examine the crystals which have developed and break off all but the best. These then form the seeds for the next stage.

Another method is to place about 50 cc of the prepared solution in an open beaker and to allow it to evaporate overnight. The seeds resulting are sorted and dried, those which are perfect in shape and about one-eighth inch long being retained.

3 Growing the crystals

Where the first method for seeding is used, the thread with its perfect seed crystal is suspended from, say, a pencil laid across the top of the jar. The jar is filled with the saturated solution until the seed is completely covered. The jar should then be covered with a piece of thin cotton cloth (for example, muslin or cheese cloth) which is held in place with an elastic band. It is then left undisturbed and at an even temperature for several days.



Where the second method is used to obtain seed crystals it will be necessary to tie the seeds to a short length of cotton or thread. This is not an easy process and children should be advised to prepare a slip knot and to slip this over the seed rather than to use a reef knot or granny knot. Once the crystal is secured to the cotton, proceed as above.

Notes

1. In a school with many streams, each pupil should still be provided with a jar in which to grow his own crystals. However, this poses a tremendous problem of storage; with five classes, the shelf area needed for storing the jars is between

ten and twenty square feet, unless the jars can be stacked. Such a school would be wise to consider replacing the jars by tapered glass tumblers that can be stacked. The supply of material for crystals must of course be provided in large quantities; but the beaker for seed crystals can be made to serve several pupils or several classes.

2. For experiments at home, pupils may be encouraged to try growing crystals of such common substances as sugar and soda, but they should also be provided with plenty of alum to take home to try.

3. If the room temperature rises suddenly, the solubility (of most salts) increases and we lose the necessary saturated solution. This is the reason for the need for an even temperature, day and night.

6 *Demonstration*

Ready-made crystal models made with foamed polystyrene spheres

Apparatus

Polystyrene spheres – item 3B

Assembly of the models

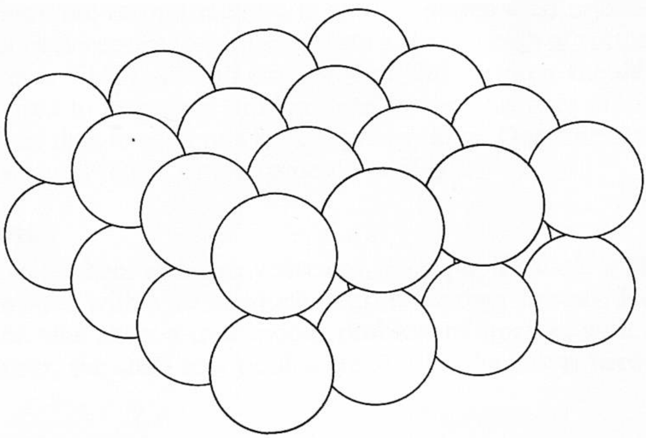
Models (1) and (2) below are necessary, model (3) is optional.

The teacher should prepare the models some time before the lesson by joining spheres together with a suitable adhesive. Conventional 'glues' will probably not work, but a good adhesive is made by dissolving some sheet foamed polystyrene (or one of the spheres) in acetone (or, better, in some amyl acetate). The adhesive should be very thick in consistency and should be applied with a wood splint to the spheres at the points of contact. Then the spheres are pressed firmly together. They should be left twenty-four hours to harden.

Some may prefer to join the spheres together using cocktail sticks or double-ended screws. In practice, glueing is easier.

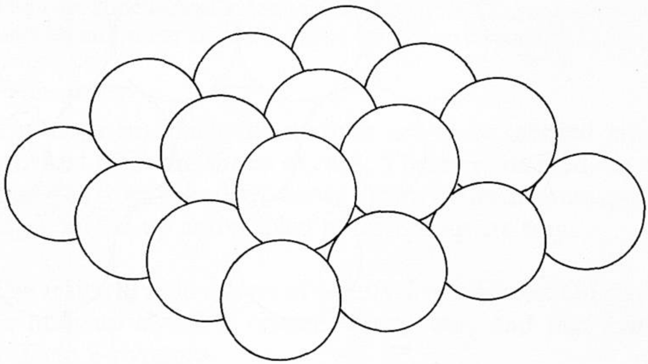
1. Simple cubic lattice

Four layers should be made and then placed one on top of the other. The layers can be fixed permanently together, left separate, or tied together with cotton.



2. Body-centred cubic lattice

a. This can be built up as illustrated by putting a second layer of nine spheres on top of the first layer of sixteen in the position indicated. On top of this layer is then put a layer of sixteen (already stuck together) similar to the first, and the process is repeated.



or

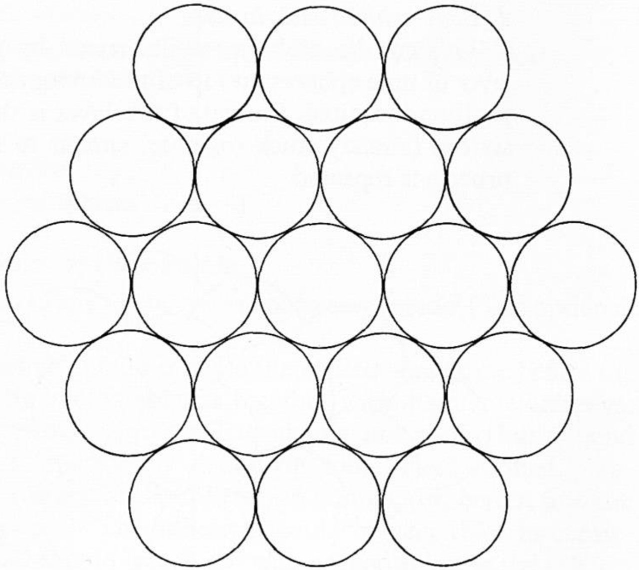
b. Alternatively, build a pyramid, starting with a 4-sphere $\times$ 4-sphere base, then nine in the second layer, four in the third, and one in the last.

or

c. Make a large number of 4×4 layers and assemble crystals both simple cubic and body-centred cubic by moving the layers on each other.

3. Hexagonal close-packed lattice (Optional extra)

A close-packed single layer structure can be built, as shown on the following page, with each sphere touching six others. A second layer similarly constructed, placed on top of the first, but displaced slightly so that the spheres of the second layer fit into depressions in the first. Further layers can then be placed on top.



Procedure

After the crystal models have been produced by the teacher, they should be added to the other exhibits.

Different packings should be shown but no attempt should be made to enlarge on detail. Above all, long names should not be given for different crystalline structures.

It should merely be pointed out that these models appear to agree with the way in which crystals seem to choose and keep their shapes.

7 *Class experiment*

'Crystals models' by packing marbles in a tray

Apparatus

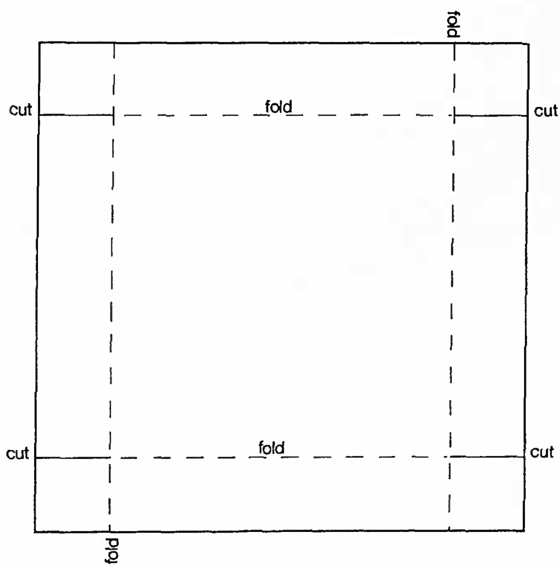
Supply of marbles (about $\frac{5}{8}$ in dia.) – item 12B
16 pieces of thin card (about 5 in square)

The two-dimensional kinetic model kit (item 12) contains 800 marbles and these should be used for this experiment.

Procedure

The trays in which the marbles are to be stacked are improvised from the sheets of card. These are marked out with lines $\frac{3}{4}$ in from the edges, cut as shown in the diagram, and the edges folded up and stapled to form a square tray.

The tray will hold a layer of twenty-five marbles. On this can be built up layers of sixteen, nine, four, and one marbles to form a pyramid.



8 *Demonstration*

Model of growing crystals with polystyrene balls on a wooden base

Apparatus

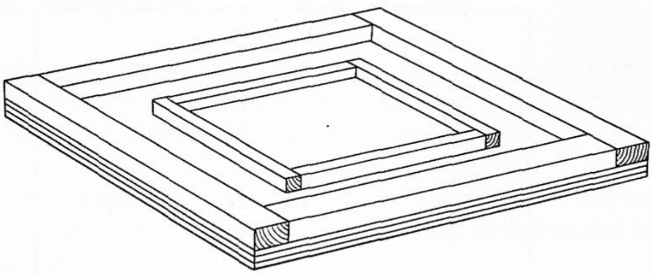
1 wooden base with ridges – item 3E
55 foamed polystyrene
spheres ($1\frac{1}{2}$ in diameter) – item 3B
1 large alum crystal – item 3J

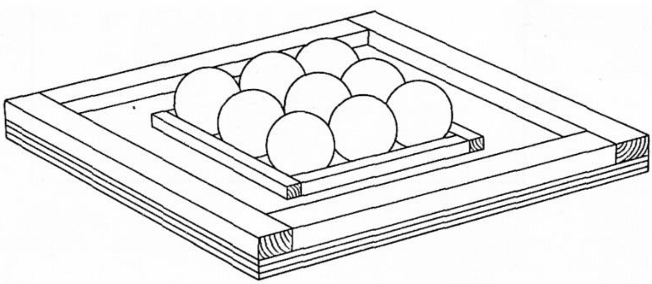
Procedure

Form a square with three balls in each side, using nine balls in all, on the special wooden base board. Then put four balls on this base and one on the top to form a pyramid.

Now let the the crystal 'grow' by the addition of more balls one at a time. Add balls carefully until there is a pyramid with a 4×4 base.

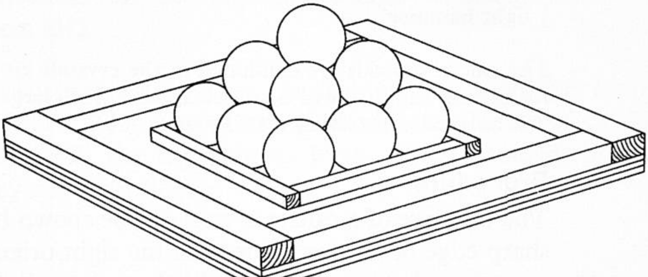
Then add more balls to make a 5×5 base.

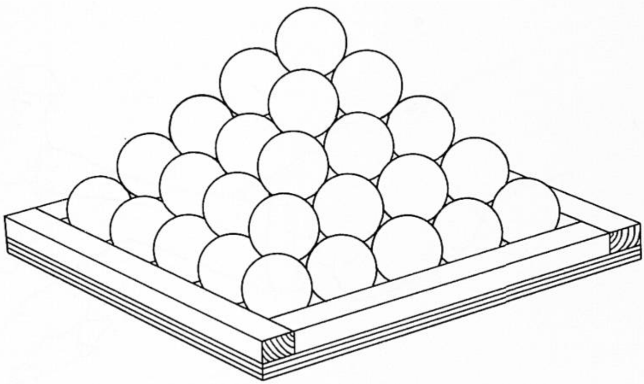




The pupils should observe the shape and look at the angles between the faces at each stage.

Finally show a large octahedral crystal of alum and compare with the model.





9 *Demonstration*

Cleavage of large crystals

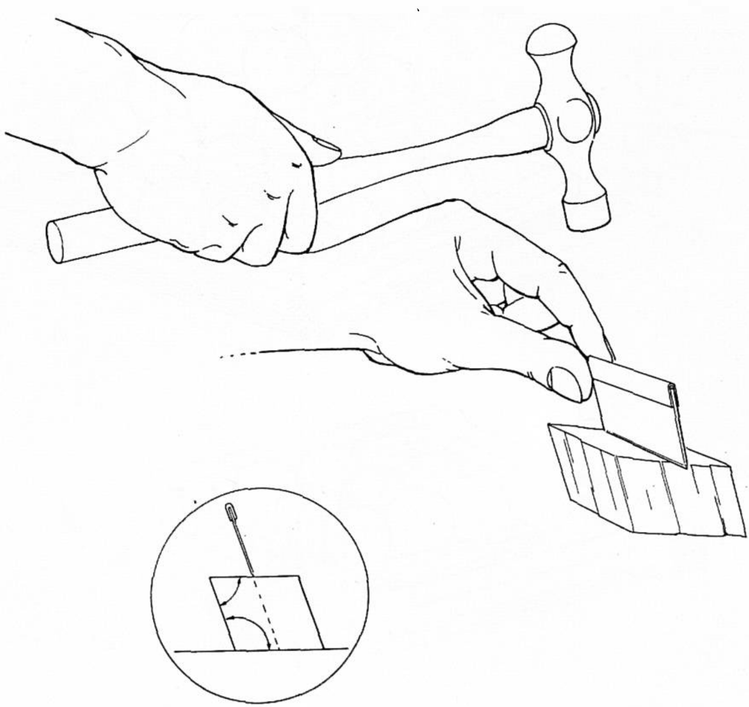
Apparatus

Large calcite crystals for cleavage	– item 3A
1 single edge razor blade	– item 3H
1 light hammer	

The calcite crystals are contained in the crystals kit (item 3). Additional supplies will be necessary as a fresh large calcite crystal will be needed for every class taught.

Procedure

The cleavage of a calcite crystal can be shown by placing the sharp edge of a razor blade with the right orientation on the crystal, and then giving the blade a sharp light tap with a small hammer or block of wood. The 'right orientation' is any plane parallel to an existing face.



If the pupils ask why it is important to have the right orientation of the blade, show what happens if the orientation is wrong – no 'clean' cleavage is obtained.

Note

Single-edged (Ever Ready type) razor blades are particularly convenient for cleaving and are supplied in the crystals kit (item 3H).

It may seem easier to use a knife or even a screwdriver hit by a hammer. This brute-force method lacks the art of cleavage and spoils the experiment. It should be avoided, however easy and tempting.

10 *Film and photographs*

a. Crystals

A P.S.S.C. film made by Alan Holden, available in the United Kingdom on hire from Sound-Services Ltd, Wilton Crescent, London SW1. This remarkable film is a very stimulating one for the teacher and pupils. It is very well worth seeing. It can be shown in the first year of the Nuffield course, but it is long for showing in one stretch to children of this age. Some trial classes found this film too long. Others have found the whole film successful when half was shown during one period and the rest during the next class time.

The film shows the technique for cleavage.

Note that it is essential that if a film is shown, it should not be a substitute for showing the actual growth of crystals under a microscope which the pupils can see for themselves. It should be shown after the children's class experiments and not before.

b. Photographs of snowflakes

11a *Class experiment*

Crystals dissolving in water

Apparatus

common salt	– item 3L
beakers of water (400 ml)	– item 512/2

Procedure

The pupils have already seen the crystalline structure of common salt. Now they put some of the salt into a beaker of water and watch it dissolve. Then add more and more salt and observe it dissolving.

This should raise questions of what has happened to the crystals. Analogies may be drawn with the 'washing away' or removal of polystyrene spheres from the pyramid model of Demonstration 8. See the *Teachers' Guide* for discussion.

Note

A fast group may do this under a microscope. Some crystals of salt are put on a microscope slide and observed under the microscope. A few drops of water are added and the crystals watched dissolving.

11b *Demonstration*

Volume change on dissolving salt in water

Apparatus

1-litre volumetric flask	– item 517
common salt	– item 3L

Procedure

Put 400 gm of salt, small crystals (not large chunks, nor powder), into the 1-litre volumetric flask. Pour in enough water to cover the salt and swirl around in order to remove the air bubbles. Fill the flask up to the 1-litre mark. Point out that most of the salt is still there.

Shake up the flask and observe the contraction.

Notes

1. The contraction is about $2\frac{1}{2}$ per cent.

2. The solubility of salt does not change much with temperature and there is no point therefore in using hot water.

12a *Class experiment*

Looking at things with magnifying glasses and microscopes

Apparatus

36 hand lenses	– item 24
8 microscopes	– item 23
8 illuminants	– item 47
8 transformers	– item 27

Each pupil must have a hand lens or magnifying glass and this will necessitate having some spares.

Microscopes are a difficult problem: pupils need to use them and not just have one look. Pressure of a long queue will spoil a young pupil's first look through this important instrument. One is needed for every four pupils: they need not be expensive instruments.

Procedure

Pupils should be encouraged to look at anything they want to. They should start with the magnifying glasses.

When first using a hand lens, the pupil will probably find it easier if he brings the hand lens right up to his eye holding it with one hand, then bringing up towards the eye the object to be viewed with the other.

If desired, the lens can be held rigid in a clamp attached to a retort stand.

Later in the lesson the microscopes can be produced and used for more than one lesson, if desired. Pupils might look at some of the following: sand, salt, blotting-paper, talcum powder, a hair, their own handwriting, blood and then red ink, a finger-print, natural asbestos, some salt dissolving, some rocks such as granite.

12b *Optional extra class experiment*

Watching crystal growth under a microscope

Apparatus

8 microscopes	– item 23
8 illuminants	– item 47
8 transformers	– item 27
32 microscope slides	– item 3G
8 Bunsen burners	– item 508
8 beakers (400 ml)	– item 512/2
8 pins	
1 bottle common salt	– item 3L

The number of pupils that can do this experiment at once depends on the number of microscopes. The minimum number of microscopes is one for every four pupils.

Procedure

Prepare an almost saturated solution of common salt overnight and decant this into the eight beakers. Warm a microscope slide over a low Bunsen flame and place a drop of salt solution on it so that it may be observed under a microscope.

In the end the microscope will have to focus on a plane just above the surface of the slide so as to see the first layer of crystal forming. It may be convenient to focus on to some mark on a piece of paper placed under the objective in order to find the correct position.

12c *Optional extra class experiment*

Looking at crystals

Apparatus

8 microscopes	– item 23
8 illuminants	– item 47
8 transformers	– item 27
8 hand lenses	– item 24

demerara sugar
granulated sugar
castor sugar
icing sugar

specimens of granite with unweathered surfaces

2 specimens of cast bismuth – item 3F

Procedure

1. The sugars should be examined in succession with a hand lens or microscope, as appropriate.

The demerara sugar is crystalline even to the unaided eye. The granulated sugar is seen to be crystalline when viewed with the hand lens, the castor sugar with the microscope. It will probably not be possible to see the crystalline nature of icing sugar though this will depend on both the grade and the microscope.

Powdered chemicals (carefully selected from the shelves as being harmless) may also be investigated. Some powders whose crystalline form is not visible may be included (e.g. talcum powder or flour).

2. Pupils can examine the specimens of granite using hand lenses.

Three main constituent materials will be observed in a specimen: clear glass-like quartz, pink or white opaque felspar and shiny flaky mica. Traces of other minerals can often be distinguished.

It may be possible to observe the perfect cleavage lines of the mica crystals, less perfect on the felspar and none on the quartz.

3. Two specimens of cast bismuth are included in the crystals kit and can be examined either with the naked eye or with a hand lens. The crystal structure is clearly visible.

Broken slabs of cast zinc can also be tried, but they are not as effective as the bismuth.

A strong illuminant at grazing incidence is helpful.

13 *Class experiment*

Measuring and weighing solid blocks, one group all the same size, then some of various sizes

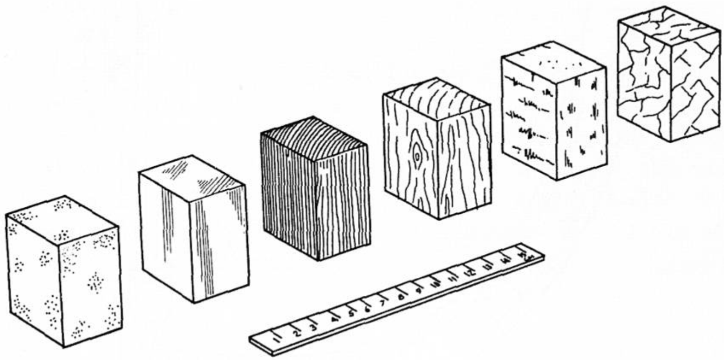
Apparatus

16 plastic measuring rules – item 25
8 lever-arm balances – item 42

Blocks, each 5 cm × 4 cm × 3 cm – in materials kit (item 1) of:
soft wood
hard wood
aluminium
iron
foamed polystyrene
paraffin wax
and of various other sizes:

aluminium	(5 × 5 × 8 cm)
aluminium	(2 × 2 × 10 cm)
Perspex	(2 × 2 × 10 cm)
slate	(2 × 2 × 10 cm)
glass	(2 × 2 × 10 cm)
soft wood	(2 × 2 × 10 cm)
hard wood	(5 × 5 × 20 cm)
lead	(5 × 5 × 2 cm)
brass	(2 × 2 × 5 cm)
marble	(2 × 2 × 10 cm)

1 foamed polystyrene sheet (2 in × 12 in × 16 in) – item 10J

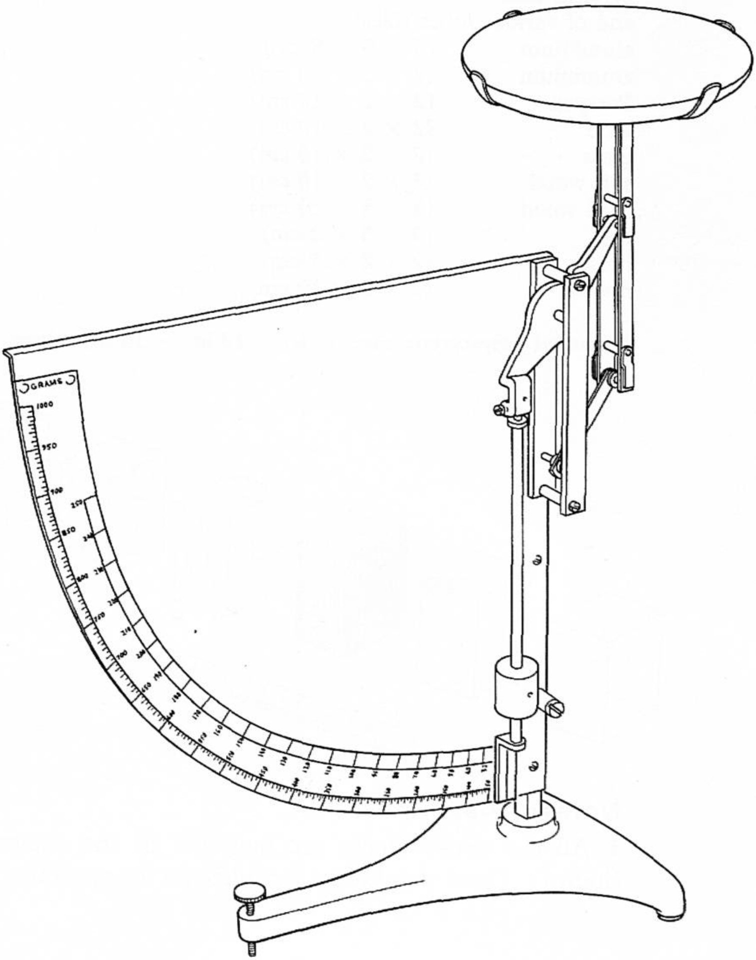


Notes on Apparatus

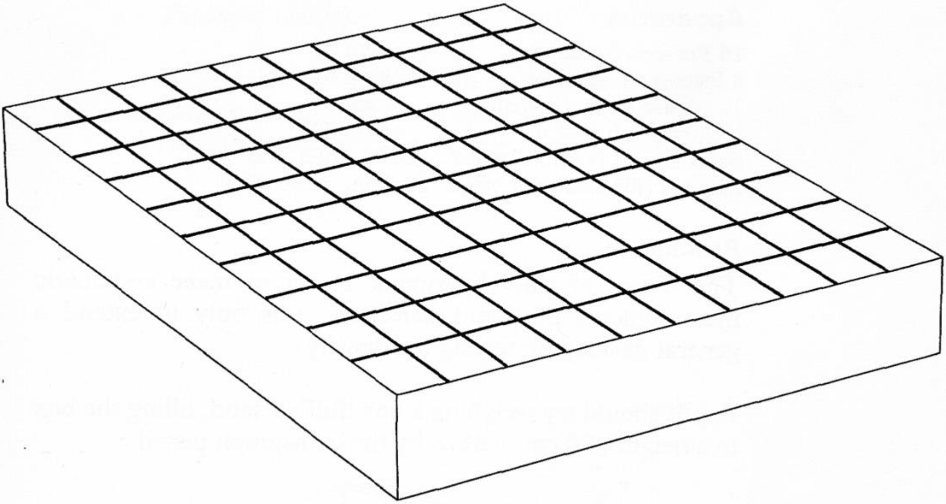
1. All the above blocks are included in the materials kit (item 1). There should be a complete set for every four pupils.

2. The plastic rules are only marked in centimetres. It is important to use these in this experiment and not to use more conventional rulers which are also marked in millimetres. If the rules are only marked in centimetres, pupils will measure to the nearest centimetre. If there are millimetres as well, some will measure a width as 1·9 cm and thereby ruin the whole experiment in a mass of complicated arithmetic in a misplaced attempt to achieve 'accuracy'.

3. There should be sufficient lever-arm balances so that there is one for every four pupils. These should read up to 1,000 gm. Chemical balances (or other equal-arm balances) should *not* be used. For some pupils it may help considerably if the second scale on the balance is covered over with black masking tape.



4. The large sheet (2 in × 12 in × 16 in) of foamed polystyrene should be marked to show that it is the equivalent of 10 × 10 or 100 of the smaller polystyrene blocks.



Procedure

The pupils should first weigh the group of six blocks which are all the same size and note the weights. This will give some feeling for density (see *Teachers' Guide*).

Introducing other blocks of different sizes will raise the question of 'weight for some standard volume'.

Note

The difficulty of weighing the small foamed polystyrene block (5 cm × 3 cm × 4 cm) should lead the pupils to the need to weigh a large number of these. The large polystyrene sheet is 2 in × 12 in × 16 in which is almost the same as 5 cm × 30 cm × 40 cm (i.e. 100 small blocks). The sheet will be supplied ruled with markings to show that it is the same as 100 small blocks, which can then be weighed all at once.

14 *Class experiment*

Weighing liquids

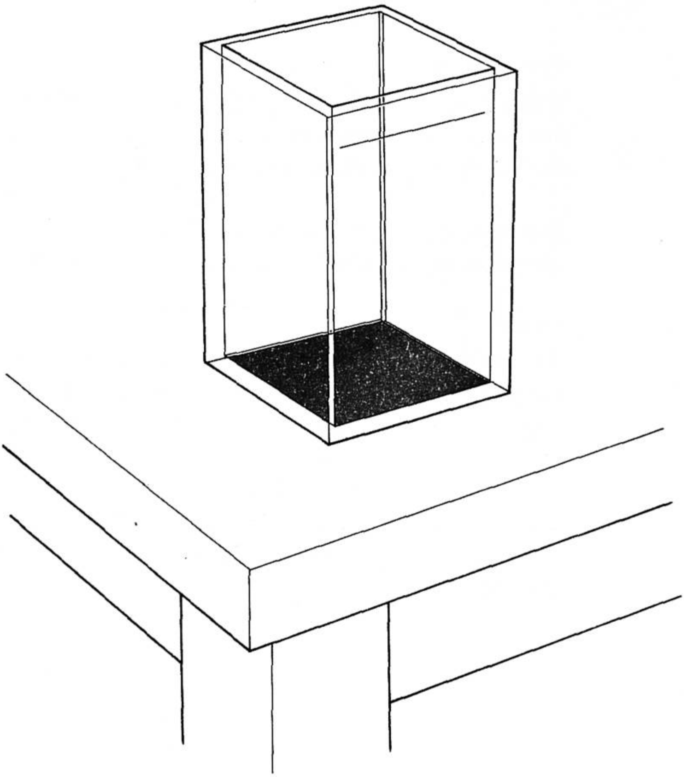
Apparatus

16 Perspex containers – item 26
8 lever-arm balances – item 42
16 plastic measuring rules – item 25
1 chinagraph pencil – item 543
Sand and, if possible, wheat, rice or dried peas.
Liquids (for example: water, paraffin, brine, oil)

Procedure

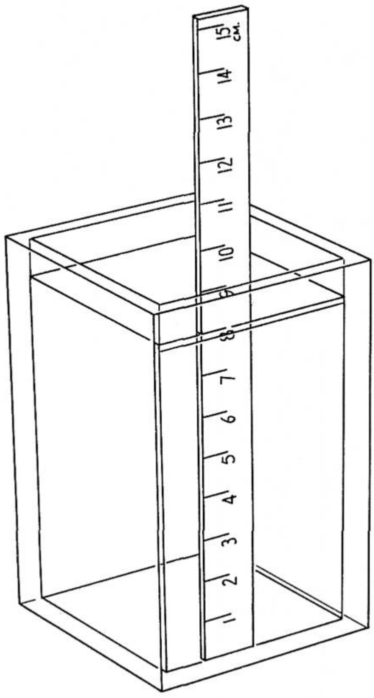
The object of this experiment is *not* to make systematic measurements of liquid densities: it is only to extend a general developing feeling for density.

Pupils should try weighing a box 'full' of sand, filling the box to a height of 8 cm marked by the chinagraph pencil.



Then they should try a 'box-full' of water, then another liquid. Those pupils who raise the question of the weight of the box itself will weigh it of their own accord, but the teacher should not give a general instruction to do this (see *Teachers' Guide*).

Weighing sand might lead to a discussion of an 'average' density for the sand and spaces combined. Start such a discussion by trying wheat or dried peas. Considering water after this may lead to a discussion once again of atoms. See *Teachers' Guide*.

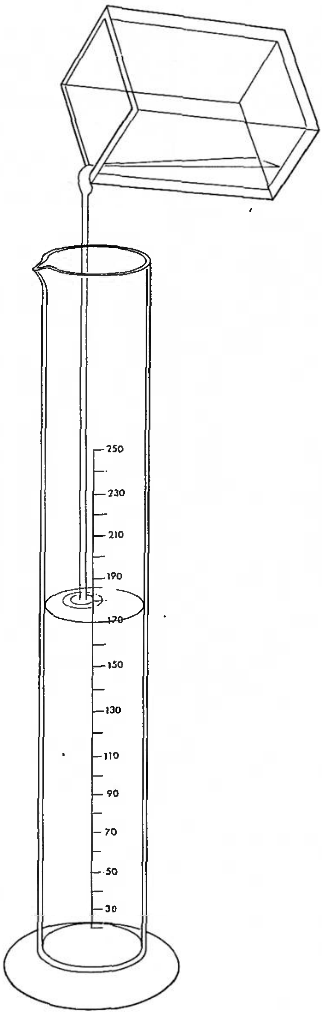


15 *Demonstration*

Testing measuring cylinders by known volumes of water from a rectangular box

Apparatus

2 250 ml measuring cylinders	– item 518/1
1 1000 ml measuring cylinder	– item 518/2
4 Perspex containers	– item 26
4 plastic measuring rules	– item 25
1 Perspex box (10 × 10 × 11 cm)	– item 10D



Procedure

The Perspex container is filled with water to a depth of, say, 4 cm using the special plastic rules which are marked only in centimetres. The volume is worked out. The contents are then poured into the 250 ml measuring cylinder and the level noted. The process may be repeated, different depths can be tried, the larger measuring cylinder can be used and the larger Perspex box. The teacher can also pour water from measuring cylinder to measuring cylinder.

Note

It is important the demonstration should not turn into a precise drill and thereby labour the discussion. See the *Teachers' Guide* for a warning and discussion about this experiment.

16a *Demonstration*

Evacuation of a bottle

Reference

See also the details discussed in Experiment 2b.

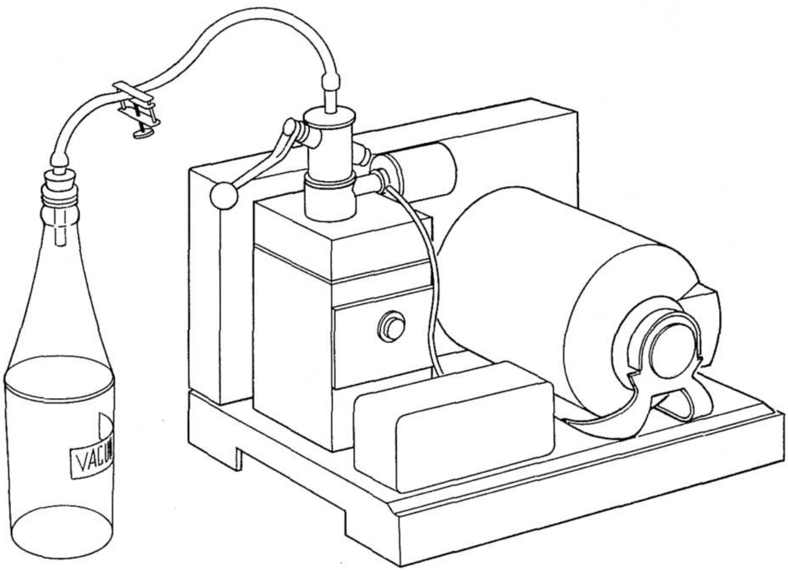
Apparatus

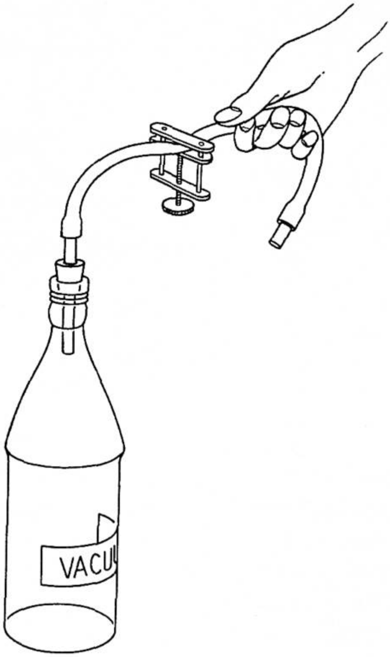
1. Ordinary bottle of clear glass with a well-fitting rubber stopper, as in Experiment 2b.

2. Motor-driven vacuum pump	– item 13
3. A 4 ft length of pressure tubing	– item 10DD
4. A large transparent trough	– item 532

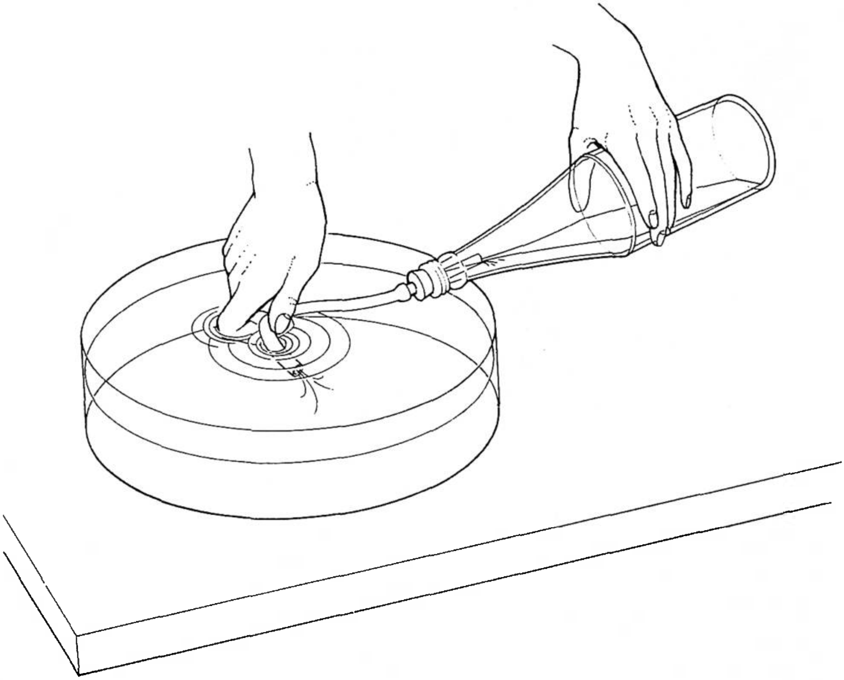
Procedure

The rubber tubing is connected to the vacuum pump with the clip open. The bung and glass tube must be tight fitting. Old or perished rubber bungs or tubes should be rejected. The air is removed by pumping and the clip on the rubber tubing is then closed.





To show that the air has been removed, the neck of the bottle (including the rubber tubing) is immersed under water and the clip is removed. Water will rush in to fill the space. If the vacuum is a good one there should be very little air inside the bottle. If the pump was not very effective or if there was a leak, then the water will not completely fill the bottle and some air will be seen in it. There will always be a small bubble left, however well the bottle is evacuated, due to air that was dissolved in the water.



It is essential to repeat the experiment without pumping air out of the bottle before immersing it, in order to show what happens in that case. This should be done second to avoid using the pump with a wet bottle.

Notes

1. The teacher should reject any old or perished rubber bungs or tubes for this experiment, as they develop cracks and will not hold the vacuum.

2. It is advisable to use coloured water when opening the bottle.

16b *Demonstration*

Effect of a pump

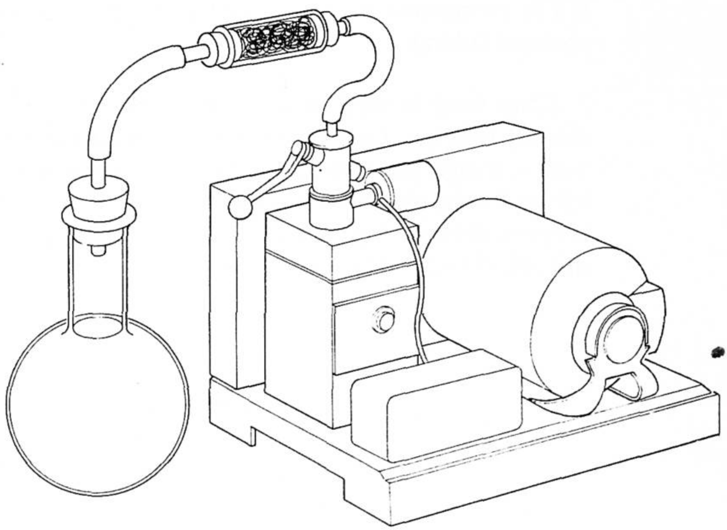
Apparatus

1 vacuum pump	– item 13
1 one litre round-bottomed flask	– item 10K
1 bung with glass tube to fit	– item 10L
1 smoke filter	– item 10CC
1 length of pressure tubing	– item 10DD

The vacuum pump should be a motor-driven rotary pump and *not* a hand pump.

Procedure

Most young pupils are unfamiliar with the action of the pump and even the idea of an empty vacuum is strange to many. To give them an idea of the pump's effect and to let them see 'air being taken out of the bottle', some visible gas should be pumped out of a flask. Unfortunately, visible gases such as bromine are highly corrosive and should not be used with school pumps. However, smoky air can be pumped out of a clear flask without harming the pump if a smoke filter is inserted between flask and pump.



The smoke filter is made with an 8 in length of $1\frac{1}{2}$ in diameter glass tubing containing glass wool. Bungs are provided at each end through which glass tubing connects on the one hand to the vacuum pump, on the other to the flask to be exhausted.

Some cigarette smoke (or smoke from a smouldering drinking straw) is blown into the one litre round-bottomed flask so that it is clearly visible. The flask is closed with the rubber bung through which a glass tube is connected by rubber tubing to the smoke filter, which in turn connects to the pump.

The pump should be switched on so that the smoke can be seen being pumped out. The needle valve on the pump should be adjusted so that the rate of pumping is as slow as possible, otherwise the operation is over too quickly. Where the pump is fitted with a gas-ballast valve, this should be left open during this process.

It is helpful to illuminate the flask brightly and to have a dark background.

Notes

1. For connection to the vacuum pump it is essential to use pressure tubing.

2. Glass wool is used inside the smoke filter (as described above), this has been a standard practice for years. Glass wool is dangerous stuff to handle and obviously it should be left inside the glass tube containing it. If any manufacturer is nervous about using it, they can use ordinary cotton wool instead, though not too much of it.

16c *Demonstration*

Effect of air pressure

Apparatus

1 polythene bottle or large syrup can (1 gallon size)	
1 vacuum pump	– item 13
1 rubber tube and bung to fit bottle or can	
1 length pressure tubing	– item 10DD

Procedure

A rubber bung with a glass tube through it, to which is attached pressure tubing, is used to connect the bottle to the pump. The air should be removed from the bottle (or the syrup can) so that it collapses.

17 *Demonstration*

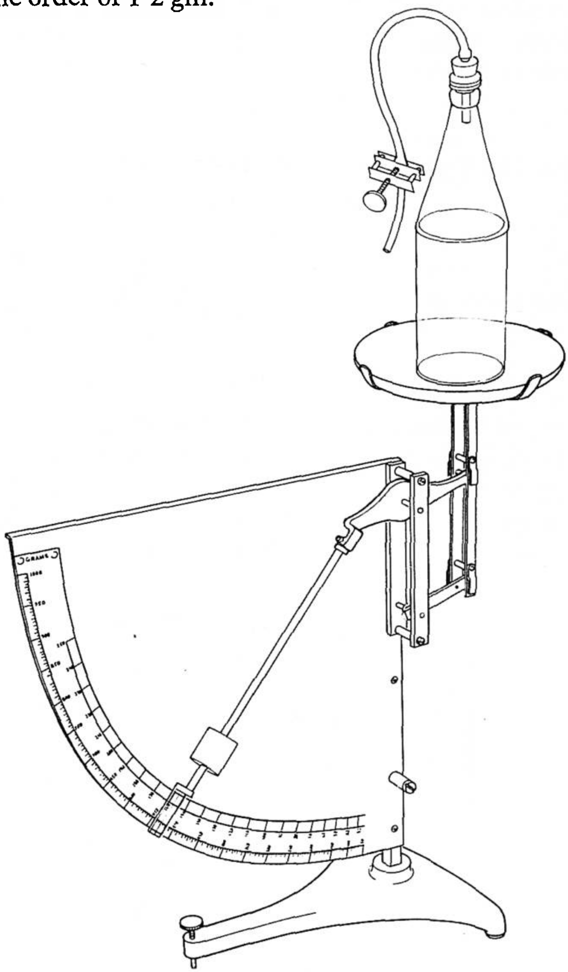
First attempt to weigh a sample of air

Apparatus

1 one litre round-bottomed flask	– item 10K
1 bung and tube to fit flask	– item 10L
1 vacuum pump	– item 13
1 lever-arm balance	– item 42
1 Perspex box (10 cm × 10 cm × 11 cm)	– item 10D
1 length pressure tubing	– item 10DD

Procedure

A one litre round-bottomed Pyrex flask weighs approximately 350 gm. The change in weight when the air is removed is of the order of 1·2 gm.



Instead of the special nature of the Pyrex flask, some teachers prefer to use the squash bottle which was used earlier in the year. This is illustrated opposite.

On the single-pan lever-arm balance, which has been used throughout the course, this amount will scarcely be appreciated. The object of this experiment is to show how small the weight difference is, in fact too small for our balance.

The one litre flask must have a well-fitting rubber bung with a glass tube through it, to which is attached a rubber tube with a screw clip.

The flask is weighed. The rubber tubing is attached to the pump and the flask exhausted. The flask is reweighed. (The volume can be found by filling the flask with water and pouring into the rectangular Perspex box.)

Note

For connection to the vacuum pump it will be necessary to use pressure tubing. See the discussion in Experiment 2b.

18 *Demonstration*

Weighing air: by pumping into a container and determining the volume by releasing it into a vessel under water

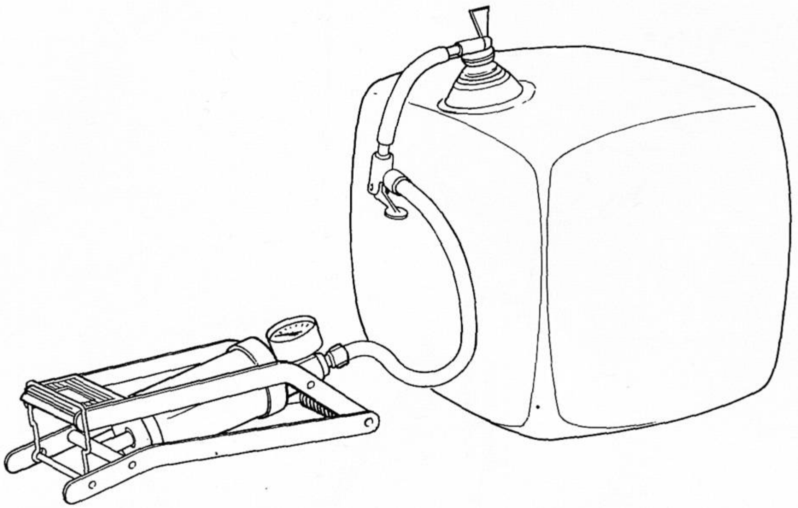
Apparatus

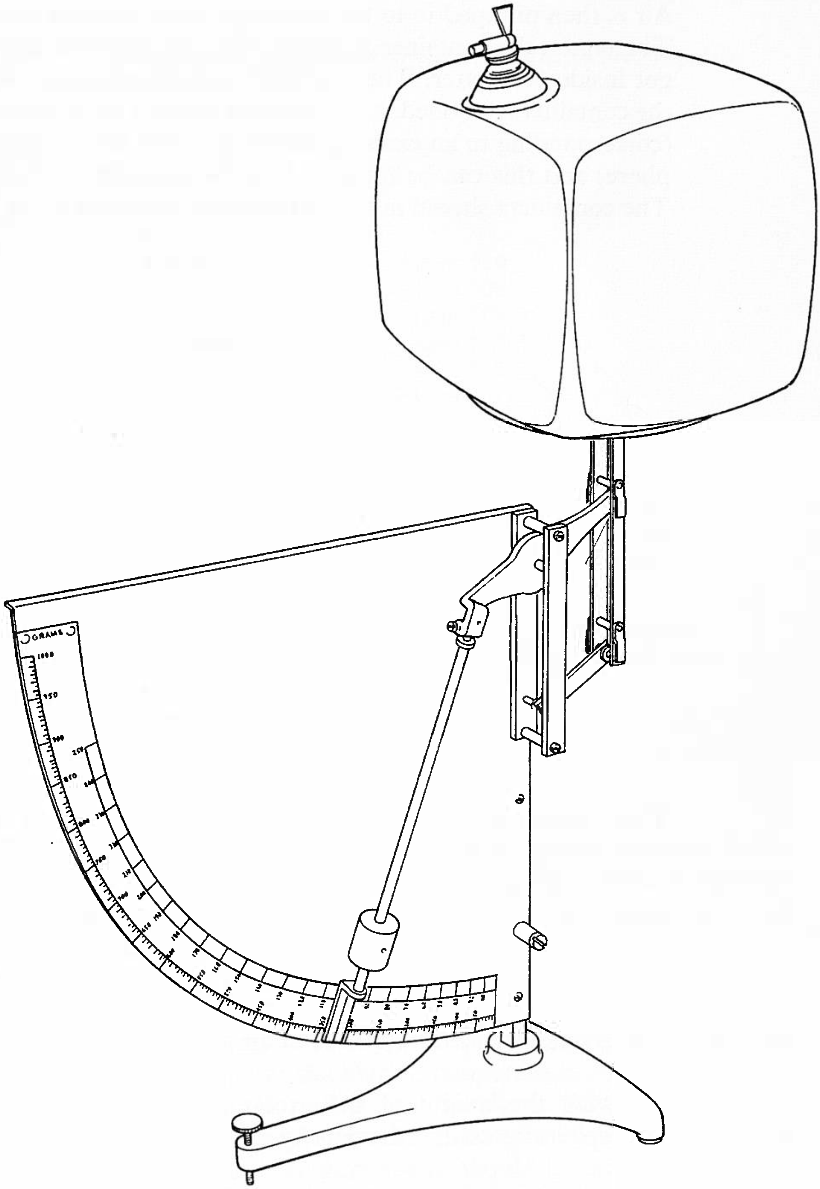
2 plastic containers with tap (at least 1 ft × 1 ft × 1 ft)	– item 10E
1 foot pump with pressure-gauge	– item 45
1 Perspex box (10 × 10 × 11 cm.)	– item 10D
1 lever-arm balance	– item 42
1 large transparent trough	– item 532

Two plastic containers are recommended for this experiment, so that there is a spare one available.

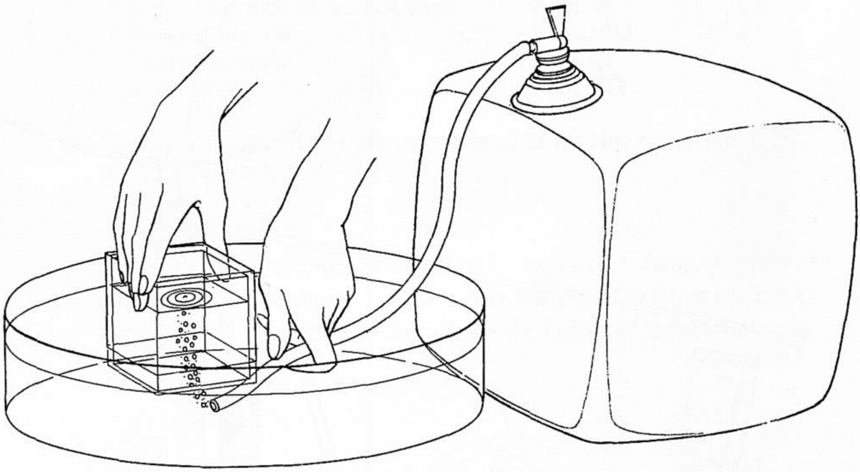
Procedure

The plastic container is weighed by hanging it from the pan of the lever-arm balance. Then a 3 ft length of rubber tubing is attached to the outlet, the air inside being at normal atmospheric pressure.




GRAMS
1000
950
900

Air is then pumped in to the container using the foot pump. The tap on the container is closed. The more air that can be got inside the better. The container is weighed again. With the containers provided, a difference of about 8 gm is possible (corresponding to an excess pressure of about half an atmosphere) and this can be measured on the lever-arm balances. The containers should not go further than about 25 lb/sq. in.



The rectangular Perspex box is immersed full of water in a large trough of water with the open side downwards. The rubber tubing is put in the water with the end of the tubing well under the inverted box. The tap is opened until the box is filled with excess air. The tap is closed, the air in the box is released to a height of 10 cm and the box is again immersed. The process is repeated several times until no more excess air comes out. Each time 1,000 cc of air are released.

Knowing the weight of the excess air and its volume at atmospheric pressure, the density can be found.

19 *Class experiment*

Examples of solids turning into liquids and liquids into gases

Apparatus

16 Pyrex test-tubes (say, 75 mm × 10 mm)	– item 546
16 test-tube holders	– item 526
16 Bunsen burners	– item 508
16 asbestos mats	– item 509
16 beakers (400 ml)	– item 512/2
16 tripods	– item 511
16 microscope slides	– item 3G
ice	
solder (not cored)	
lead strip	
iron wire or steel wool	
sulphur	
naphthalene	

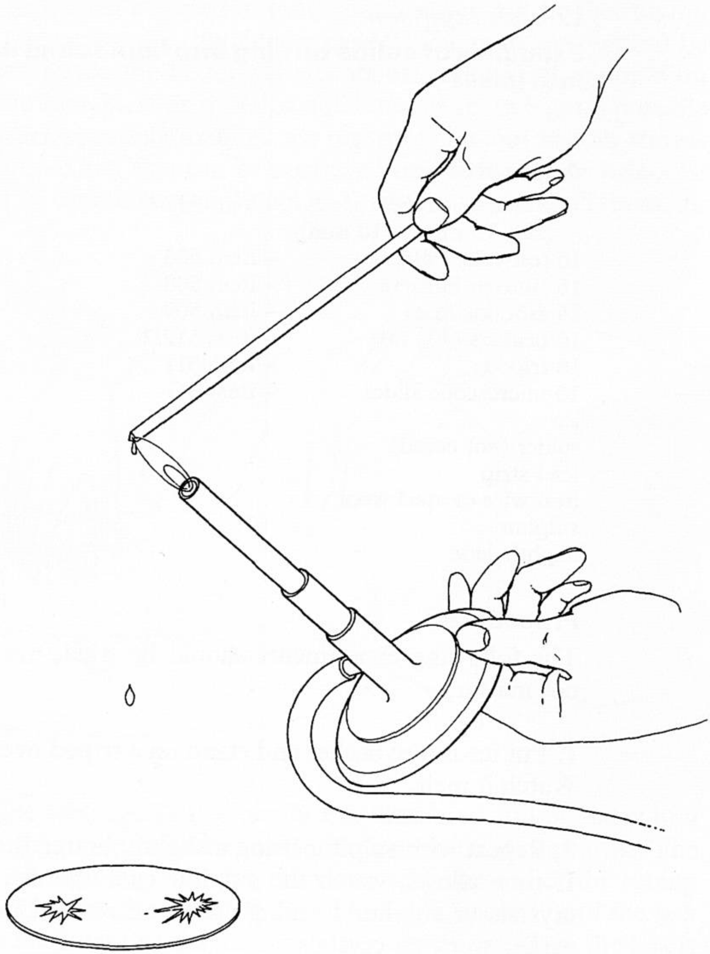
Procedure

The following experiments should be tried, the order does not matter:

1. Put ice in the beaker and stand on a tripod over a Bunsen. Watch it melt.

2. Repeat with sulphur using a slightly hotter Bunsen flame. If time allows, watch the sulphur cool and see monoclinic crystals of sulphur forming: this will remind pupils of the earlier work on crystals.

3. Hold the Bunsen at 45° so that the centre of the flame is vertically over the centre of the asbestos pad. Adjust the Bunsen flame for the highest temperature. Stick the end of a short length of solder into the flame. Molten solder will splash on to the asbestos. Resin-cored solder may make small flashes of flame, so pure solder should be used. The Bunsen should be at 45° to avoid solder falling back into it.



4. As 3 using a short length of lead strip either held in a Bunsen flame or placed in a tin-lid with the flame directed on it.

5. As 3 using iron wire. Pupils might try copper wire too.

6. Boil a little water in the beaker or test-tube. It takes a few minutes to boil dry. This experiment could obviously be a continuation of 1 provided only a little ice was used.

7. Put a few drops of alcohol (methylated spirit) on to a piece of glass and see how quickly it evaporates to dryness. It helps to blow gently on it. Water will also evaporate in this way, but it takes much longer. Pupils should also dip their fingers in alcohol and water and observe the evaporation.

8. *Optional.* Some crystals of naphthalene heated in a test-tube. This must be done in a test-tube as molten naphthalene catches fire in an open dish. Alternatively, the tube containing the naphthalene may be heated by holding it in a beaker of boiling water.

20a *Demonstration*

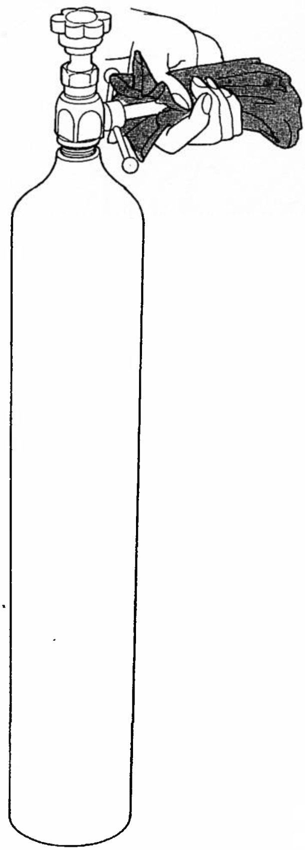
Solid carbon dioxide turning into gas

Apparatus

1 carbon dioxide cylinder	– *item* 19/1
1 dry ice attachment	– item 19/2
1 balloon	

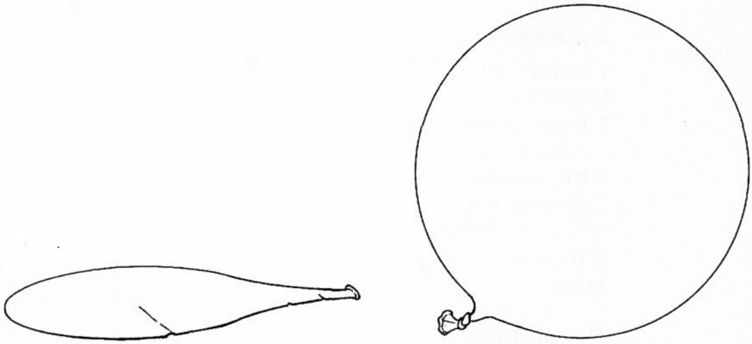
Preparation of solid carbon dioxide

To obtain some solid carbon dioxide from the cylinder, fold a piece of closely woven cloth (preferably of dark colour) in the form of a bag. Hold this bag tightly round the nozzle of the cylinder and open the valve at full blast for five to ten seconds. Where the cylinder is of the syphon type it should be kept upright, but if it is an ordinary cylinder it should be held upside-down during this process. See also the note opposite.



Procedure

Stretch the neck of the balloon and hold it open with several fingers whilst about half a teaspoonful of the carbon dioxide snow is scraped off the cloth and poured in. Quickly flatten the balloon and knot the neck firmly.



Note

Some teachers may prefer to purchase a block of solid carbon dioxide instead of using the CO_2 cylinders and the dry ice attachment. See Section C of the *Nuffield Guide to Physics Apparatus* for details on the availability of solid carbon dioxide in block form for use in schools.

20b *Optional demonstration*

Change of volume: water to steam

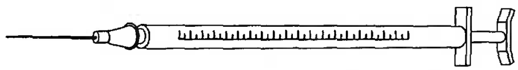
(This optional demonstration is probably better postponed until a later year.)

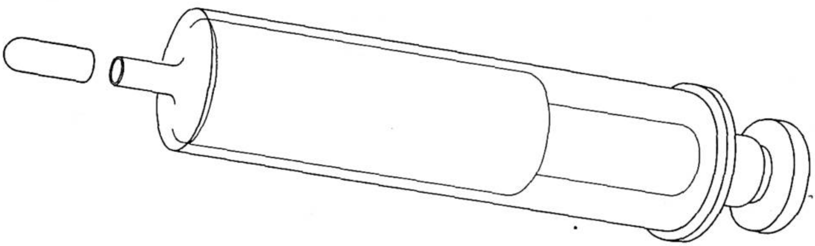
Apparatus

1 syringe kit	– item 148
including	
1 large syringe	
1 rubber cap	
1 hypodermic syringe	
2 Bunsen burners	– item 508
2 deep beakers	– item 513
2 tripods	– item 511
brine	

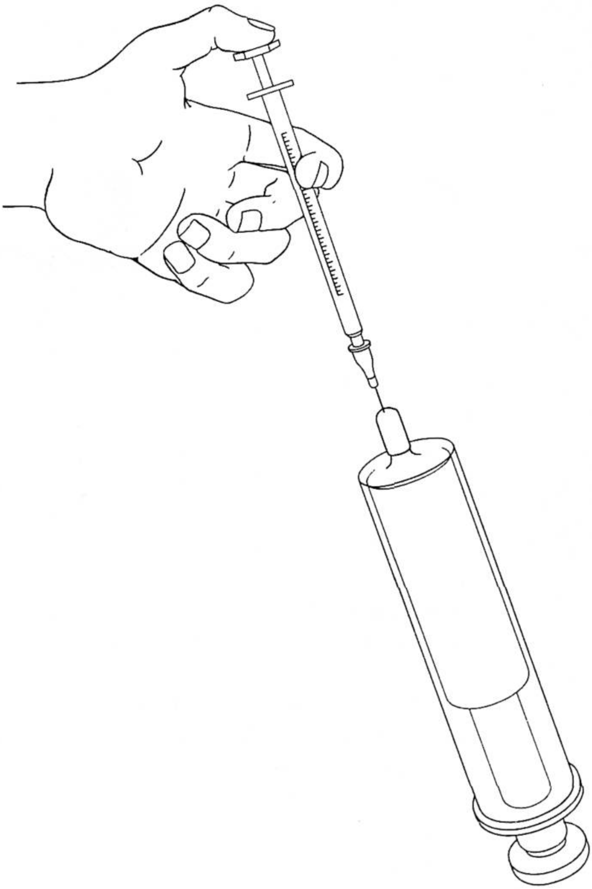
Procedure

As it takes time to heat the syringe, it is recommended that the syringe be pre-heated in advance before the arrival of the class.

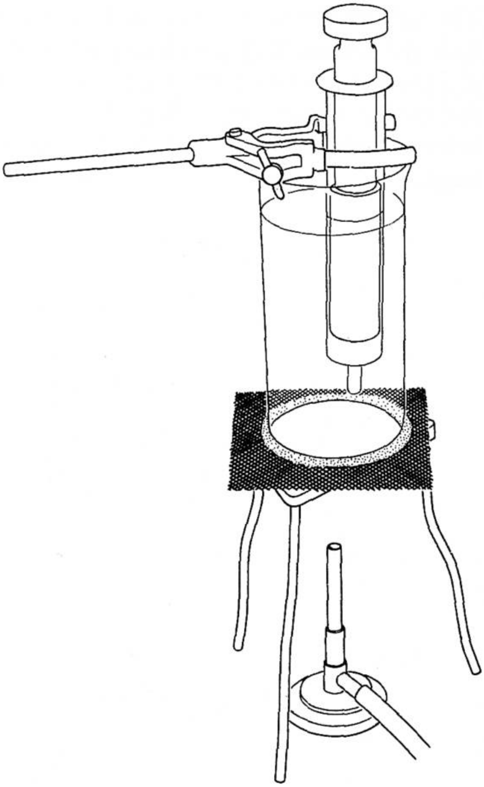




The rubber cap should be fitted over the end of the syringe with the piston of the syringe pushed down to zero volume and the whole immersed in a deep beaker (1000 ml) of water and brought nearly to boiling. The second beaker containing brine should also be brought to boiling before the lesson begins.



For the demonstration, partially fill the hypodermic with water. Remove the large syringe from the hot water. If necessary, hold in a clamp attached to a retort stand. Invert the hypodermic and eject any air in it and then inject 1/10 ml of water through the rubber cap into the syringe. The cap 'seals' up on removing the needle.



Immerse the large syringe in the boiling brine. The water will turn to steam and the volume change will be observed.

After the water has all turned to steam, the syringe should be removed so that the steam condenses back to water and the decrease in volume will be seen.

Notes

1. It is essential that the syringe be internally dry before use.

2. Twisting the piston as the volume changes may be helpful, though pupils will doubtless call this cheating unless the decrease in volume on condensation is also shown.

3. The caps provided are tight fitting: this is essential as otherwise they can be blown off.

4. Precise results will not be obtained from this experiment. The accuracy of the experiment will show an order of magnitude: 0·1 ml of water becoming at least 100 ml of steam. (The recognized value is a change 1 : 1600.)

21 *Demonstration*

A simple balance

(This is an essential introduction to the microbalance class experiment.)

Apparatus

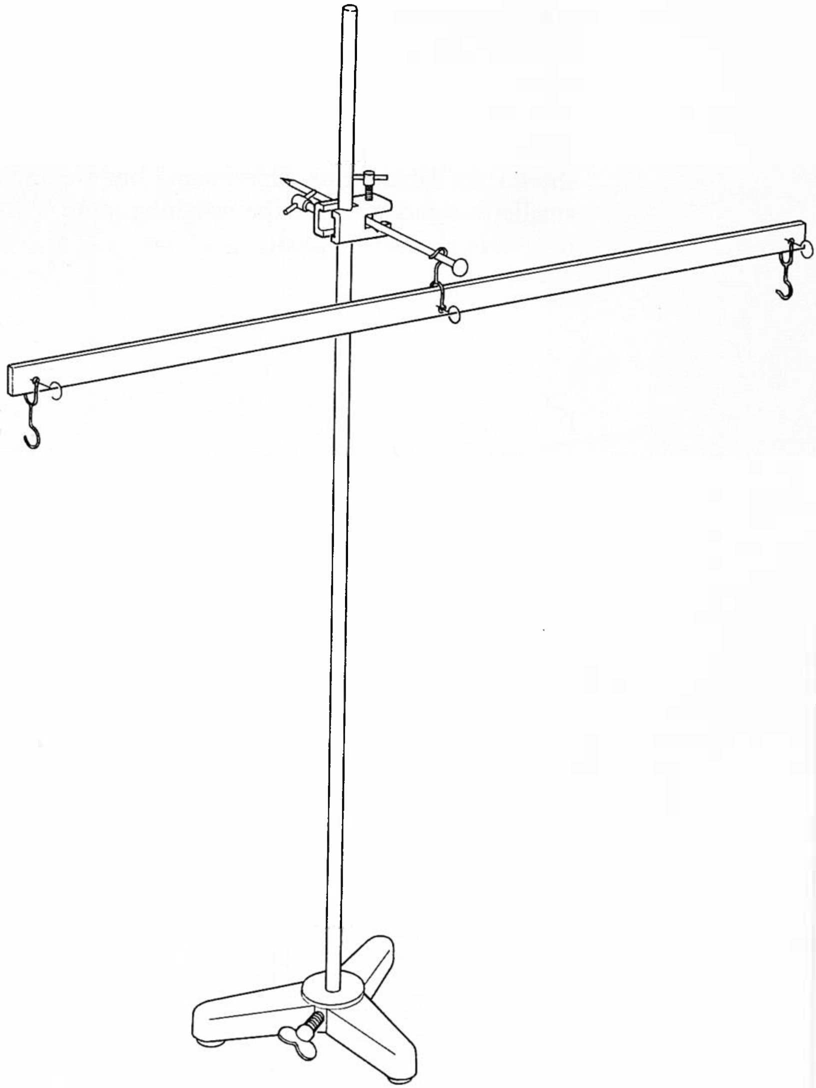
1 crude balance	– item 10C
1 retort stand, boss and clamp	– items 503–506
1 weight hanger with slotted weights (10 gm)	– item 31/1
1 weight hanger with slotted weights (100 gm)	– item 31/2

Also required are objects for weighing, such as a small parcel (about 1 lb) and a letter (about 2 oz).

Procedure

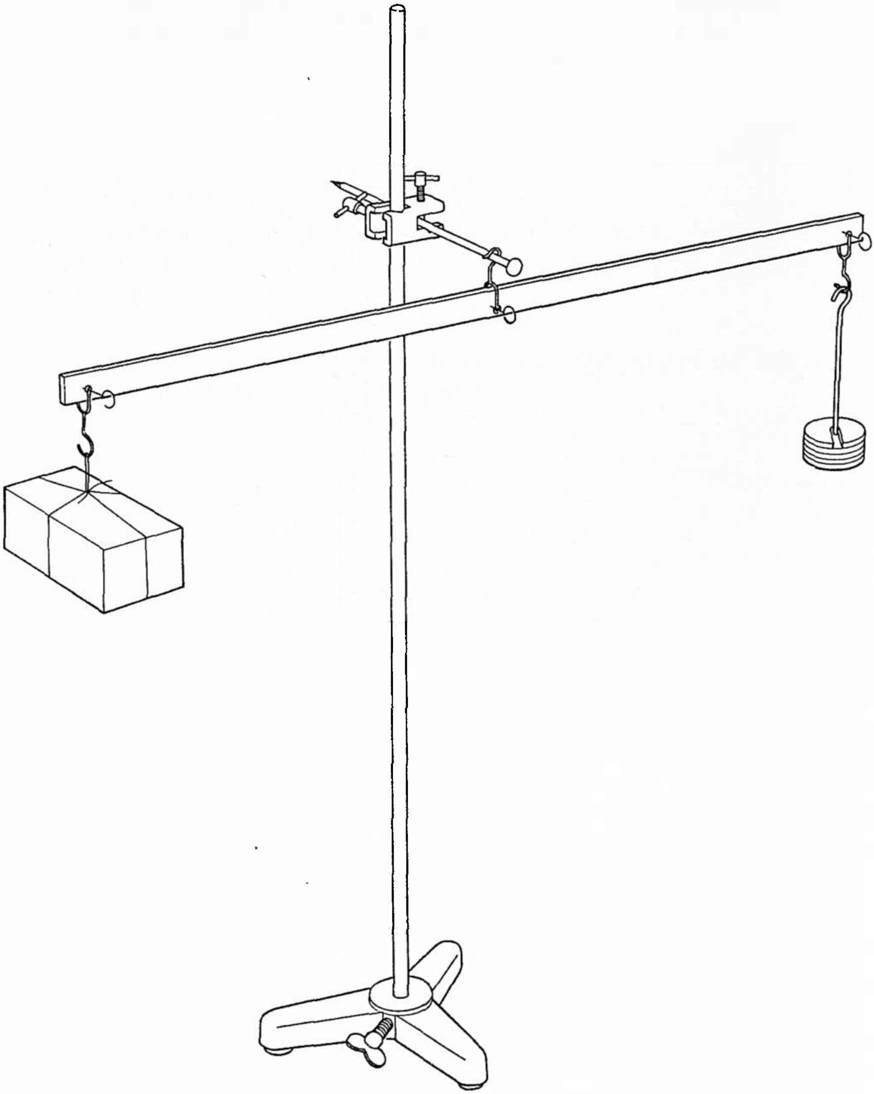
Suspend the simple lever by one of the hooks positioned centrally. It is convenient to support the hook from a clamp attached to a retort stand by a boss.

The other two hooks are positioned near the ends of the lever at equal distances from the centre.



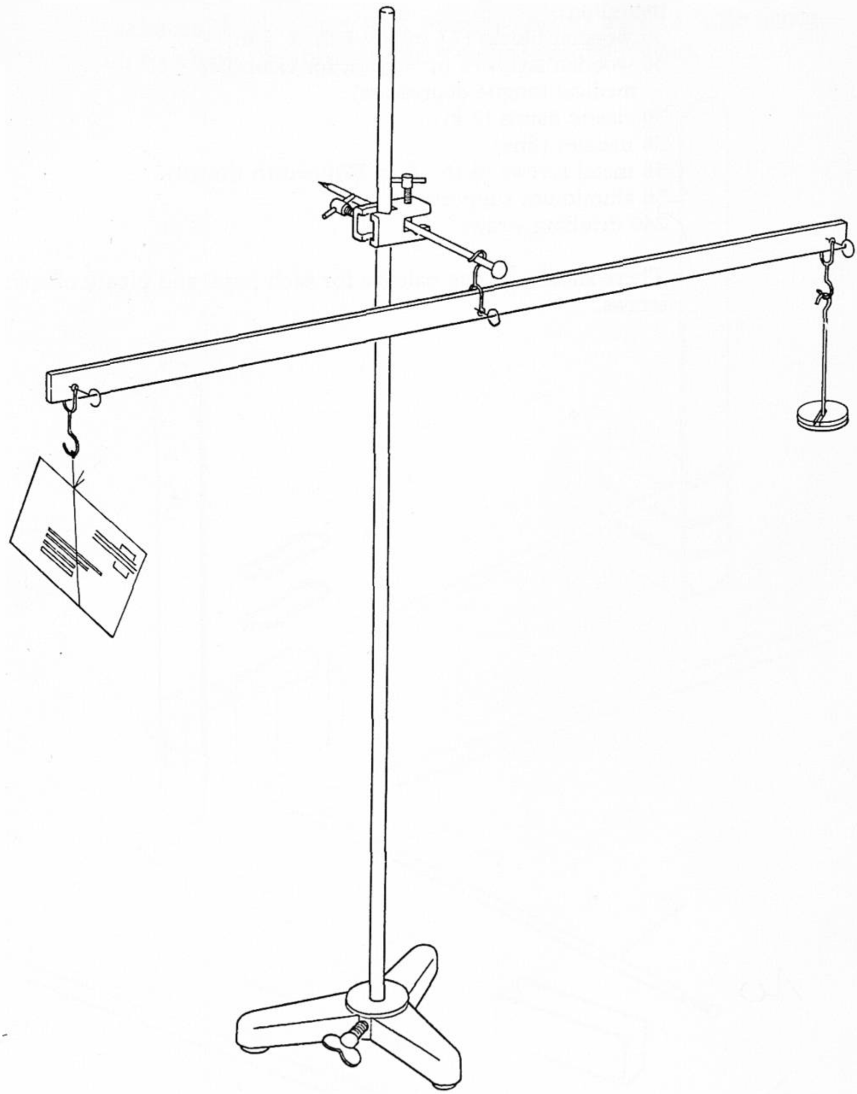
a. Weigh a small parcel (about 1 lb), using a 100 gm hanger and 100 gm slotted weights on one side, the parcel on the other.

Since this is only a demonstration to introduce a problem we should not labour this experiment; but we should not add smaller weights to make the weighing more 'accurate'. It is only a rough measurement.



b. Weigh a letter to the nearest 10 grams by the same method, using the 10 gm slotted weights (item 31/1).

c. Ask whether the beam will weigh a single hair. It fails, and that leads to the microbalance class experiment.



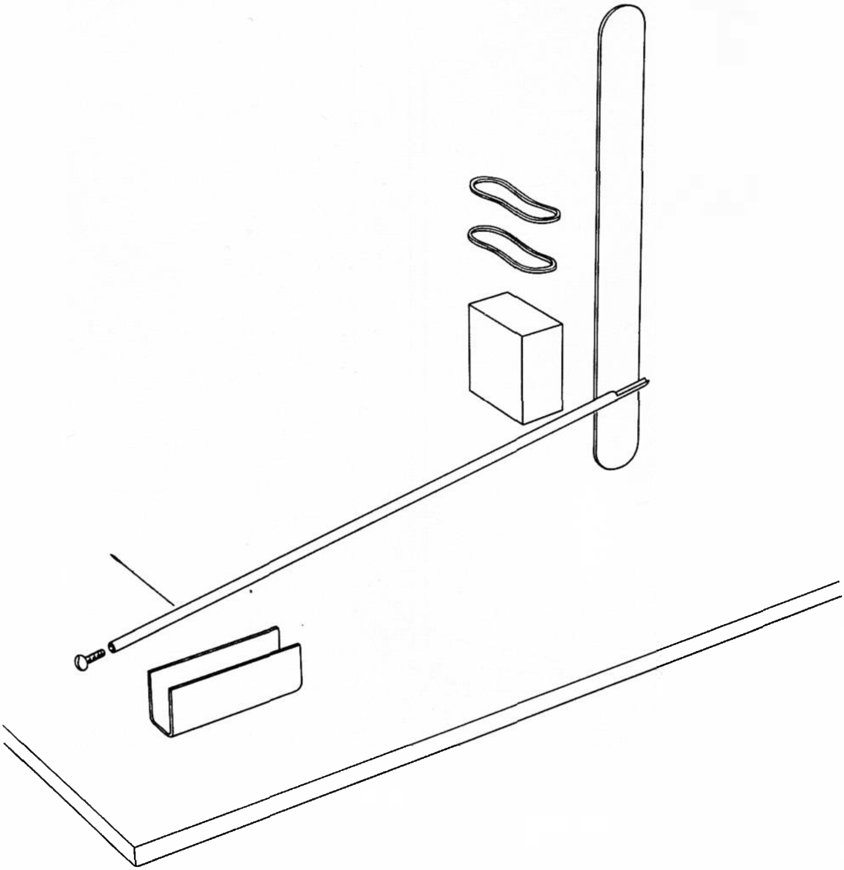
22 Class experiment

Making a microbalance

Apparatus

1 microbalance kit – item 4
including:
36 wooden blocks ($1\frac{1}{2}$ in × $1\frac{1}{2}$ in × $\frac{3}{4}$ in)
36 wooden strips (6 in × $\frac{3}{4}$ in, for example, medical tongue depressors)
36 elastic bands (2 in)
36 needles (fine)
36 metal screws ($\frac{1}{2}$ in, $\frac{5}{32}$ in Whitworth thread)
36 aluminium supports
240 drinking straws

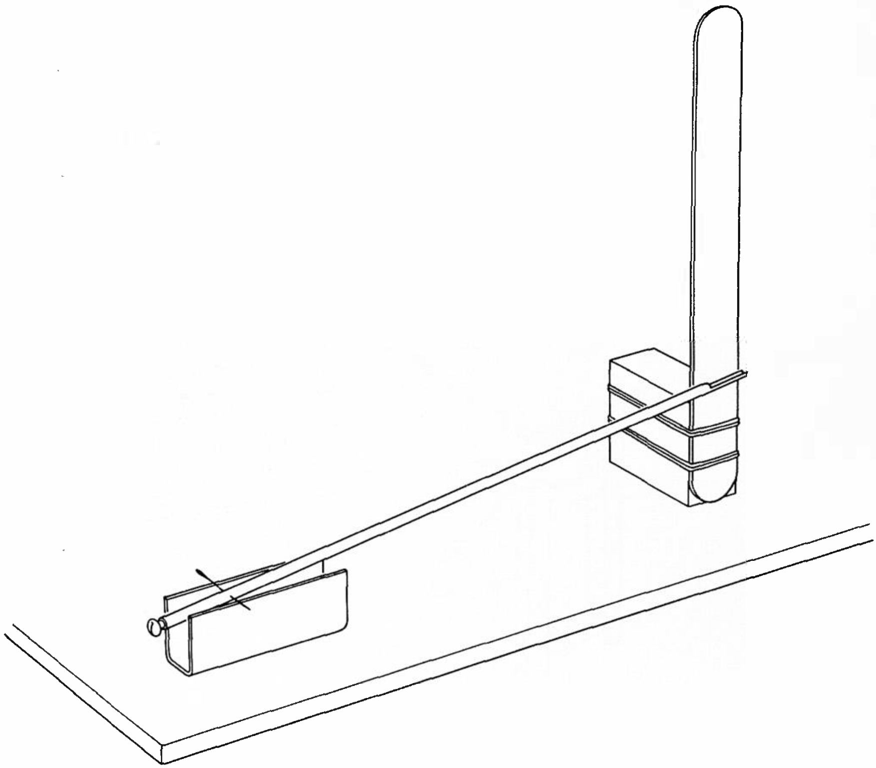
There should be one balance for each pupil and plenty of spare straws.

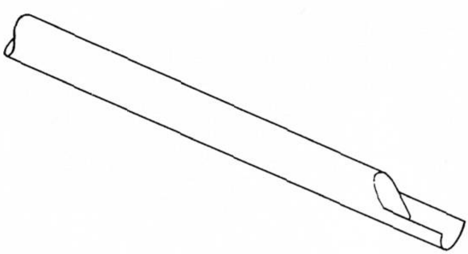


Procedure

The wooden strip is fixed to the wood block as illustrated using the elastic band twisted twice round the block.

The small metal screw is inserted in one end of the drinking straw, the other end is cut away with a razor-blade (or scissors) both to act as a pointer and to make a little scoop into which the things to be weighed can be placed.





The approximate centre of gravity can be found by balancing the straw on the needle. The needle is then put through the straw to act as the rolling axle: it should be put through just above the long axis of the straw. How high up on the cross-section of the straw determines the sensitivity, but pupils are left to find this out for themselves. However, slower pupils may need help. When help is given the teacher should take away the 'right' straw he has set up and give the pupil a new straw.

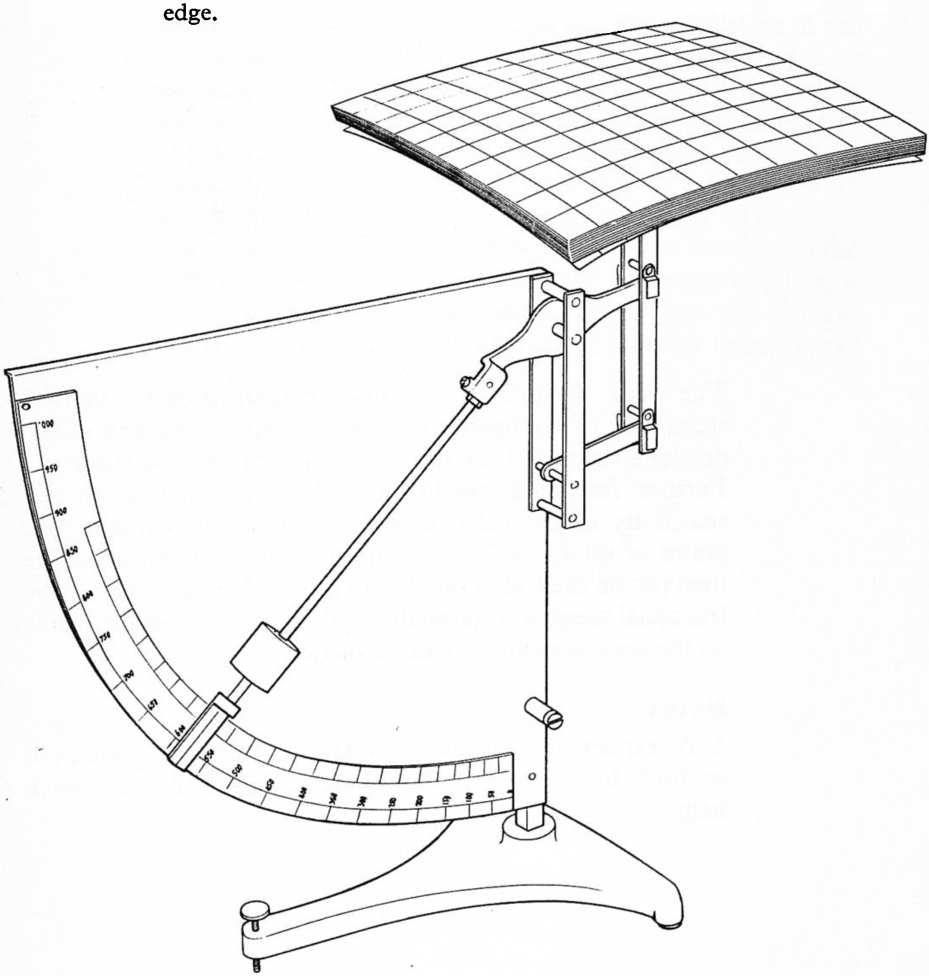
23 Class experiment

Making weights for the microbalance using a pile of paper

Apparatus

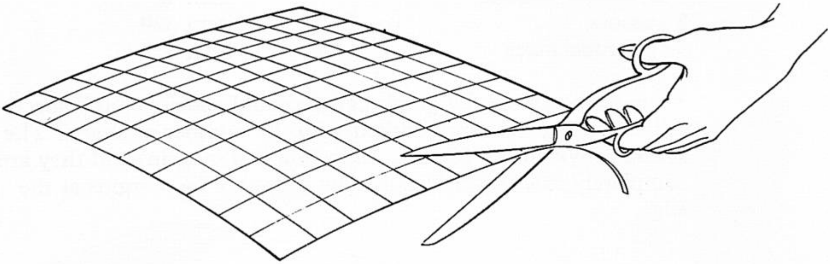
1 packet of special graph paper*	– item 10B
1 stack of loose sheets of same paper	– item 10B
1 lever-arm balance	– item 42
8 scissors	– item 529
32 microbalances	– item 4

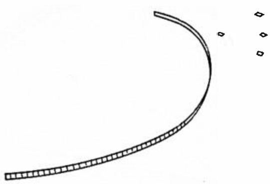
*The packet of special graph paper should consist of 100 sheets sellotaped together and marked with the number of sheets. The sheets provided are 10 in × 10 in (marked in $\frac{1}{10}$ in) and they are completely ruled with lines so that there are no margins at the edge.



Procedure

The pile of graph paper is weighed on the level balance (with one pile of 100 sheets of paper, each 10 in $\times$ 10 in, the weight was approximately 500 gm). Arithmetic will give the weight of one sheet. Further arithmetic will give the weight of, say, one small 1/10th inch square. Thus a series of fractional weights can be made.





The 'zero' position of the pointer is marked on the vertical scale. One of the fractional weights is put on the end of the drinking straw and the new position is marked on the scale. Further fractional weights are added (depending on the sensitivity of the balance) and the positions marked. The grains of sand, the hair or other objects to be weighed are then put on the end of the drinking straw having removed the fractional weights. Intermediate positions between the marks on the scale are found by extrapolation.

Notes

1. As explained in the *Teachers' Guide*, the pupils should not be told this procedure: but slower pupils will need much help.

2. Should the pupils experience difficulty because grains of sand run up the straw when being weighed, the cut away portion should not be completely severed at the top and should then be pushed in to act as a plug.

3. It is not possible for manufacturers to supply this graph paper with the weight held accurately to 500 gm per 100 sheets. Changes in humidity and details of manufacture will make batches vary from each other; so teachers will find 100 sheets weighing anywhere between 450 and 550 gm. Since this is only a quantitative extension of the main experiment – which is for each child to construct his own microbalance and make it work – we should not insist on great precision in making the little weights for the balance. Teachers, themselves, will appreciate the wisdom of using a rough round number 500 gm per 100 sheets, so that the calculation of the size for a 'unit weight' is easy. However, pupils may well be dismayed by this 'inaccuracy' of taking 500 gm as a close enough measure for, say, 460 – the 8 per cent difference might seem to them to spoil the experiment, unless they are already in the right frame of mind to accept it. Therefore we suggest that teachers should discuss this matter of accuracy and a rough round number with pupils before starting on the making of weights. By advertising the advantage of taking a round number and giving some assurance that the weights will still be very useful, teachers can avoid some unhappiness and save considerable time.

24 Class and home experiments

Measuring lengths in centimetres

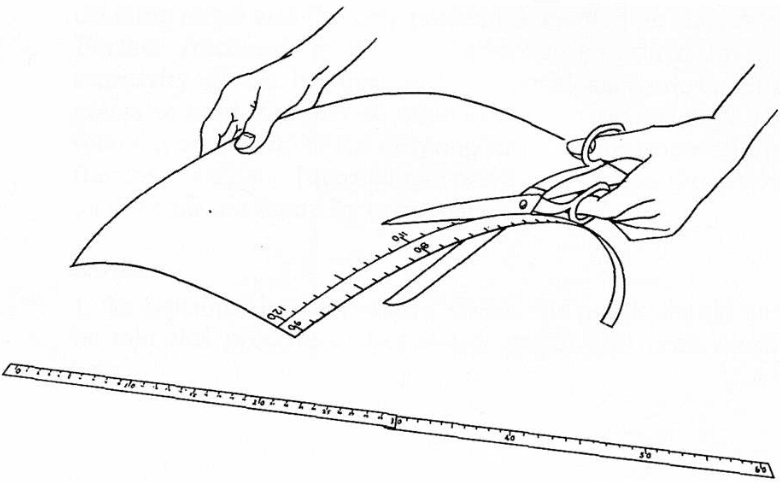
Apparatus

16 metre rules – item 501
32 paper scales – item 33

Procedure

a. In order to start the use of metric units, each pupil is asked to measure the length and width of a sheet of paper, in centimetres, and write them down in his notebook and work out the area. This is not the time to continue with a series of measurements, or give a lesson in formal record-making – those come in another experiment soon (Experiment 28), and this experiment is meant simply to give an introduction to centimetres.

b. We also give each pupil a centimetre scale of paper to take home and keep. This is a sheet of thick paper with sections of cm scale printed on it. General directions and suggestions of things to measure are printed in the middle of this sheet. The sections can be cut out and joined with paste or paper clips. We ask each pupil to take his scale home and use it to measure the height of some grown-up person there, the width of his own hand and length of his foot, the length of the longest table in the house, and the height from floor to ceiling, etc., and bring a note of them back.



25 Class experiment

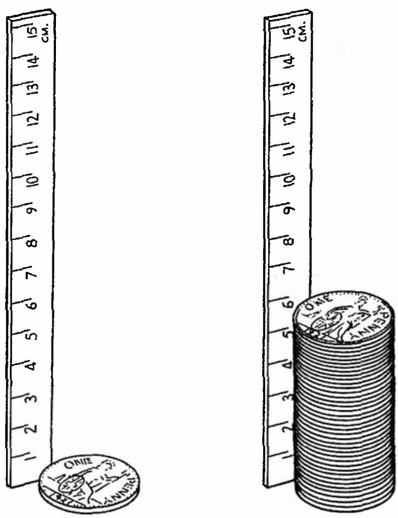
Measuring the thickness of a penny

Apparatus

large supply of pennies
32 rules with graduations in mm
(metre rules, item 501, will suffice)

Procedure

After first guessing the thickness of the pennies, the pupils should try to measure them with the rule. See *Teachers' Guide* for a discussion on how the roughness of this should lead the pupils to suggest measuring a pile of pennies stacked on each other.



26 *Class experiment*

Measuring the thickness of a sheet of paper

Apparatus

6 or more large packets of paper each containing a known number of sheets (e.g. 500). (Books may also be used.)
32 sheets of the same paper
32 rules with mm graduations (metre rules, item 501, will suffice)

Procedure

The pupils have already measured the length and breadth of a sheet of paper and the thickness of a penny. The difficulty of measuring the thickness of a sheet should lead to measuring the thickness of a pile of a known number of sheets (say, 100 or 200).

Alternatively, a textbook can be used, but beware of the factor $\frac{1}{2}$, since a book has half as many leaves as pages.

27 *Optional class experiment*

Measuring the thickness of aluminium leaf

Apparatus

8 books of aluminium leaf – item 10G
16 plastic measuring rules – item 25
32 microbalances – item 4

Each pupil will need two pieces of aluminium leaf, each 5 sq. cm.

The microbalance should be the pupil's own balance made in Experiment 22. He will also require the microbalance weights made in Experiment 23.

Procedure

The teacher should put the problem of how the thickness of the aluminium leaf can be measured. It is not possible to adopt the procedure of the previous experiment and measure the thickness of a pile of aluminium leaf.

The best procedure is to use the microbalance to find the weight of a known area of aluminium leaf (5 sq. cm), screwed up into a ball. The density of aluminium has already been found, so the volume of the leaf can be calculated. Since the area was known, the thickness can be estimated.

28 *Class experiment*

Practice with metric measurements of length

Apparatus

16 metre rules – item 501
16 foot rules – item 502

There should be one of each of the above for every two pupils and the metre rules should preferably be graduated in both metres and inches.

Procedure

In order to give familiarity with metric units, each pupil is asked to make the following measurements and record them formally in his notebook (see suggested form in *Teachers' Guide*):

the length of a sheet of paper,
in inches, in centimetres and in metres

his own height,
in centimetres and in metres.

Pupils are asked to compare (with the help of rulers) a metre and a yard. They are asked about the difference between a 100-yard race and a 100-metre race.

Then, as an optional experiment, pupils may be asked to measure in millimetres a small diameter such as that of a sewing needle or a French nail. That will call for some ingenuity, drawing upon the earlier experiment with a pile of pennies.

29 *Class experiment*

Guessing measurements

Apparatus

1 metre rule	– item 501
1 foot rule	– item 502
1 stop-clock or stop-watch	– item 507
1 measuring tape (optional)	
8 1 lb weights	– item 36
8 1 oz weights	– item 37
16 1 kg weights	– item 32
16 100 gm weights	– item 31/2 from
1 lever-arm balance	– item 42

Purpose

This experiment is to make the pupils familiar with the idea that rough estimates are a good part of science and to give them practice and confidence in guessing. It is deferred until now so that pupils have acquired some familiarity with metric scales.

Procedure

For a discussion of the estimates to be made see *Teachers' Guide*.

30a *Class experiment*

Measuring time intervals

Apparatus

16 stop-clocks or stop-watches	– item 507
several metre rules	– item 501

Procedure

Some rough measurements of time should be made to gain familiarity both with time intervals, such as the time between hand claps, the time for a book to drop, the time to walk or run a given distance.

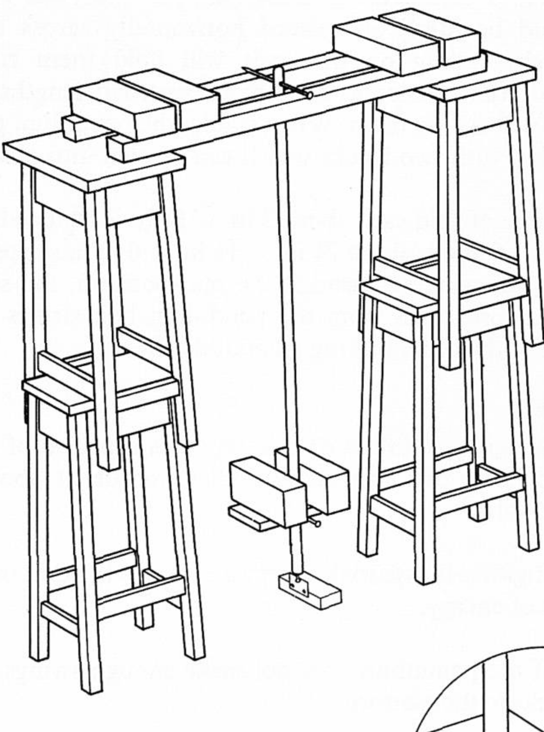
30b *Demonstration*

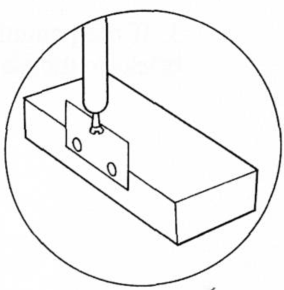
Time intervals using a heavy pendulum

Apparatus

1 broom handle – item 10F
1 wooden platform – item 10F
2 6 in nails
4 bricks
2 cross-beams of wood
laboratory stools

The basic parts for the heavy pendulum are included in the Year 1 general kit (item 10F), they are of course easily improvised as there is nothing special about them.





Construction

A broom handle is drilled about an inch from the end to take a 6 in nail.

A wooden platform about 8 in $\times$ 3 in $\times$ $\frac{3}{4}$ in, with a hole in it to take the broom handle, is pushed over the handle and is secured in place by a second nail pushed through a hole drilled in the lower end of the handle. This second hole should be about 110 cm below the top hole.

A 1 in round-headed screw is then screwed into the bottom of the broom handle so that the head projects about $\frac{1}{2}$ in.

A suitable number of laboratory stools is erected on the bench. Two lengths of wood (not provided, but 2 in $\times$ 2 in would be ideal) are placed horizontally across the stools. (Bricks resting on the ends will hold them rigid.) The pendulum is supported from these wood lengths, the 6 in nail will roll on them. When stable, the pendulum platform is loaded with two bricks which can be tied into place.

A piece of thin card about 3 in $\times$ $1\frac{1}{2}$ in is fastened to a small block of wood (about $2\frac{1}{2}$ in $\times$ $1\frac{1}{2}$ in $\times$ 6 in) and positioned so that, in swinging through the mid-position, the screw head which protrudes from the pendulum bob strikes the broad side of the card, making an audible click.

Notes

1. A rigid pendulum of this type has a period of about two seconds so that the audible clicks occur at about second intervals.

2. Rigidity is essential, otherwise there will be an unnecessary loss of energy.

3. If the pendulum does not make enough swings, add more bricks to the platform.

4. It is worth noting that the period of the pendulum will not be altered when the bob strikes the thin card provided the card is placed so that the contact occurs in the mid-position.

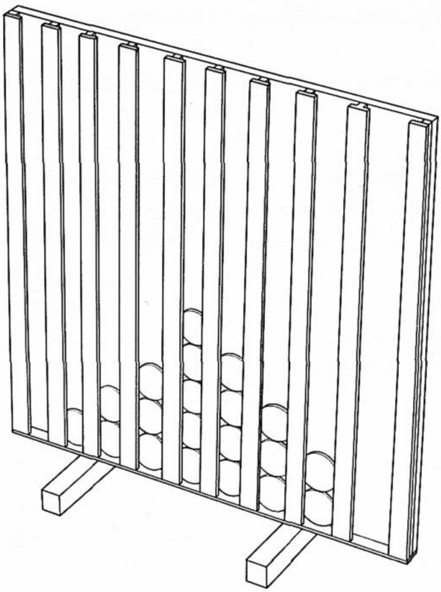
5. The sound can be reinforced by sticking the card to part of a balloon, which is stretched tight and tied over the top of a 1000 ml beaker.

31 *Demonstration*

Introduction to statistics using a tally

Apparatus

1 statistics frame – item 48



Procedure

The statistics frame is set up in front of the class: it can be used with brass blanks or with pennies. It incorporates nine slots.

If the pupils know their own weights, each slot can be ascribed to different weights: up to 10 kgm, 20, 30, 40, 50, 60, 70, 80, 90 kgm. A brass blank is inserted for each pupil, but it will soon be apparent that one or two slots are over full. Discussion should lead to spreading out the histogram and 'shifting' the origin: the first slot might be 35-40, the next 40-45, the next 45-50 and so on. An even larger spread might then be tried.

Secondly, the board can be used for recording results when all the pupils make the same measurement (for example, weighing a given block of material). This will show the statistical spread of the readings.

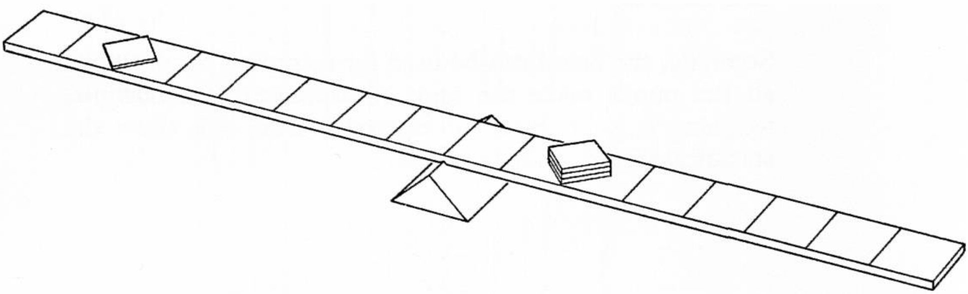
32a *Class experiment*

Empirical methods: an investigation leading to the Lever Law

Apparatus

16 wooden beams	– item 5A
16 triangular fulcrums	– item 5B
160 special square pennies	– item 5C

The necessary items are all contained in the lever kit (item 5). There should be one beam for every two pupils.



Procedure

The wooden beam is supported symmetrically with the groove in the beam resting on the top of the triangular fulcrum.

Should the beam not balance, a drawing-pin and a paper-clip should be installed in an appropriate position underneath to ensure a balance.

The pupils should be asked to make the see-saw balance with piles of brass plates ('square pennies') as though weighing sweets.

For a full discussion see *Teachers' Guide*.

The brass plates have been deliberately cut square so that they can be placed on the beam with their diagonals along the lines ruled on the beams.

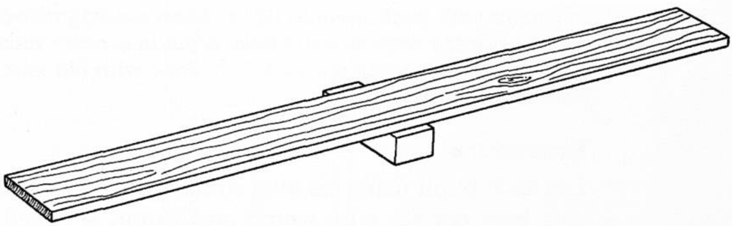
32b *Demonstration*

Use of a see-saw to weigh a child

Apparatus

1 wooden plank (6 to 8 ft long, at least 8 in wide and 1 in or more thick)
1 brick or wood block, as fulcrum
1 metre rule – item 501
16 1 kg weights – item 32

The wooden plank is not provided: it is assumed the teacher can find one.



Procedure

The plank is balanced on the brick as shown and the pupil is asked to stand or sit on it at a distance of, say, 2 ft from the brick. Kilogram weights can be added at the other end until the balance is achieved.

For discussion see *Teachers' Guide*.

33a *Class experiment*

Empirical investigation of home-made springs of copper wire

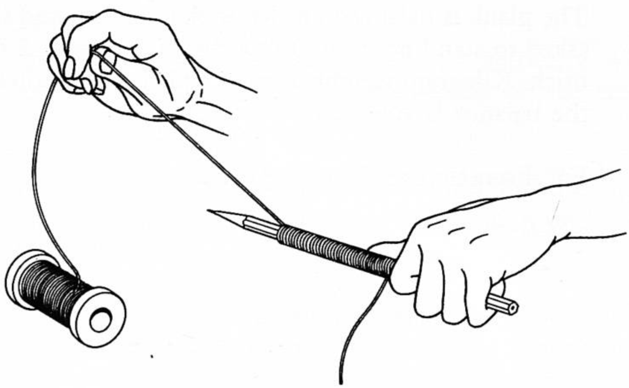
Apparatus

8 2 oz reels 26 swg bare copper wire	– item 2C
32 retort stands	– items 503–504
32 bosses	– item 505
32 6 in nails	– item 10H
16 weight hangers with slotted weights (10 gm)	– item 31/1
16 metre rules	– item 501

New copper wire must be used for this experiment for two reasons: (*a*) old wire is often uneven in its hardness as the using of copper wire work-hardens it; (*b*) when winding wire on a pencil in the ordinary way, an extra twist is put in at every turn and that will lead to an uneven spring if it is done with old wire that already has twists.

Procedure

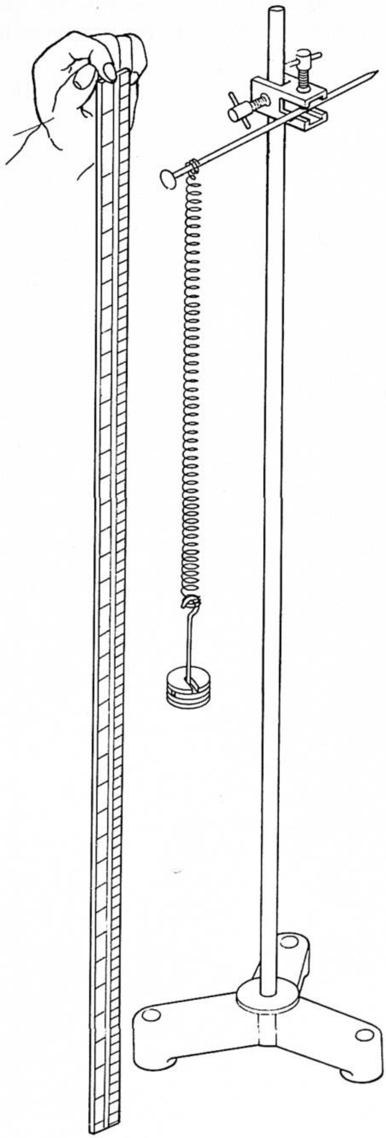
Let each pupil make his own spiral spring by winding the 26 swg bare copper wire round and round a pencil for 25-30 turns. Each pupil will require about 80-90 cm of wire. A twisted loop should be made at the ends.



The 6 in nail is put through the loop and fixed to the retort stand with a boss. The rule is held in a vertical position at the side of the spring.

The weight hanger should be attached to the springs and a series of equal loads (10 gm) added to stretch the spring, noting the change in length.

See *Teachers' Guide* for discussion of the scope of this experiment.



Note

It is important that each pupil should have his own copper wire spring and that he should damage his own and not merely watch his partner do it – that is merely frustrating. Although sufficient retort stands and bosses are available for each pupil to have his own (and of course he can wind his own copper spiral), there will have to be some sharing of the weight hangers, though some teachers may care to improvise so that even this sharing is not necessary.

33b *Class experiment*

Investigating simple steel springs

Apparatus

100 expendable steel springs	– item 2A
32 retort stands	– items 503–504
32 bosses	– item 505
32 6 in nails	– (item 10)
16 metre rules	– item 501
16 weight hangers with slotted weights (100 gm)	– item 31/2

The pupils should work in pairs, but there must be plenty of spare springs as they will be stretched beyond their elastic limit and replacements will be necessary.

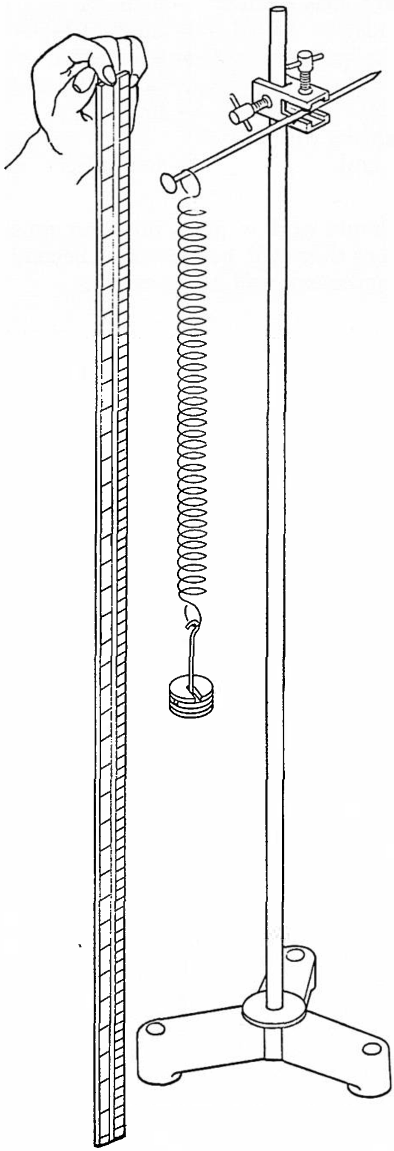
Procedure

The 6 in nail should be put through the loop in the end of the spring and secured to the retort stand with a boss. The 100 gm weight hanger is attached to the other end of the spring.

At first the pupils will hold the rule beside the spring when measuring the extension. Later they may come to appreciate the advantage of fixing the rule in a clamp attached to the same retort stand with a boss.

Preparation of the spring

The springs may be supplied with the last two turns at each end turned up and hard soldered (soft solder may give way). This could be done at school with a saving of cost, but it takes considerable time.



If the springs are supplied close-coiled, it is better to have the coils of the spring separated and this should be done before the springs are issued to the pupils. Hanging about 500-600 gm gently on the tightly coiled springs will do this.

Note

As in the previous experiment, 33a, it is important that each pupil should have his own steel spring, that he should damage his own and not be frustrated by merely watching his partner. Sufficient retort stands, bosses and supporting nails are available for each pupil to have his own and of course there must be plenty of the expendable springs. There will have to be some sharing of the weight hangers, though teachers may care to improvise so that even this sharing is not necessary. Extra rules will also be required, but these need not be metre rules – any foot rulers would do – and again it is assumed teachers will be able to improvise.

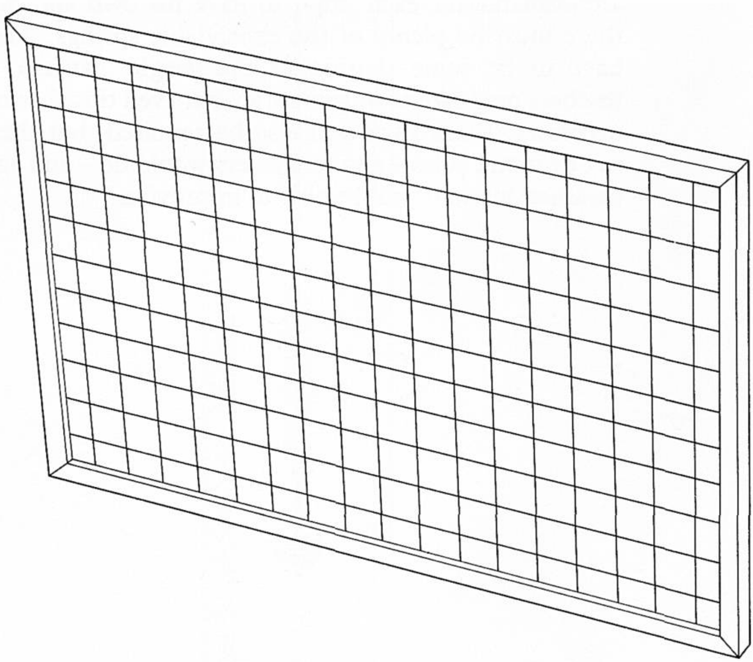
34 *Demonstration*

Graph plotting board

Apparatus

1 graph plotting board – item 149
1 chinagraph pencil – item 543

Alternatively, any blackboard with rulings can be used in place of the graph plotting board.



Procedure

As a first introduction to graph plotting, the board is set up in front of the class with the squared background behind the transparent plastic front.

Discussion will suggest plotting either extension or length against load and points can be put on the board using a chinagraph pencil.

The board can also be used for demonstration graphs throughout the course.

35 Demonstration

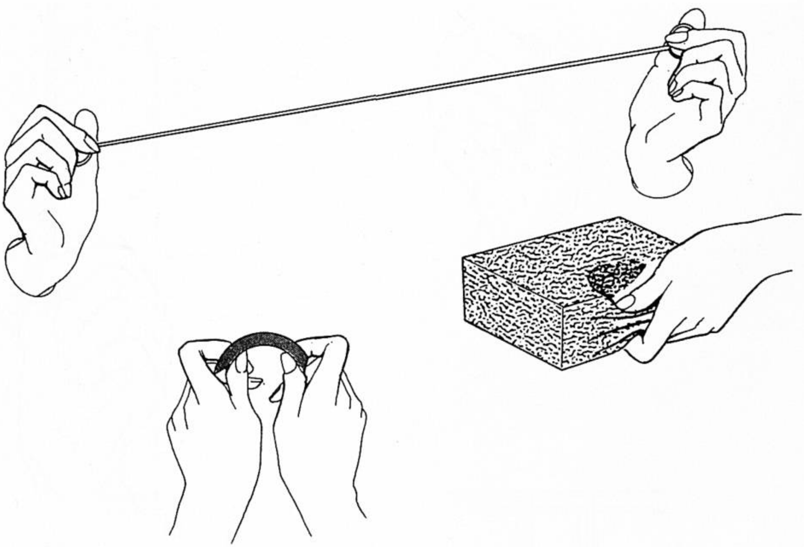
The stretching and compression of materials

Apparatus

8 wide steel springs	– item 2D
8 latex foam blocks	– item 2E
16 lengths of elastic cord	– item 2G
16 soft erasers for twisting	– item 2H

Procedure

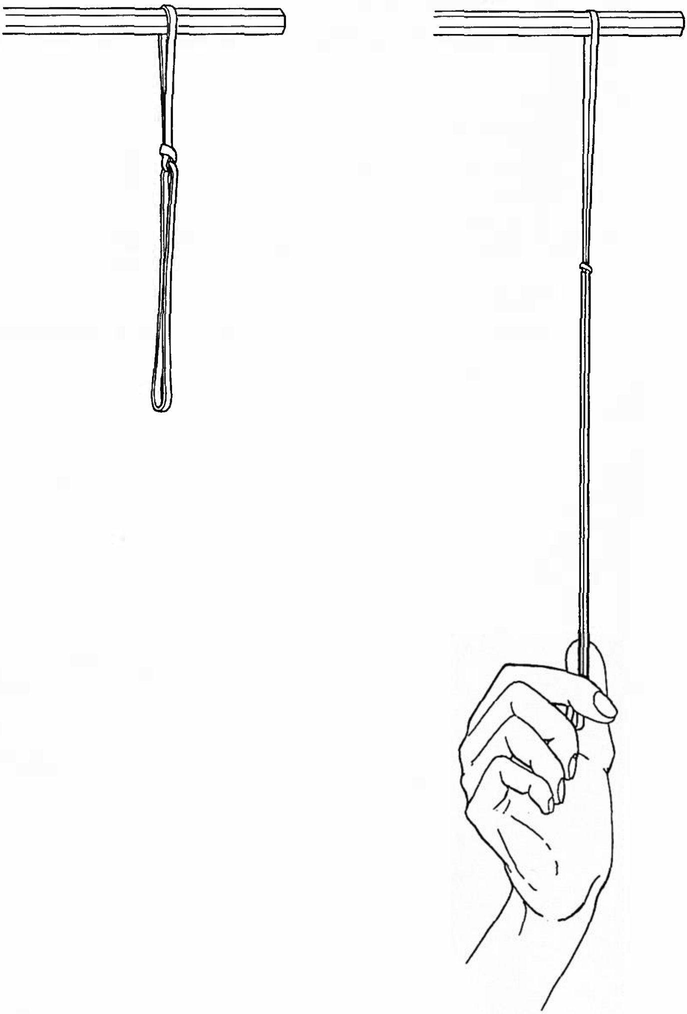
Pupils should try stretching and compressing various materials.

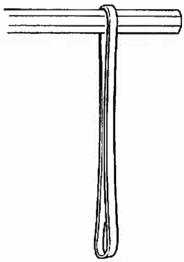


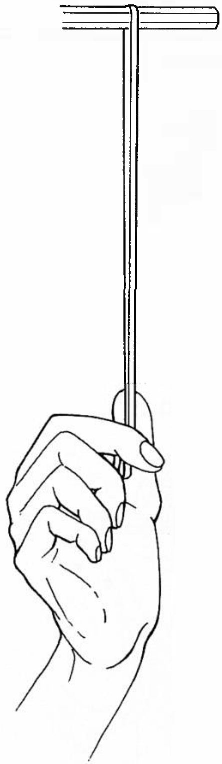
All this should go quickly as there are no clear conclusions or detailed records to be made: it is a matter of increasing experience.

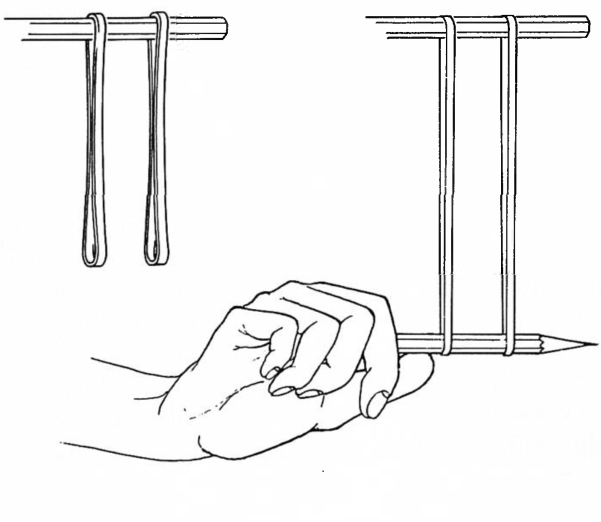
Home experiment

Pupils might explore at home the effect of loading single, double and triple rubber bands in series and in parallel.







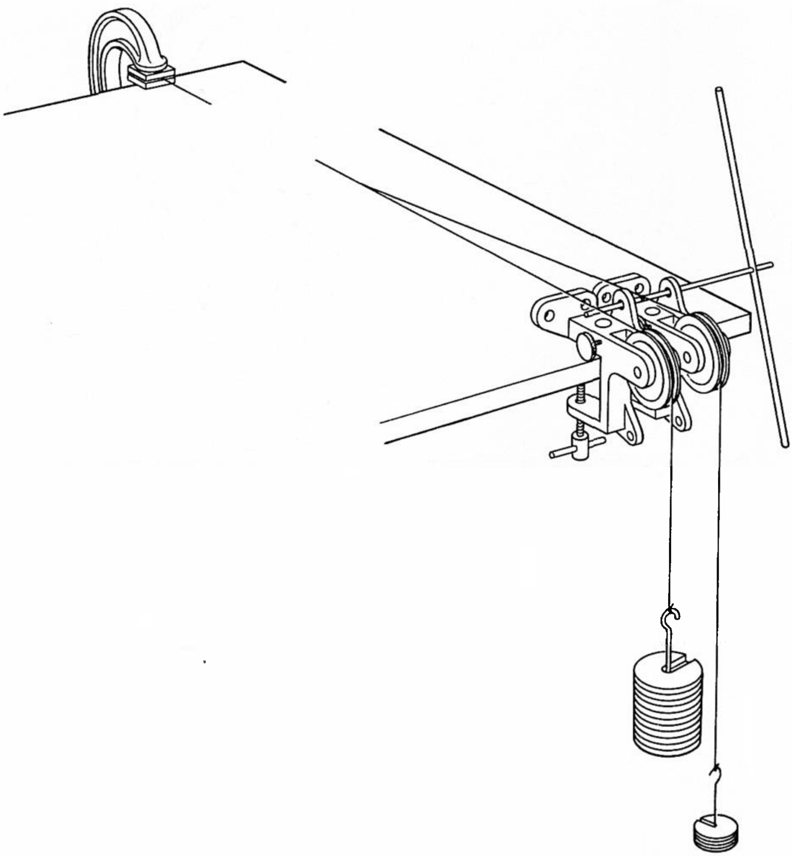


36 Demonstration

The stretching, yielding and breaking of copper wire

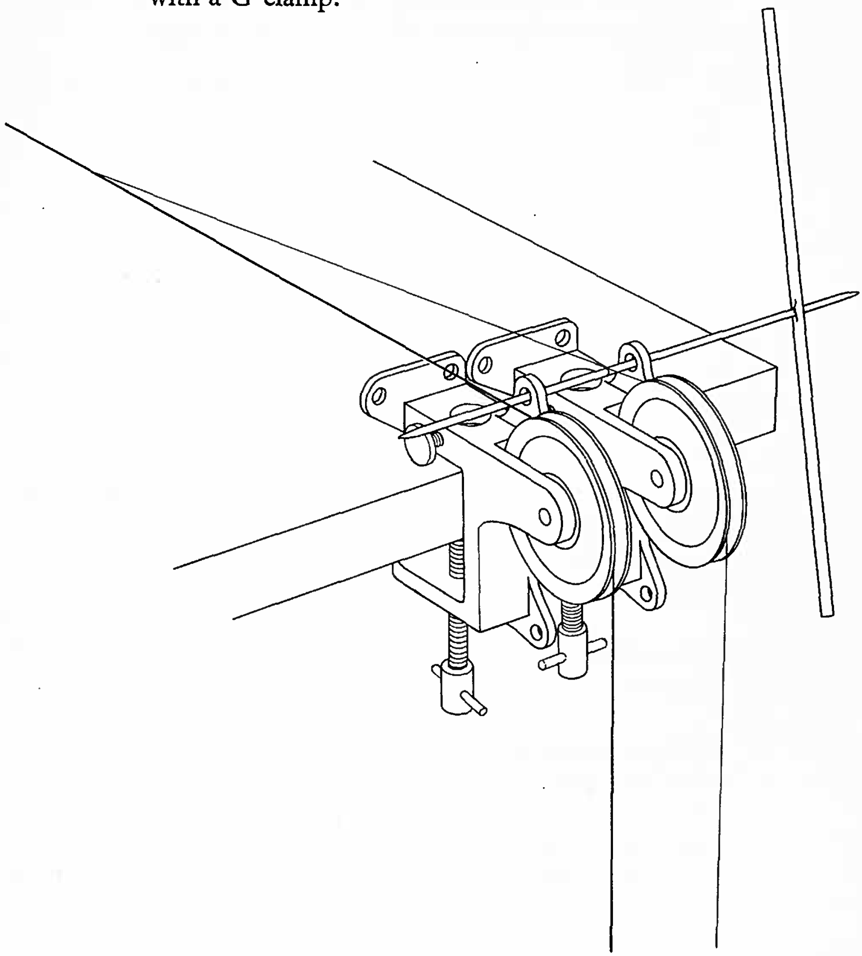
Apparatus

1 reel 26 swg bare copper wire (new)	– item 2C
1 Hoffman clip	– item 10V
2 single pulleys on clamps	– item 40
2 weight hangers with slotted weights (100 gm)	– item 31/2
1 weight hanger with slotted weights (10 gm)	– item 31/1
1 G-clamp	– item 44/1
1 needle (darning needle or thin knitting needle)	
1 drinking straw	– item 4A
Evostik	
thread	



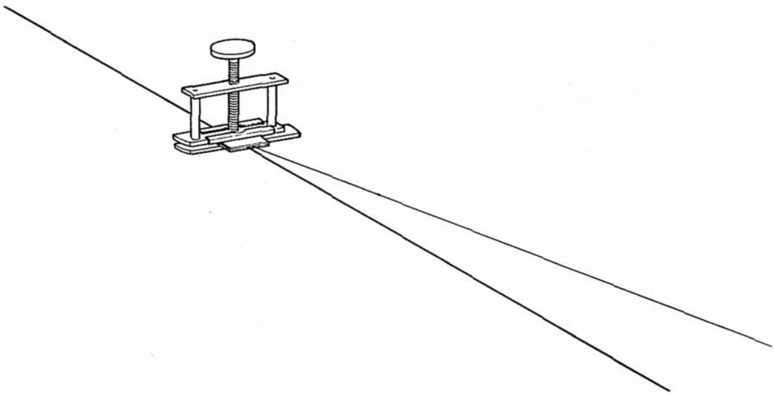
Procedure

Clamp the end of a suitable length (not less than 5 ft and preferably at least 8 ft) of the copper wire between two small polythene pads and secure rigidly to the end of the bench with a G-clamp.



At the other end of the bench, clamp the two pulleys as close together as possible. Pass the end of the copper wire over one of the pulleys to the larger weight hanger which should be about 18 in above the floor.

About 2 ft from this pulley, stick the end of a length of thread to the wire with Evostik. After the glue has set, pass the thread over the second pulley and hang the light hanger from it so that the base of this hanger is about 12 in above the floor. (Alternatively, use a Hoffman clip with two small pieces of sheet polythene as jaws to hold the thread and wire together.) Put four 10 gm weights on this weight hanger to make a total of about 50 gm. This load, which is not changed, serves to keep the thread taut.



Pass a needle through the two holes in the pulleys – as illustrated. Take a single turn of the thread round the needle, and push the needle point through a drinking straw to form a pointer.

When all is taut, the position of the tip of the drinking straw is noted.

100 gm weights are then added to the load on the wire. As the wire stretches, the thread will move and rotate the needle. This movement will be shown by the movement of the tip of the pointer. An additional 500 gm added to the wire can be expected to shift the position of the tip of the pointer about 3 cm per metre-length of the wire.

If now the load is taken off in 100 gm steps the pointer will return to its original position thus revealing the elastic nature of the stretching.

If now the wire is reloaded in 100 gm steps to a total of about 1500 gm (using a second weight hanger as well as the first), the wire will yield visibly. (At an extension of about 12 in, the weight on the thread will reach the ground and disengage so that the assembly is protected from damage as the wire yields gently through a considerable distance.) The loading should be continued until the wire breaks.

This can be seen very clearly if a flag of, say, cotton wool is stuck to the wire about a foot from the metal channel.

37 Class experiment

Qualitative stretching of very fine copper wire

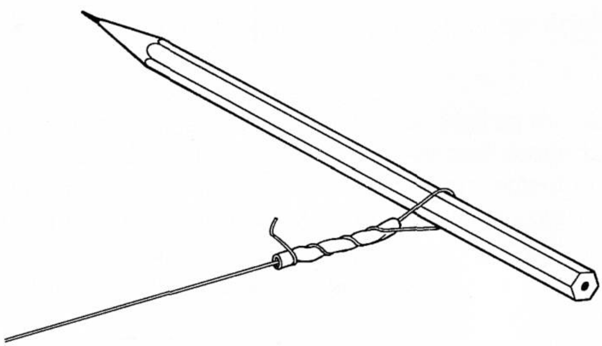
Apparatus

4 2 oz reels of 32 swg bare copper wire	– item 2B
2 3 in lengths valve rubber tubing	– item 2F
32 pencils or wood dowels	
32 G-clamps (4 in and 2 in)	– items 44/1 and 44/2

Procedure

Each pupil should have a good length of the 32 swg bare copper wire (say, 4 ft) with which to see and feel the stretching of the wire when it yields.

Each end of the copper wire must be secured to a pencil or wood dowel. It is not satisfactory merely to wind the wire round several times and twist the end as it weakens the wire and it is likely to break at the twist. The simplest arrangement which obviates this difficulty is to put an inch of valve rubber tubing on the wire near each end, to put two turns of wire beyond the tubing round the pencil and then four turns of the end around the rubber tubing.



The pupils should anchor one end of the wire to their bench with a G-clamp, to hold the dowel. Alternatively, they can hold the dowel on the floor between their feet.

Each pupil should experience for himself (*a*) the elastic stretching of the wire and (*b*) the 'cheesy' yielding.

Pupils should look at the fine point at the end of the wire where it does break.

Notes

1. It is essential to take fresh wire off the reel each time the experiment is done and all bending or kinking must be avoided. Each pupil should pull out a length of wire and lay it full length on his bench while fixing the ends.

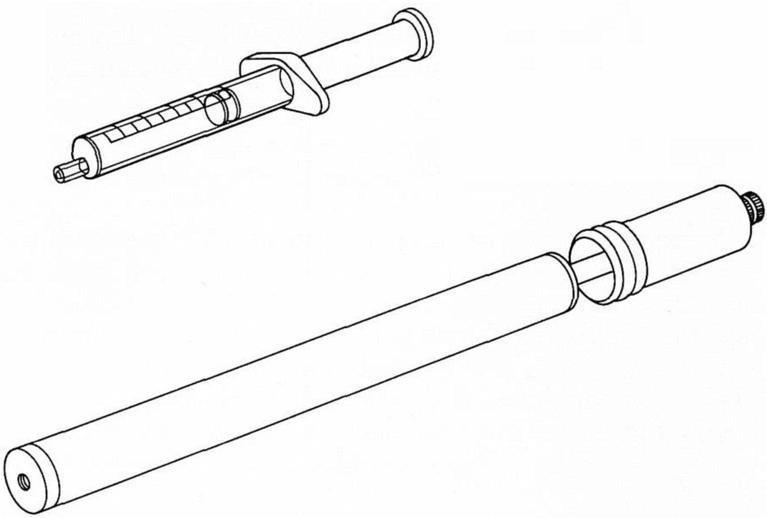
2. With very fine wire, some pupils will dispense with the dowel in their hand and wind the wire round their fingers.

38 *Quick class experiment*

Using a nylon syringe or bicycle pump to feel the springiness of air

Apparatus

16 nylon syringes – item 6D
several bicycle pumps



Procedure

Each child compresses air in the syringe (or the bicycle pump) with a finger over the outlet and feels its springiness.

39a. Demonstration

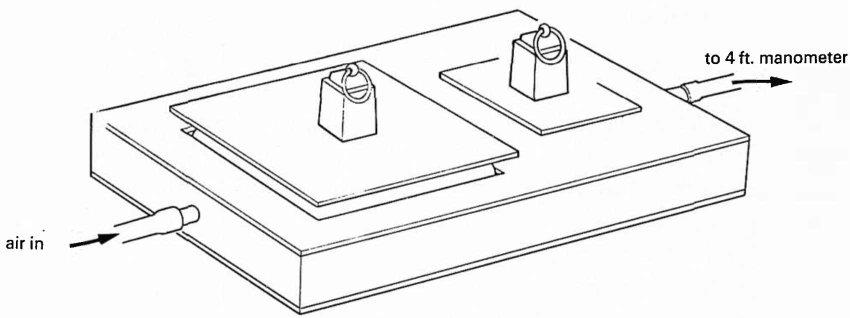
Discussion of pressure

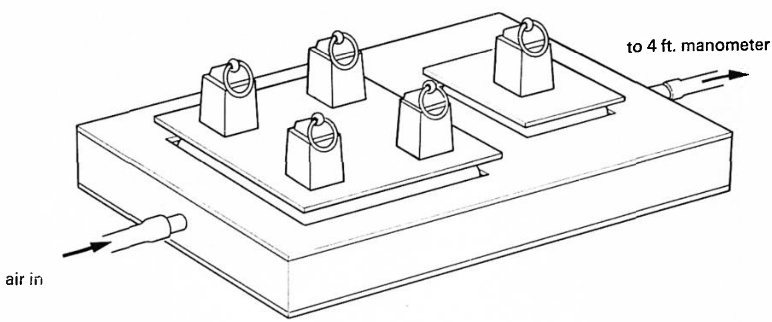
Apparatus

1 Evesham pressure apparatus	– item 41
1 4 ft mounted U-tube	– item 6G
2 slotted bases	– item 30
5 1 lb weights	– item 36

Procedure

The purpose of this demonstration is to discuss the effect of area on pressure. The 4 ft manometer is filled with water coloured with a few drops of methyl orange to make it clearly visible to the class. It is set up vertically using two slotted bases to hold it. One of the outlets from the apparatus is connected to the manometer with a 3 ft length of rubber tubing. The other outlet is connected to another 3 ft length of tubing into which the teacher can blow.





The apparatus itself has two movable platforms – the smaller is 4 in × 4 in, the larger 8 in × 8 in. The teacher begins by putting a 1 lb mass on each platform. He blows into the tube, the large platform rises. (The difference in level in the manometer at which the platform starts to rise is noted.)

He repeats the experiment with two 1 lb masses on the large platform, still only one on the smaller platform. Again the larger platform rises first. The manometer difference is again noted when the platform starts to rise. About twice the difference is obtained.

He repeats using three 1 lb masses on the large platform, arranged as symmetrically as possible. Again the larger platform rises first.

Finally he puts four 1 lb masses on the large platform with still the one 1 lb mass on the small platform. Both now rise together.

Note

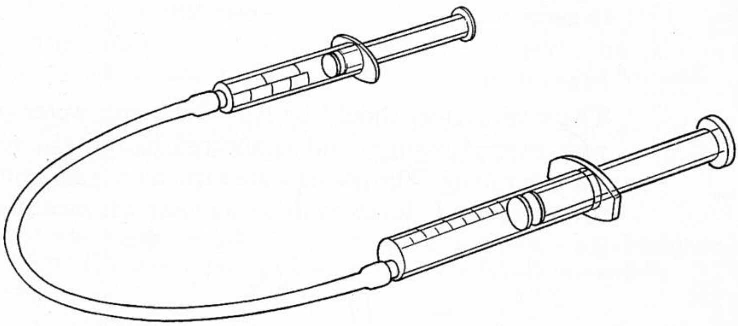
The whole point is to use the manometer in association with the apparatus. It is this that links the experiment with the other work on pressure done with manometers.

39b *Class experiment*

Pressure and force: feeling forces with two nylon syringes of different sizes connected together

Apparatus

16 large nylon syringes connected to
small nylon syringes – item 6E



Procedure

The syringes provided are sufficient for pupils to work in pairs.

The syringes and connecting tube are filled with water. One pupil holds one syringe, while his partner holds the other and they try pushing water to and fro. They should change over so that the one who had the larger syringe now has the smaller. Then each pupil in turn should hold both syringes so that he can feel how the forces differ.

Note

During the trials, many teachers commented on the syringes breaking. This usually occurred when trying to disconnect the syringes from the tubing. The Bristol pressure kit therefore includes 16 large syringes not connected to the tubing for use in, for example, Experiment 38 so that there is less need for disconnection. If, however, they need to be disconnected, the wrong method is to pull on the plastic tubing: it merely tightens the tubing around the end of the syringe and breakage is likely. The correct method is to *push* the tubing towards the syringe and it will come apart easily.

The apparatus itself has two movable platforms – the smaller is 4 in $\times$ 4 in, the larger 8 in $\times$ 8 in. The teacher begins by putting a 1 lb mass on each platform. He blows into the tube, the large platform rises. (The difference in level in the manometer at which the platform starts to rise is noted.)

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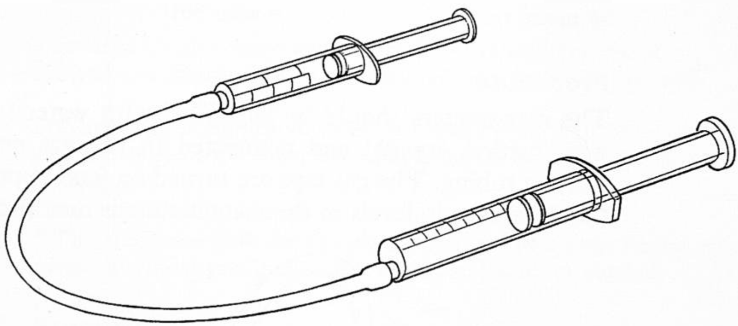
39b *Class experiment*

Pressure and force: feeling forces with two nylon syringes of different sizes connected together

Apparatus

16 large nylon syringes connected to small nylon syringes – item 6E



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39c *Class experiment*

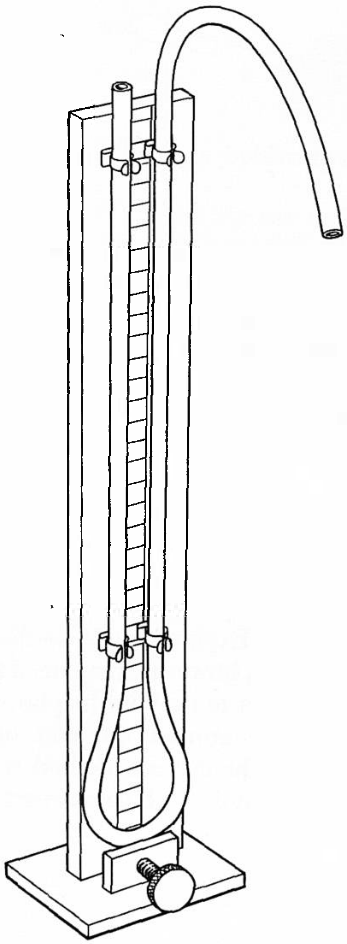
Using U-tube manometers to measure gas supply

Apparatus

8 U-tube manometers	– item 6A
8 slotted bases	– item 30
1 bottle of methyl orange	– item 6C
8 lengths of Bunsen tubing	
16 metre rules	– item 501

Procedure

The manometers should be half filled with water (coloured with methyl orange) and connected to the gas supply by Bunsen tubing. The gas taps are turned on (and kept on) and the difference in levels in the manometers is measured.



40 *Class experiment*

Measuring lung pressure using an 8 ft U-tube

Apparatus

2 8 ft mounted U-tubes	– item 6F
1 sterilizing bath*	
32 mouthpiece tubes	– item 6M
1 bottle of methyl orange	– item 6C

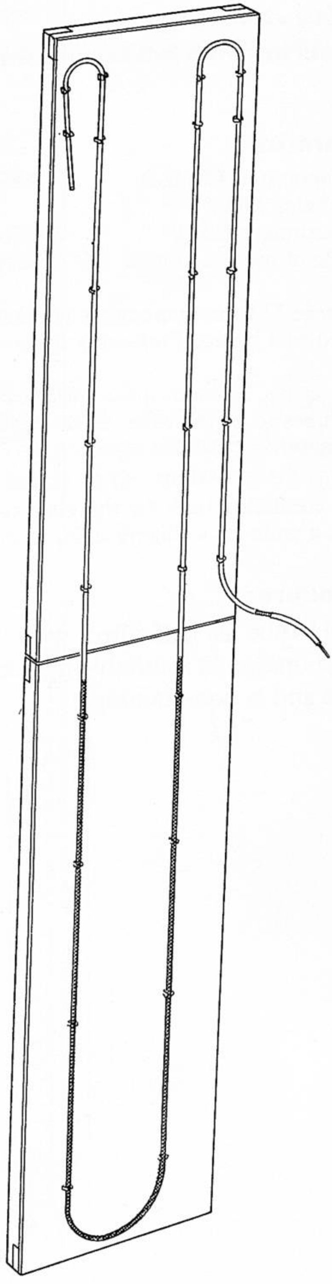
The large U-tube manometer is made of transparent plastic, secured to a board. Preferably it should be attached to the wall.

For hygiene, 32 mouthpieces are necessary – i.e. 2 in fire-polished glass tubes to fit the tube. Each pupil can fit his own tube to the manometer.

* The sterilizing bath for the glass tubes can be a large beaker or, better, a wide crystallizing dish, of dilute T.C.P. or alcohol.

Procedure

The U-tube is half filled with water together with some methyl orange as a suitable dye, as it makes the water clearly visible and is non-staining.



Let the pupils measure their lung pressure by blowing on this manometer: also by sucking.

Note

The teacher will probably find it easier to avoid air bubbles in the manometer if the tube is filled before fixing it to the board. Make a preliminary estimate of length of water column required, immerse one end of the tubing in a beaker of coloured water, suck at the other end until there is the required length and finally fix the tube to the board.

41 *Demonstration*

Measurement of the local gas pressure using water manometers, first with equal arms, then with unequal and finally with very unequal arms

Apparatus

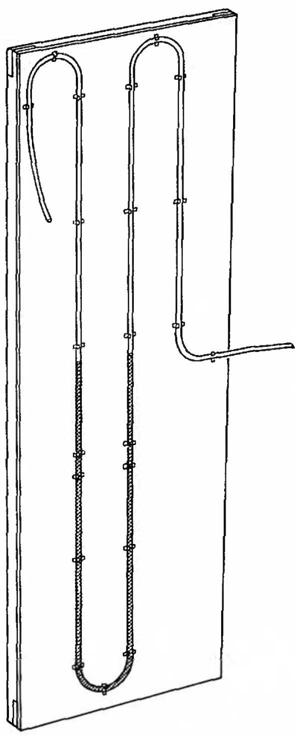
1 4 ft mounted U-tube	– item 6G
1 2 ft manometer with unequal limbs	– item 6H
1 aspirator (10 litres)	– item 523

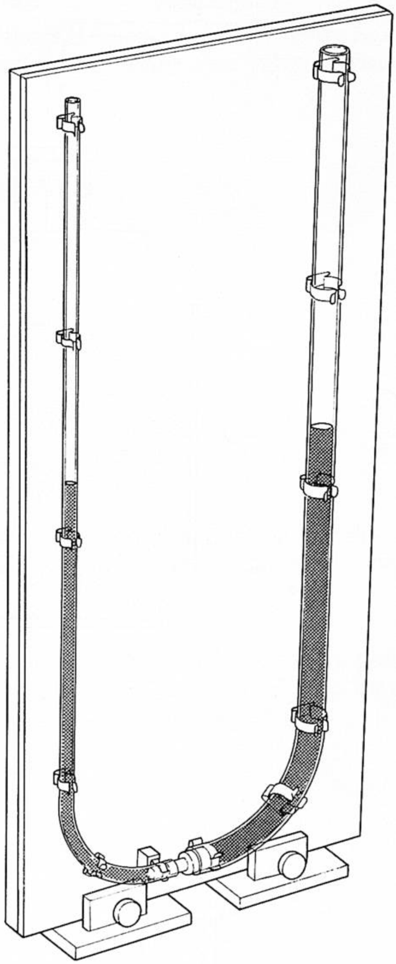
Procedure

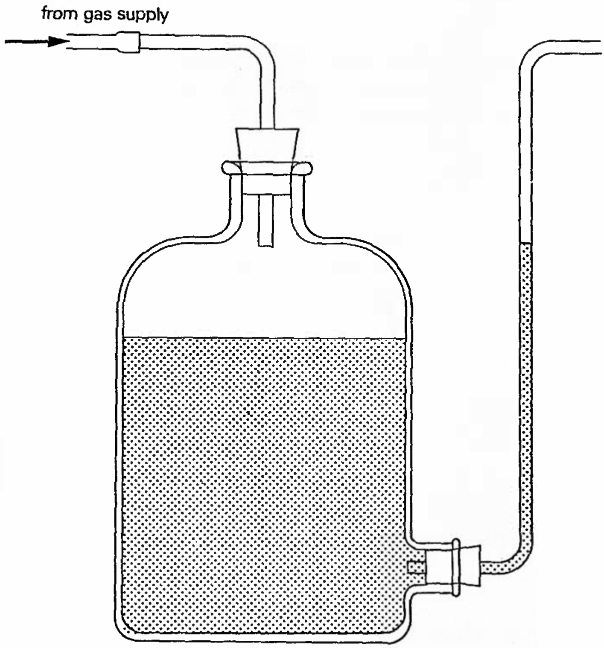
The local gas supply is connected to the three different manometers, filled with water, as shown.

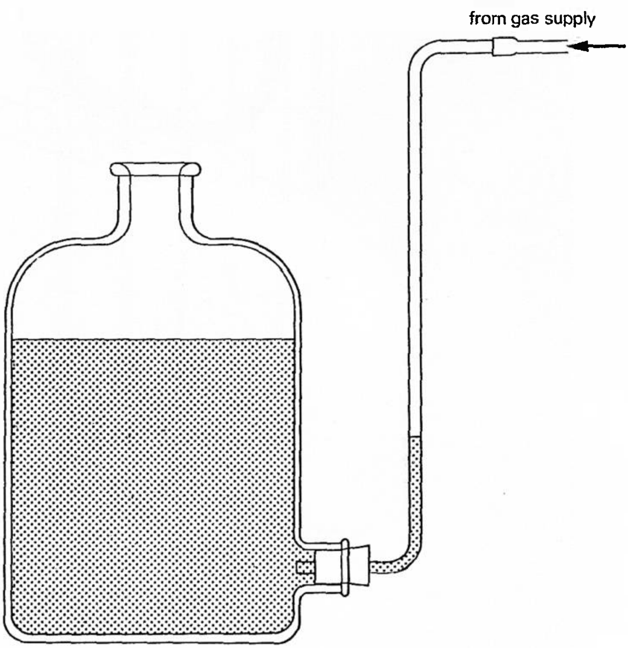
The gas pressure in most areas will be about 3 in to 5 in of water. When filling the tubes with water there must be sufficient water to allow for this change in level.

The gas supply should be connected to both ends of the aspirator as indicated to show the difference in level is still the same.






from gas supply


from gas supply

42 Demonstration

A mercury-filled U-tube used to measure lung pressure and compared as a manometer with a water-filled one

Apparatus

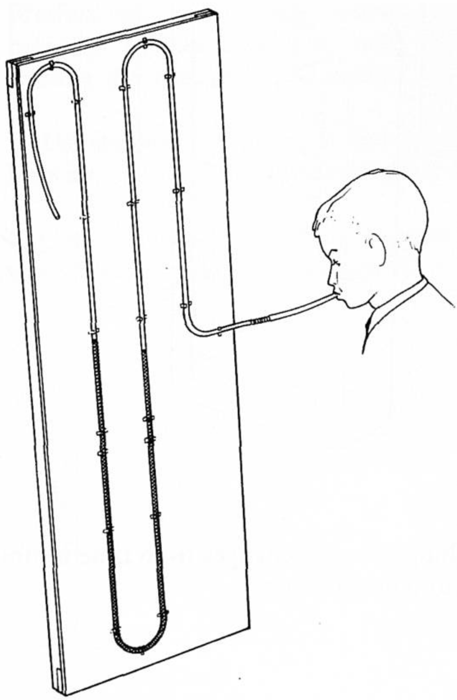
1 4 ft mounted U-tube	– item 6G
1 mercury tray	– item 524
1 bottle of mercury	– item 535
3 bottles (medicine type)	– item 534
1 lever-arm balance	– item 42
32 mouthpiece tubes	– item 6M
1 sterilizing bath	

The mercury manometer is made from 4 mm bore plastic tubing mounted on a board as shown, and half filled with mercury. It must be tall enough to show an 80 cm pressure difference without any danger of spilling mercury.

The three medicine bottles must all be equal in size and shape and be filled with water, mercury and air respectively, and all be corked.

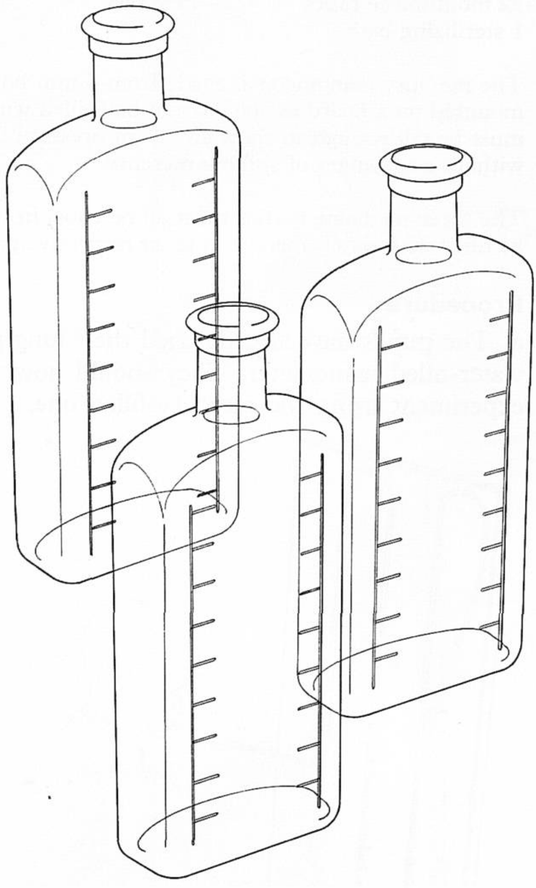
Procedure

a. The pupils have already tried their lung pressure using a water-filled manometer. They should now repeat the same experiment using the mercury-filled one.



As discussed in the *Teacher's Guide*, it will be simply pointed out that the difference in heights is a matter of relative density.

b. The teacher should let pupils lift the three medicine bottles – filled with air, water, and mercury respectively – and then estimate the relative densities of water and mercury by weighing on the lever-arm balance or on a household spring scale.



Note

A pupil's lung pressure changes from time to time: it will be necessary to point this out.

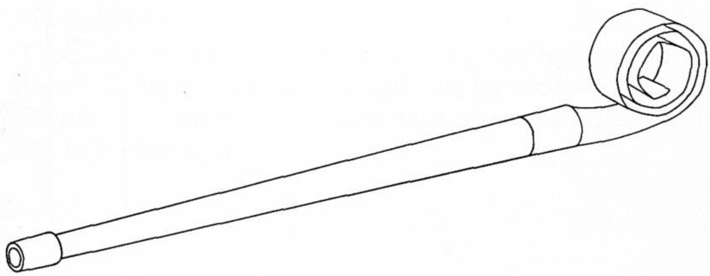
43 *Class experiment*

Introduction of a Bourdon gauge to measure lung pressure

Apparatus

1 Bourdon gauge	– item 67
32 paper Bourdon gauges	– item 6B
1 foot pump	– item 45

The Bourdon gauge reads absolute pressure from 0–20 lb/sq. in.

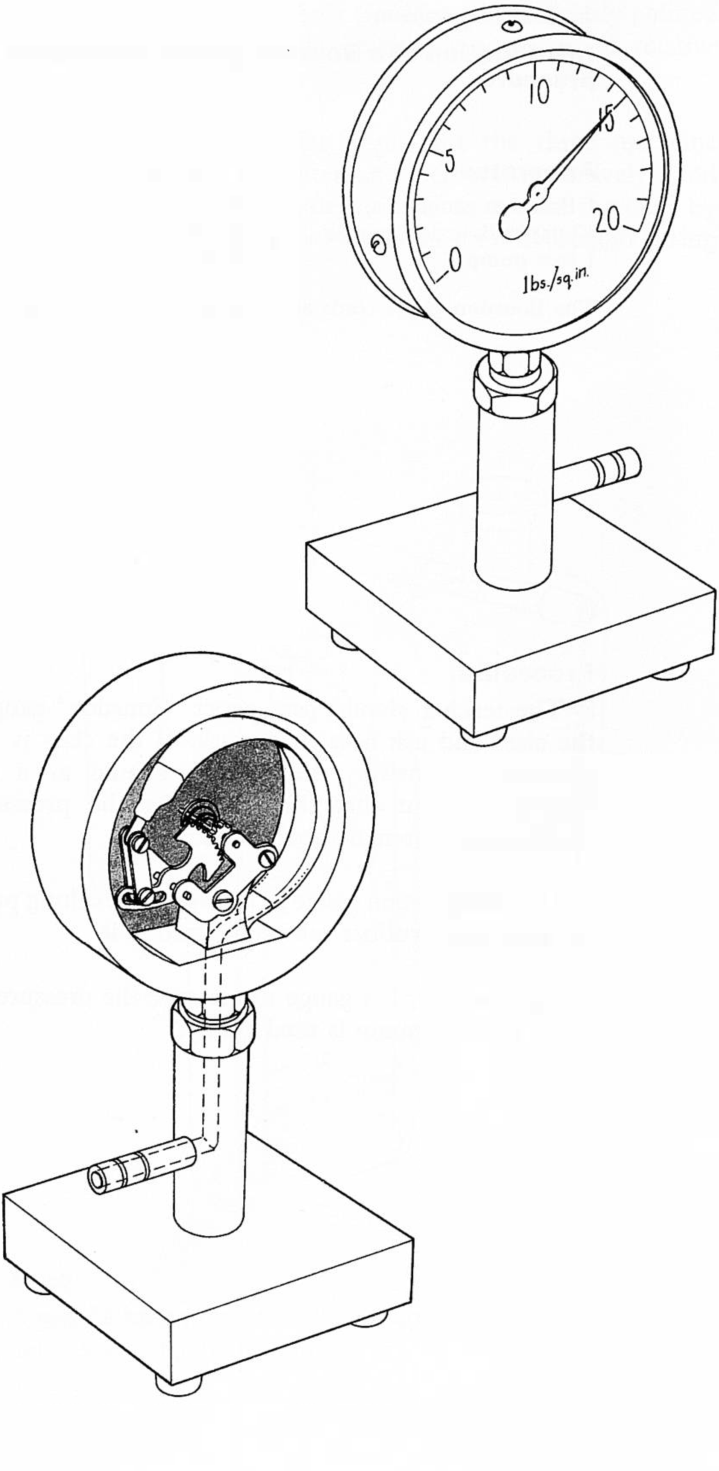


Procedure

a. The teacher should pass paper 'Bourdon' gauges round the class and ask how they work. If the class is unable to produce an answer, the teacher should as a desperate measure explain that they work by the pressure inside making the flattened tube uncoil.

b. Use the Bourdon gauge to measure excess lung pressure by blowing into a rubber tube connected to it.

c. Use the Bourdon gauge to measure the pressure obtained when the foot pump is used gently.


0
5
10
15
20
lbs./sq.in.

44 *Demonstration*

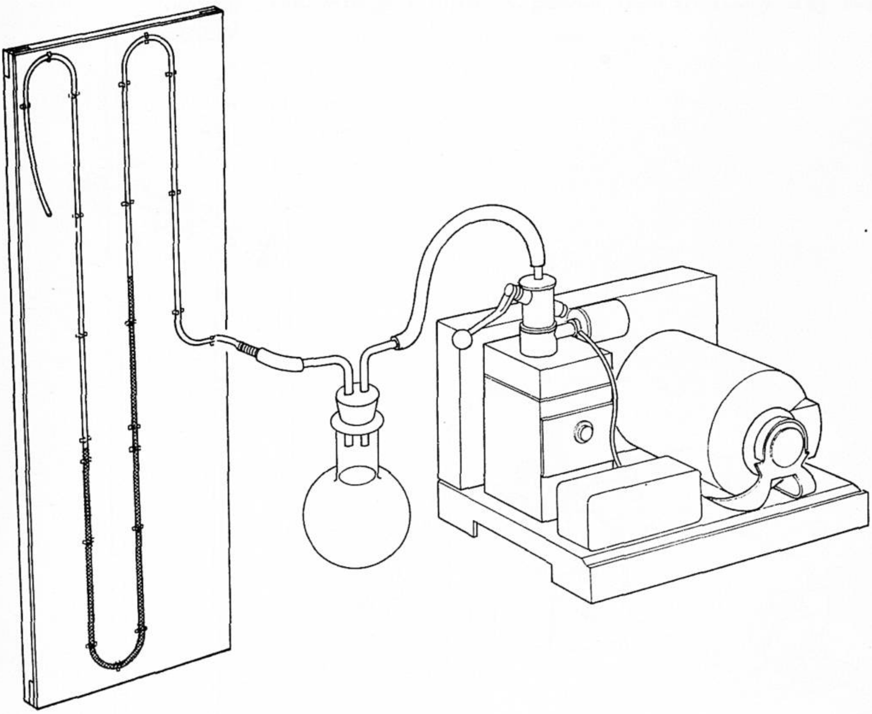
Atmospheric pressure shown by pumping out air on one side of a mercury-filled U-tube manometer

Apparatus

1 4 ft mounted U-tube	– item 6G
1 bottle of mercury	– item 535
1 length of pressure tubing	– item 10DD
1 vacuum pump	– item 13
1 mercury tray	– item 524

Procedure

The vacuum pump is connected to the manometer as illustrated below. The pressure should be reduced gradually showing that there is a definite limit when the difference in height is measured.



The pressure must be reduced gradually by careful operation of the tap on the pump. This is made easier if there is a needle valve on the pump, alternatively a side tube can be used with rubber and clip to provide a leak.

Note

It is advisable to insert a trap between the pump and the tube to ensure that mercury does not enter the pump. This has the additional advantage of making it easier to evacuate slowly.

45 Demonstration

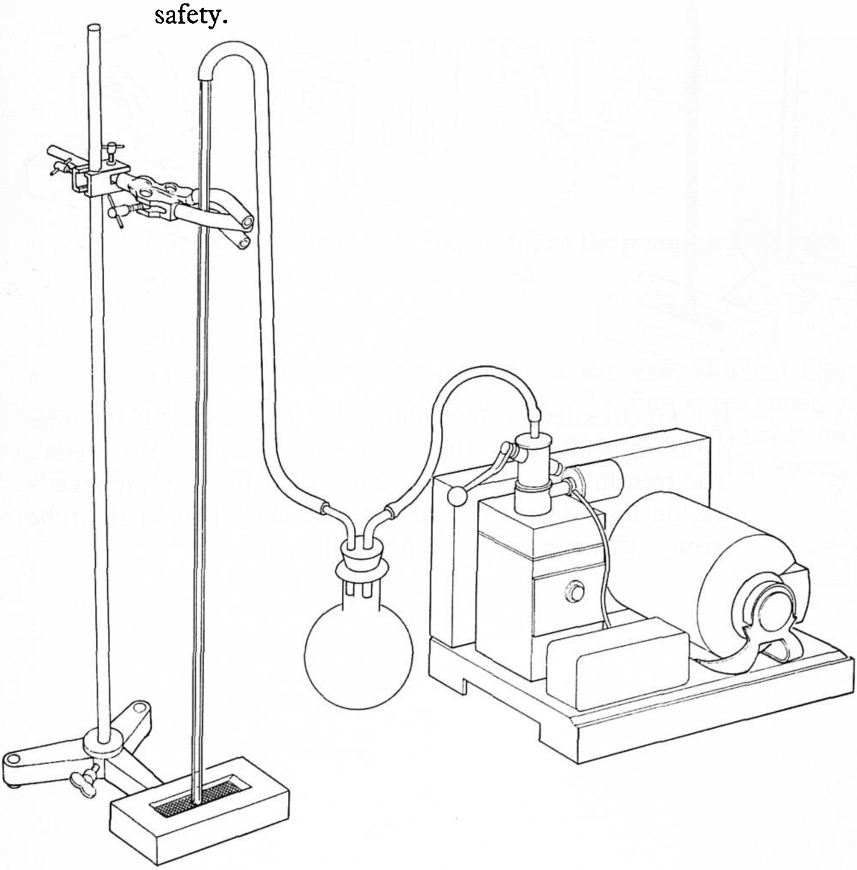
A plain glass tube, set up by pumping air out of the top end with the lower end in a mercury trough

Apparatus

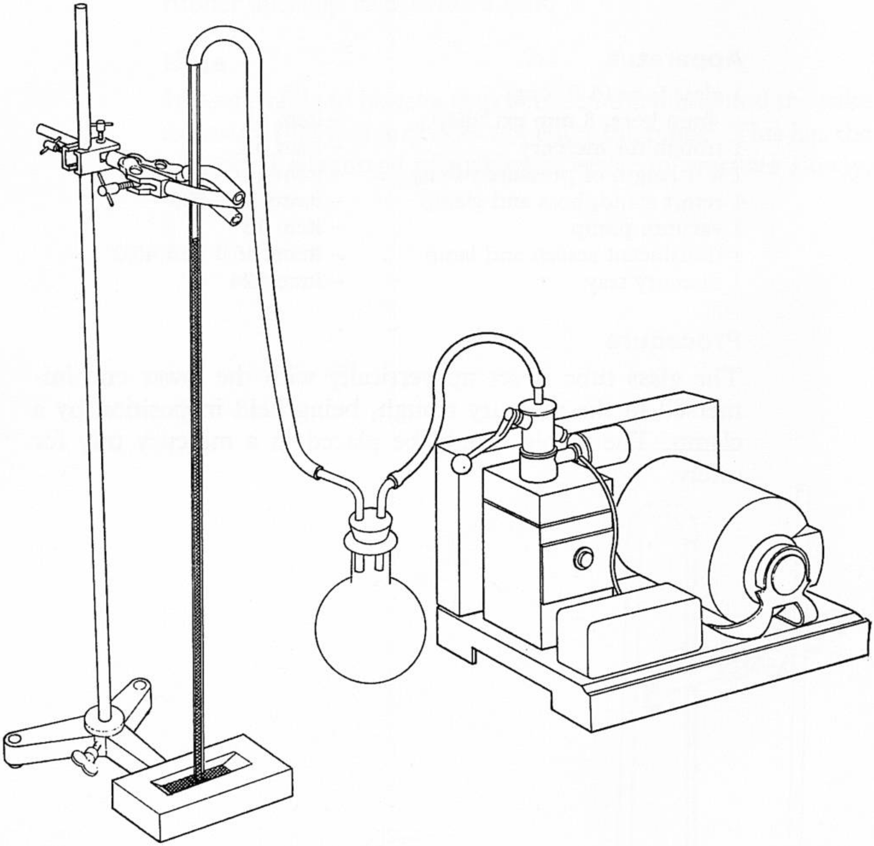
1 glass tube (4 ft long, 4mm bore, 8 mm ext. dia.)	– item 6J
1 trough for mercury	– item 6K
1 4 ft length of pressure tubing	– item 10DD
1 retort stand, boss and clamp	– items 503–506
1 vacuum pump	– item 13
1 translucent screen and lamp	– items 46/1 and 46/2
1 mercury tray	– item 524

Procedure

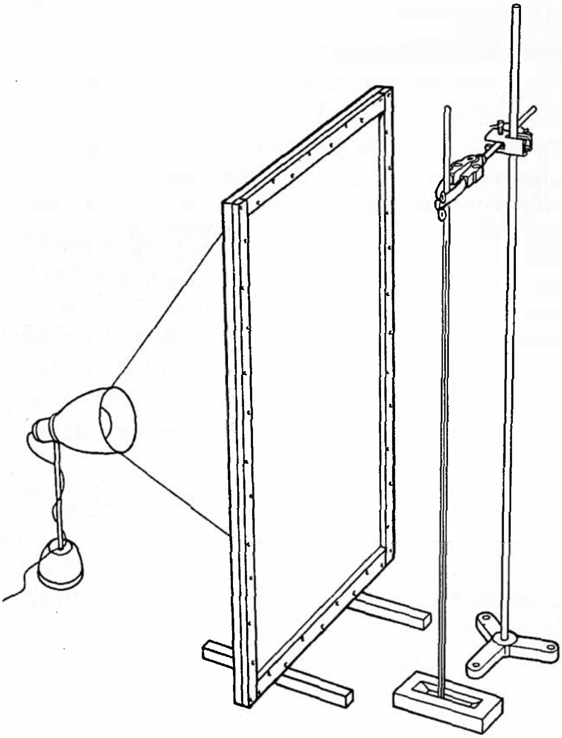
The glass tube is set up vertically with the lower end immersed in the mercury trough, being held in position by a clamp. The whole should be placed in a mercury tray for safety.



The top end of the tube is connected to the vacuum pump by pressure tubing. After pumping, measure the difference in levels.



It is much easier for the pupils to see the mercury if the tube is placed in front of a lighted sheet of translucent material. The translucent screen recommended is made of architect's tracing linen in a wooden frame. A lamp behind the tube ensures that the tube is seen in silhouette.



Note

It is advisable to insert a trap between the pump and the tube, so that the pump is fully protected.

Film

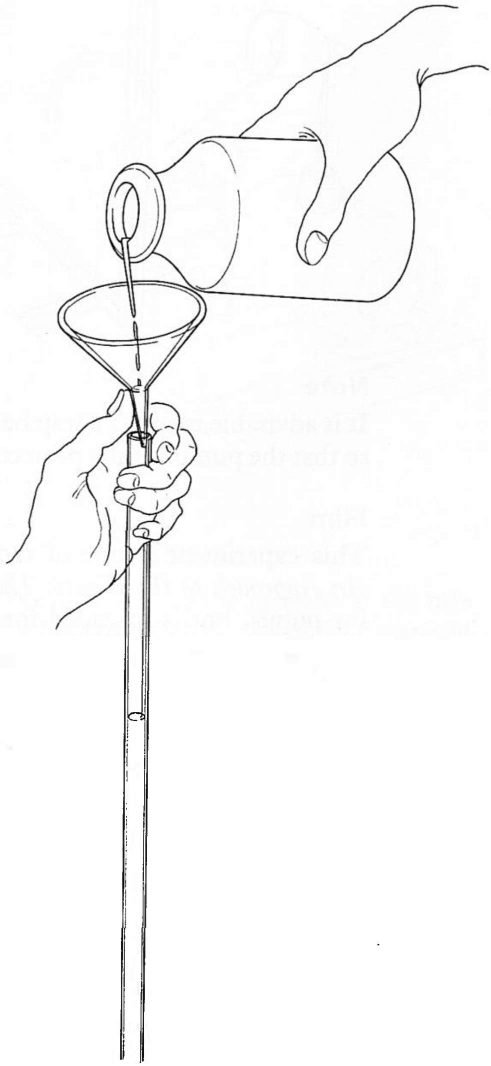
This experiment is one of those in the Esso-Nuffield film *An Approach to the Kinetic Theory.* This film is *not* suitable for pupils, but is intended for teachers. It is obtainable on free loan from Esso Petroleum Company, Victoria Street, London, S.W.1.

46a *Demonstration*

The simple barometer

Apparatus

1 barometer tube	– item 61
1 bottle of mercury	– item 535
1 small funnel	– item 6L
1 mercury trough	– item 6K
1 mercury tray	– item 524
1 retort stand, boss and clamp	– items 503–506
1 translucent screen and lamp	– items 46/1 and 46/2



Procedure

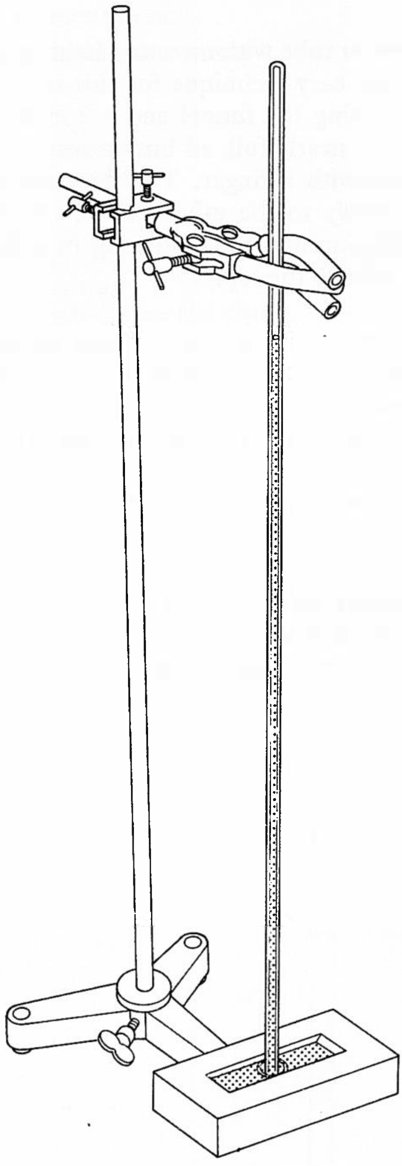
Fill the barometer tube with mercury, holding it over the tray throughout. (An easy technique for this is to pour mercury into the tube, using the funnel and a 2 in length of rubber tubing, until it is nearly full, all but an inch at the open end. Close that end with a finger. Tilt the tube to run the air bubble very *slowly* to the other end of the tube and back again, collecting up any small sticking bubbles on the way. Then fill the tube to the top.)

Hold a finger on the top and invert into the trough. Do not remove the finger until the end of the tube is below the surface. Then ask pupils if air can get in. They should then watch what happens when the finger is taken away.

Hold the barometer in a clamp and measure the height.

Note

As in the previous experiment, it is much easier for pupils to see the mercury if the tube is silhouetted against the translucent screen with the lamp behind.

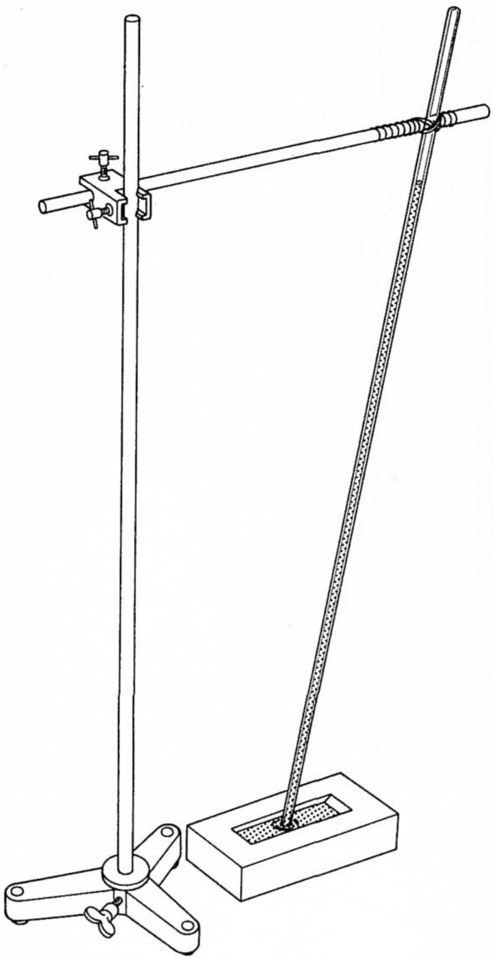


46b *Demonstration*

Effect of inclining a barometer tube

Apparatus

1 barometer tube	– item 61
1 bottle of mercury	– item 535
1 small funnel	– item 6L
1 trough for mercury	– item 6K
1 mercury tray	– item 524
1 retort stand, and boss	– items 503–505
1 retort stand rod	– item 503
1 length of stout iron wire	
1 translucent screen and lamp	– items 46/1 and 46/2



Procedure

The barometer is set up as in Experiment 45 and then supported by a retort stand as illustrated. By securing it with a spiral of wire, the tube can be conveniently inclined to show the mercury level remaining the same height above the trough.

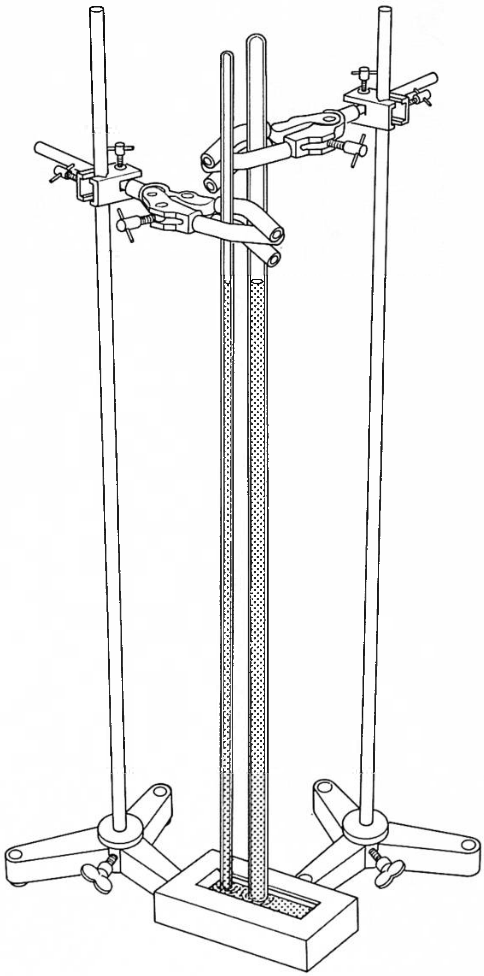
If the height does not remain the same, air has been included and the barometer must be refilled.

46c *Demonstration*

Comparison of barometer tubes of different diameters

Apparatus

2 barometer tubes (with different diameters)	– item 61
1 trough for mercury	– item 6K
1 bottle of mercury	– item 535
1 mercury tray	– item 524
2 retort stands, bosses and clamps	– items 503–506
1 translucent screen and lamp	– items 46/1 and 46/2



Procedure

Two barometer tubes of different diameter are set up side by side in the same trough, as described in Experiment 46a. It will be seen that the mercury levels are the same in each tube.

Note

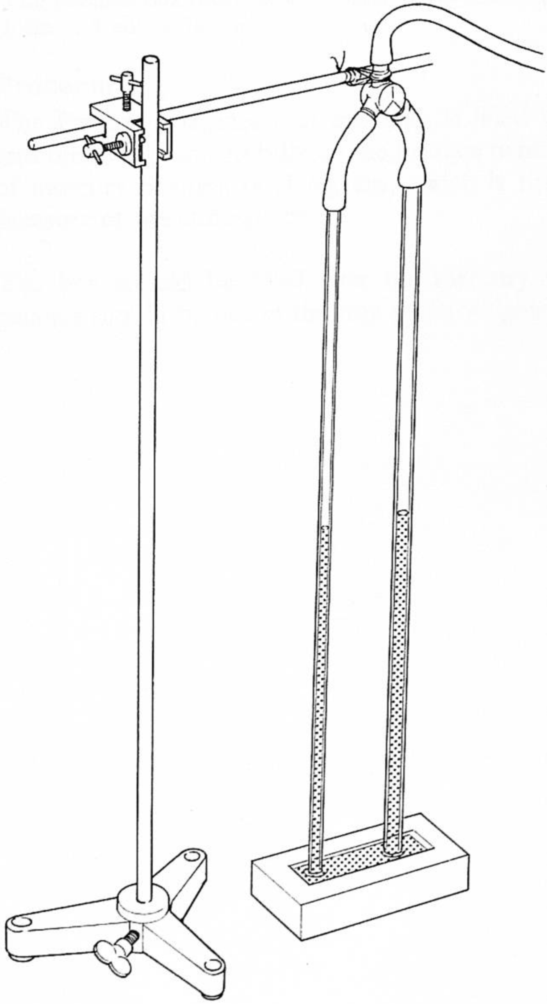
The barometer tubes need to have very different bores for this demonstration to be effective: 4 mm and 8 mm are recommended.

46d *Optional extra demonstration*

Comparison of tubes of different diameters

Apparatus

2 glass tubes of different diameters (3 ft long)	
1 trough for mercury	– item 6K
1 bottle of mercury	– item 535
1 mercury tray	– item 524
2 retort stands, bosses and clamps	– items 503–506
1 vacuum pump	– item 13
1 translucent screen and lamp	– items 46/1 and 46/2
1 T or Y piece fitted with 2 short lengths of tubing	
1 4 ft length pressure tubing	– item 10DD



Procedure

The two tubes are set up side by side in the same trough as in Experiment 44. The tops are connected to the vacuum pump through the Y piece as shown and the air carefully pumped out. It is advisable to include a mercury trap as already discussed in experiment.

46e *Optional extra demonstration*

Weight of a barometric column

(This is an additional luxury experiment where a school has the Perspex box required and also sufficient mercury.)

Apparatus

1 Perspex box	
1 bottle of mercury	– item 535
1 mercury tray	– item 524
1 domestic balance	
(5Kg · ıpressions type)	– *item* 20

The Perspex box must have a square cross-section and be 1 cm × 1 cm × 76 cm.

Procedure

The Perspex box, closed at one end, is filled with mercury and then weighed carefully on the balance to find 'the weight of mercury pushing on 1 sq. cm, which is the same as the pressure of the atmosphere'.

The box should be filled over the mercury tray and the balance should be put in the tray when weighing.

46f *Optional extra experiment*

The water barometer

Apparatus

1 40ft length clear p.v.c. tubing	
1 bucket	– item 533
1 vacuum pump	– item 13

Procedure

Where schools have tall (30 ft or more) teaching blocks and a suitable length (40 ft) of clear p.v.c. tubing it is possible to set up a water barometer. The tube dips into a bucket of water at the lower end and is marked with coloured tapes at one foot intervals. The upper end is connected to the vacuum pump (preferably with the gas-ballast valve open) and the air is gently pumped out.

47 Class experiment

Investigating the direction and strength of water pressure

Apparatus

16 600 ml beakers	– item 512/3
48 small beakers or tea-cups	– item 512/1 or 512/2
48 tin cans*	
hammers	
$1\frac{1}{2}$ in round nails	

*The tin cans should preferably be about pint size and can be obtained from home.

Note

These experiments are intended to be rough simple ones that can be repeated at home. Therefore it is essential to use ordinary things for the apparatus, such as tin cans, tea-cups, and to make the hole with a nail. The teachers, with a subsequent year in mind, may feel tempted to prepare special apparatus for this which can have identical holes drilled so that it works well and can be stored away. That would miss the point of the present experiment, so rough apparatus should be used and pupils encouraged to make the holes for themselves using a nail.

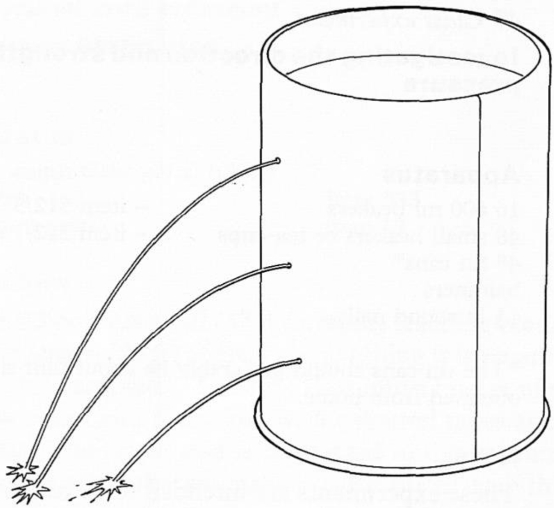
Procedure

a. Let each pupil take a tin can and make holes in it with a round nail. A block of wood, placed as an anvil inside the can, is a considerable help. The holes should be made at different places round the can all at the same level. With care, the nail will make the holes all the same size.

Pupils fill the cans with water and watch how the water spouts out.

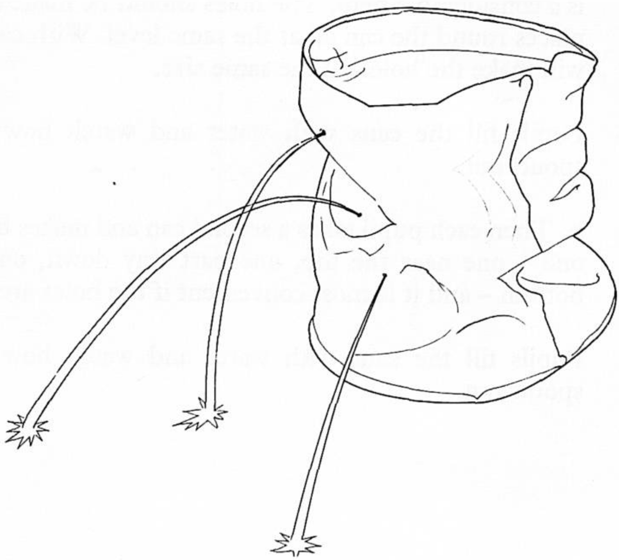
b. Then each pupil takes a second can and makes holes in this one – one near the top, one part way down, one near the bottom – and it is most convenient if the holes are staggered.

Pupils fill the cans with water and watch how the water spouts out.



By pouring replenishing water into the can from the 600 ml beaker, the level of water in it can be kept constant. The pupil can collect the water spouting from the three holes in three separate beakers and observe what happens.

c. Let the pupil take a third can and batter it into an irregular shape with a hammer. He should then make holes with a nail at three different places, *all near the bottom*, where the metal surface is orientated in three different directions. With care, the holes can be made all the same size. Then he fills the can with water and observes the direction in which the water comes out and collects each stream in a separate beaker.



This provides a good opportunity to be a detective and squeeze information from the clues observed.

It is helpful to have a supply of sponges available for this experiment.

d. As an optional *home* experiment, the pupil may fill a balloon with water and pierce with a pin. First put a hole near the top, next half-way down, finally in the lower half, to see the direction of the pressure. This experiment does not always give consistent results. It is probably best to do this experiment in the bath!

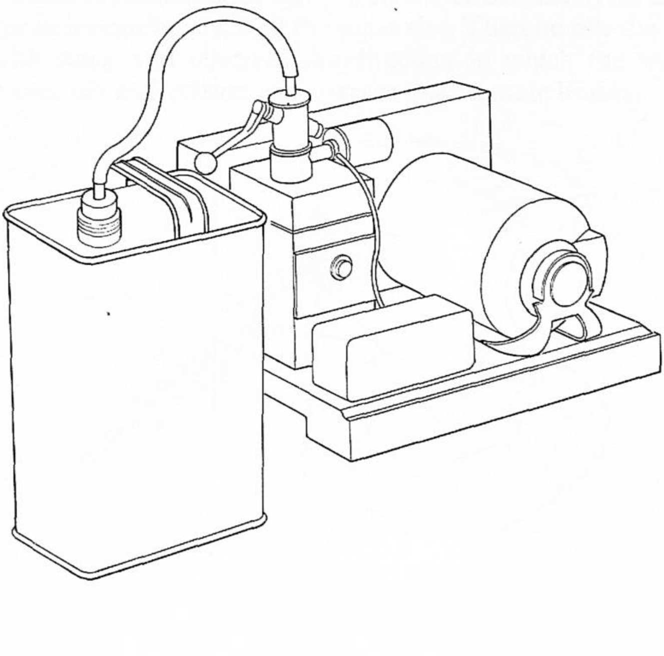
The pressure of the atmosphere

Apparatus

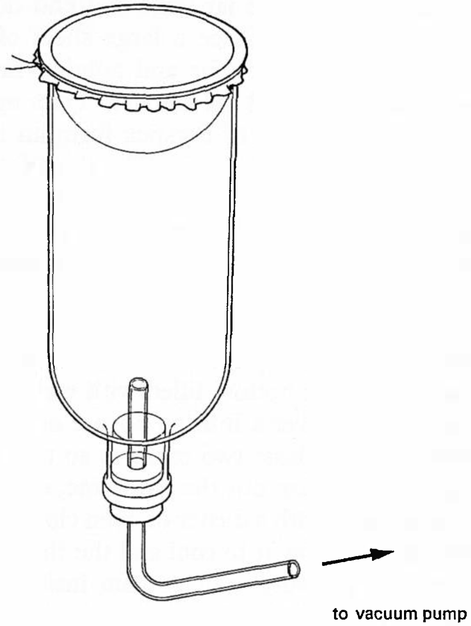
1 tin with bung and tubing
1 length pressure tubing – item 10–DD
1 5 in bell jar – item 521
1 vacuum pump – item 13
1 large balloon
1 small balloon
1 thin sheet of glass
(6 in × 6 in)
1 thick sheet of glass
(6 in × 6 in) – item 10W
1 tube vacuum grease – item 10X
2 safety sheets of $\frac{3}{16}$ in Perspex (one 30 in × 30 in, one 36 in × 24 in)

Procedure

a. The tin can – rectangular, not cylindrical and preferably quart size or larger – should have a well-fitting bung in the top with a short length of glass or brass tubing through it. This is connected by pressure tubing to the vacuum pump. The air should be pumped out slowly and the can will collapse. Instead, or as well, a polythene bottle or a hollow rubber toy is pumped out.



b. The outlet of the inverted bell jar should have a well-fitting rubber bung with a glass tube through it. This is connected by pressure tubing to the vacuum pump. A part of a large rubber balloon, obtained by cutting off the neck, can be stretched across the top of the bell jar, being held on by its own tension. Air should be pumped out slowly to show the effect on the rubber sheet.

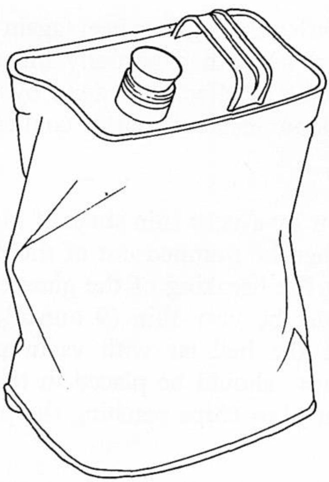


c. Close the bell jar with a thick glass sheet (again using some vacuum grease to seal it) with a partially inflated balloon inside it. Or this can be as effectively done by putting the partially inflated balloon inside a bottle connected to the pump.

d. Replace the balloon by a very thin sheet of glass over the bell jar. Air should then be pumped out of the bell jar very slowly indeed so that the breaking of the glass can be seen. The glass, which must be very thin (9 ounce), should be sealed to the rim of the bell jar with vacuum grease. A crumpled sheet of paper should be placed in the bottom of the bell jar to prevent glass chips reaching the pump.

This cracking of a sheet of glass is an impressive demonstration; but it is dangerous unless done with proper precautions. Very thin glass, which would make the demonstration easier and safer, is not easily obtained. Therefore we suggest that if the teacher shows this at all he should use ordinary window glass with the following precautions: (i) Use a bell jar which has a neck at the rounded end with stopper and tube to connect to the pump. Place the sheet of glass across the open end of the bowl and hold the jar with that end downward, very close to the table. (ii) Place a large sheet of Perspex between the class and the bell jar and another fairly large sheet between the bell jar and the teacher. Then operate the pump. These 'safety sheets' of Perspex form an important safeguard to be used again and again. The sheet for the class should be 30 in × 30 in. The sheet for the teacher should be 36 in high × 24 in wide – full enough to protect his face but narrow enough to enable him to get his hands round comfortably from behind.

e. As an experiment for the pupils to do themselves at home, a rectangular can has the bottom filled with water to a depth of about $\frac{1}{4}$ in. It is put over a Bunsen burner or gas ring and boiled vigorously for at least two minutes so that the steam drives out all the air. Turn out the gas flame, or remove the can from it, holding it with a duster or oven cloth. After that, cork the can tightly. Allow it to cool and the tin will collapse under atmospheric pressure as the steam inside condenses. The condensation can be speeded up by pouring cold water over the can.



If pupils wish to try this as a home experiment, they should be warned that most small cylindrical cans withstand atmospheric pressure, so a rectangular can should be used.

This can be a most spectacular demonstration done by the teacher with a large oil drum.

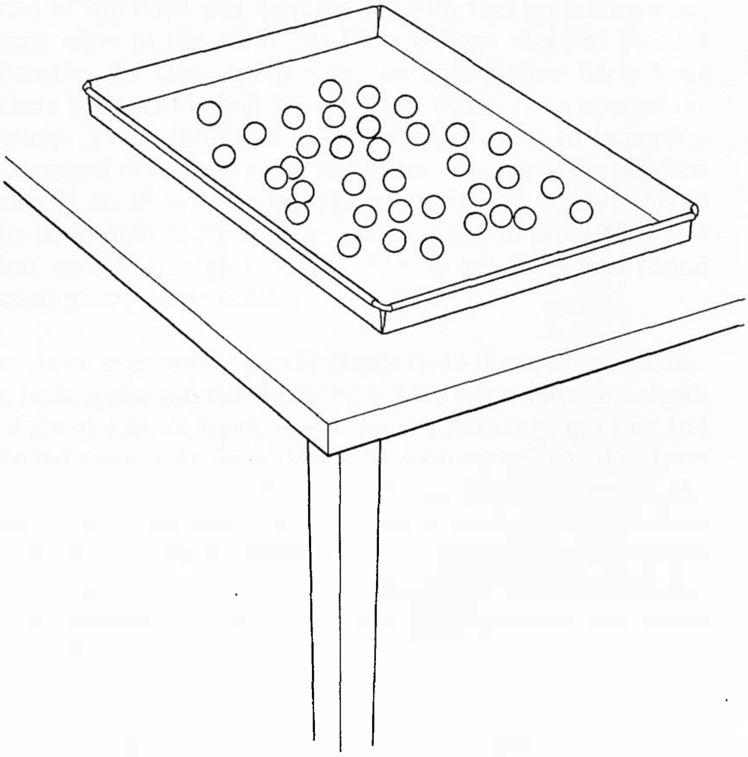
49 *Class experiment*

Kinetic theory: two-dimensional model

Apparatus

Two-dimensional kinetic model kit – item 12

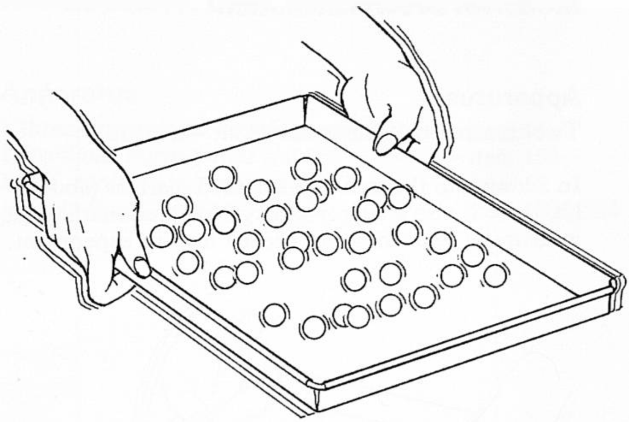
The kit includes 16 metal trays enabling pupils to work in pairs.



Procedure

Each group should have 20-24 coloured marbles – these are included with the kit and are the standard size of toy-shop coloured marble, about $\frac{5}{8}$ inch in diameter. It is important that these are coloured so that the pupils can concentrate on a particular one if they wish.

Pupils keep the tray in random shaking motion, on the table.



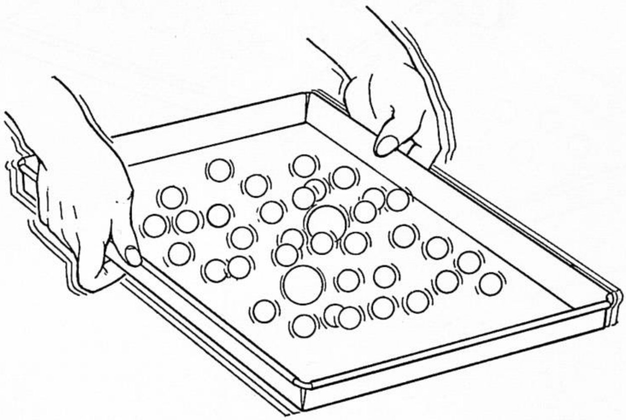
50 *Class experiment*

Model for Brownian motion

Apparatus

Two-dimensional kinetic model kit – item 12

In addition to the standard coloured marbles (about $\frac{5}{8}$ in) in the kit, there is also a supply of large coloured marbles (about 1 inch in diameter) and these are needed for this experiment.



Procedure

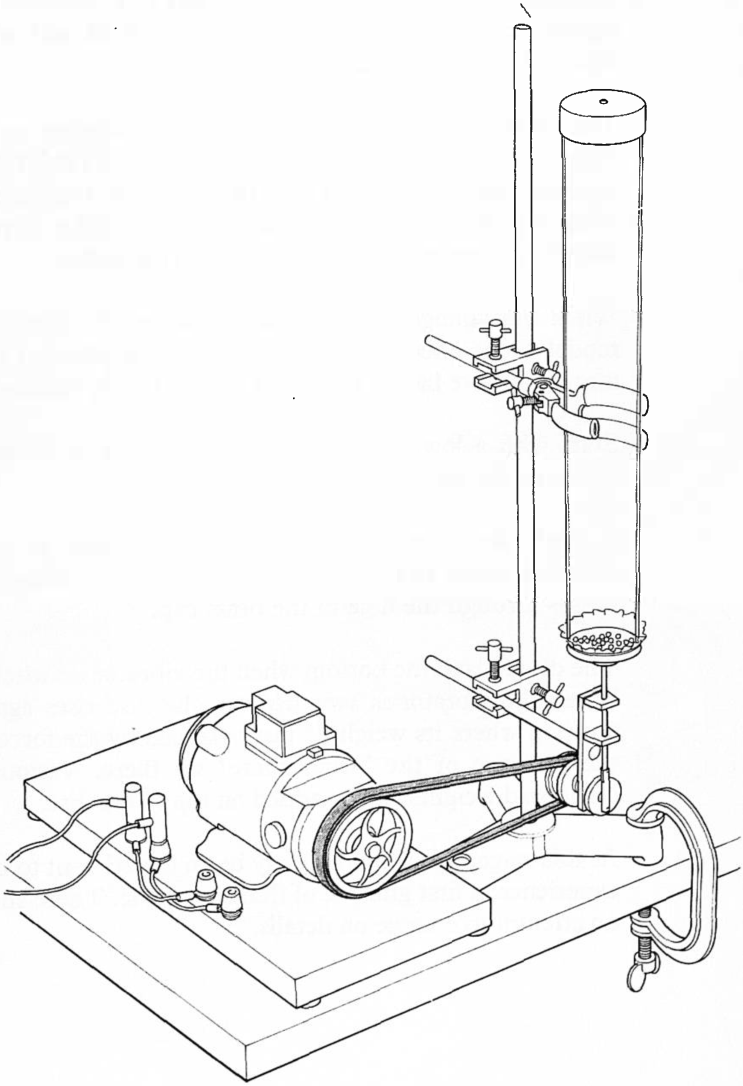
After Experiment 49, one or two large marbles should be added to the trays with the standard size marbles. A random motion is again given to the trays and the slower motion of the heavier marbles will be apparent.

51 *Demonstration*

Kinetic theory: three-dimensional model

Apparatus

1 three-dimensional kinetic model kit	– item 11
1 fractional horse-power motor	– item 150
1 L.T. variable voltage supply	– item 59
1 retort stand, boss and clamp	– items 503–506



Procedure

The rubber base is fixed over the lower end of the plastic tube, which is held in a vertical position using a retort stand, boss and clamp.

The height of the tube is adjusted so that the rubber base is a millimetre or two above the vibrating rod in its mean position. The fractional horse-power motor is used for activating the vibrating rod. The d.c. terminals of the L.T. variable voltage supply are connected in parallel to the field and armature terminals of the motor.

The small phosphor-bronze ball-bearings are put inside the long tube so that they rest on the bottom. The most effective number will cover about two-thirds of the base area. The brass cap should be put over the top of the tube: it prevents balls from coming out and it cuts down the noise.

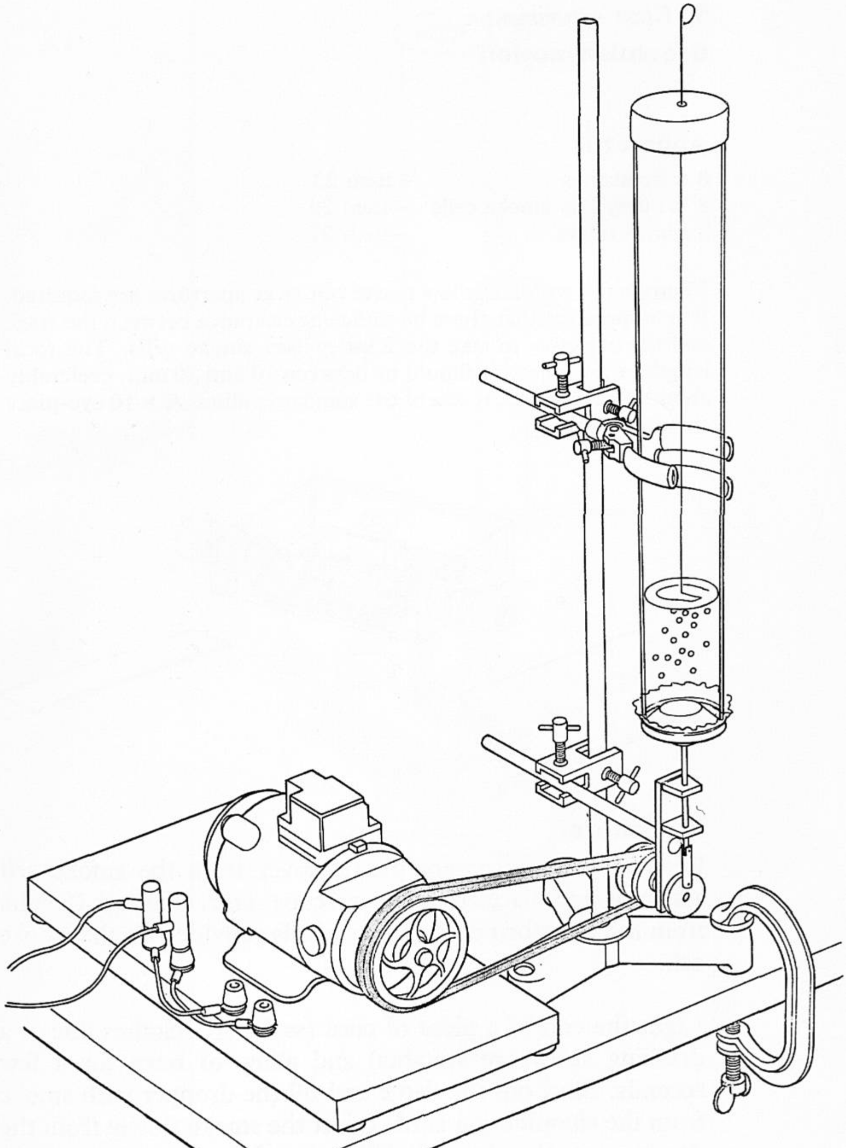
When the voltage is increased (maximum 12 volts, but the model works effectively on 4 – 6 volts), the vibrator is set in motion and we have a simulated kinetic theory motion.

Start with a low voltage, gradually increase it showing the action of the balls increasing.

A cardboard disc can be put inside the tube to act as a movable lid for this 'atmosphere'. The wire holding the disc passes through the hole in the brass cap.

The disc falls to the bottom when the vibrator is switched off. When the vibrator is switched on, the disc rises again to a position where its weight is just balanced by the force due to the pressure of the 'atmosphere' up there. Various small cardboard weights can be added on top of the disc.

At this stage, this should merely be an experiment to broaden experience, a first glimpse of things to come. There should be no attempt to enlarge on details.



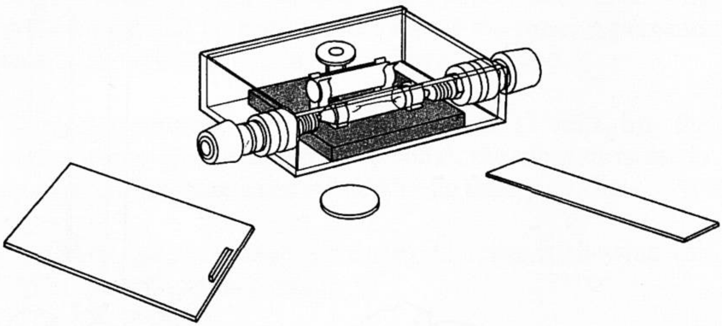
52 Class experiment

Brownian motion

Apparatus

8 microscopes	– item 23
8 Whitley Bay smoke cells	– item 29
8 transformers	– item 27

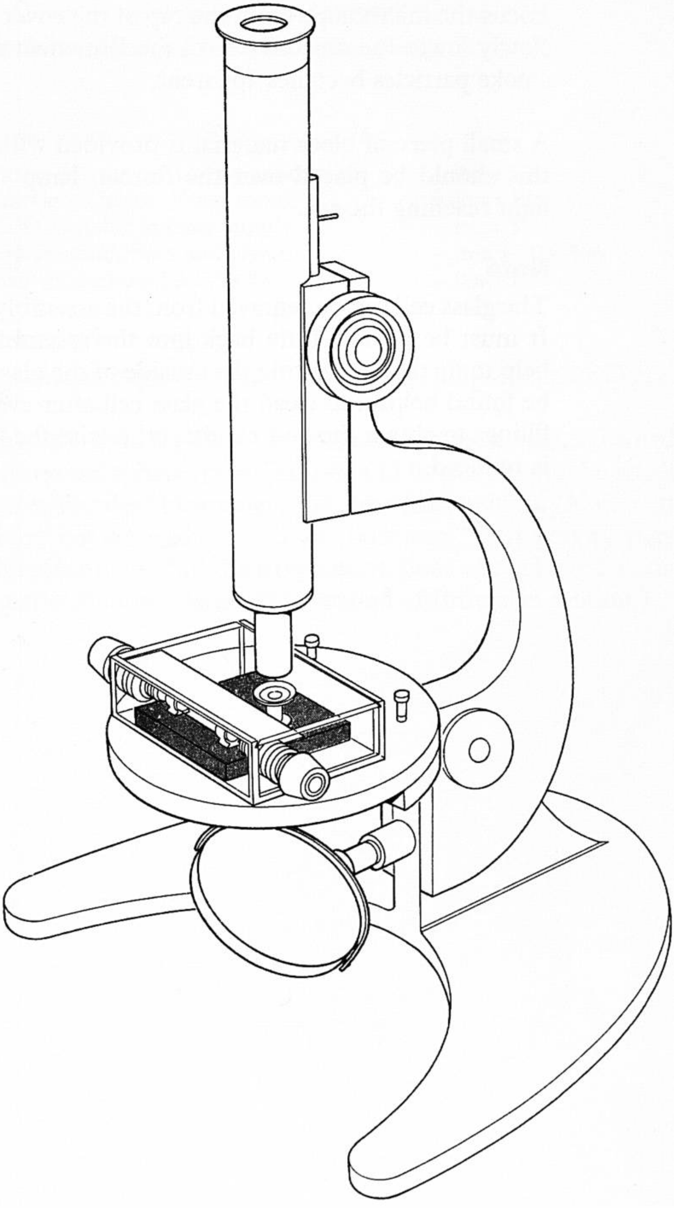
Microscopes with fairly low power but large apertures are required. It is imperative that there be sufficient clearance between the stage and the objective to take the Whitley Bay smoke cells. The focal length of the objective should be between 10 and 30 mm, preferably about 18 mm, which is one of the standard values. A $\times$ 10 eye-piece should be used.



Procedure

Remove the transparent plastic cover from the smoke cell assembly and place on the microscope stage. Connect 12 volts from the transformer to the terminals provided on the smoke cell.

Light the end of a piece of cord (sash cord, clothes line or a drinking straw are suitable) and allow to burn for a few seconds. Blow out the flame and fill the dropper with smoke from the smouldering cord. Inject the smoke slowly from the dropper into the glass cell. When it is full, seal with the cover slip provided.



Focus the microscope on to the top of the cover slip and then slowly lower the objective until the Brownian motion of the smoke particles becomes apparent.

A small piece of black material is provided with the cell, and this should be placed over the festoon lamp to avoid stray light reaching the eye.

Note

The glass cell can be removed from the assembly and cleaned. It must be pushed fully back into the assembly and it may help to do this by wetting the outside of the glass tube. It will be found helpful to clean the glass cell after every five to ten fillings to obtain the best results, otherwise the light intensity is reduced.

53 *Demonstration and class experiment*

Models of gas molecules in motion

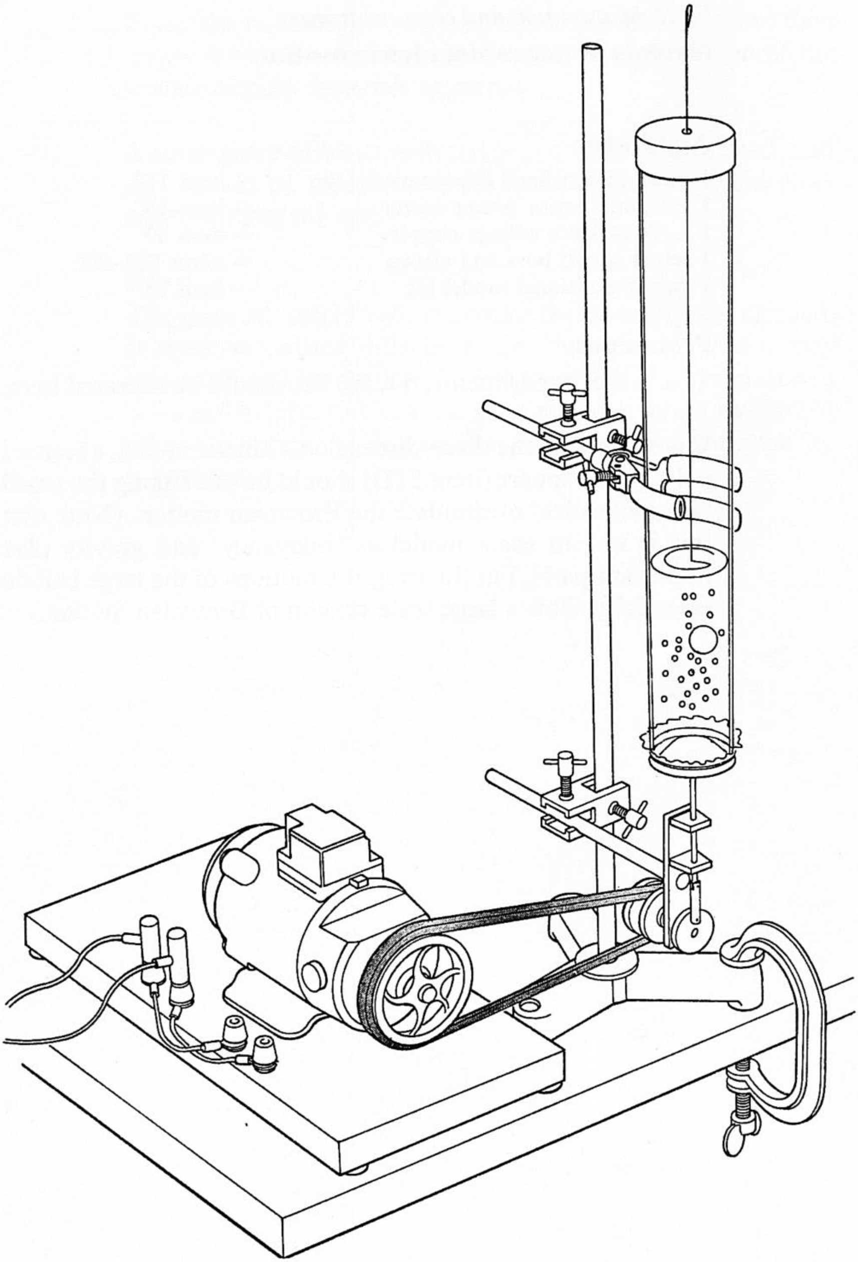
Apparatus

1 three-dimensional kinetic model kit	– item 11
1 fractional horse-power motor	– item 150
1 L.T. variable voltage supply	– item 59
1 retort stand, boss and clamp	– items 503–506
1 two-dimensional model kit	– item 12

Procedure

The earlier experiments, 49, 50, 51, should be repeated here.

When showing the three-dimensional kinetic model, a foamed polystyrene sphere (item 51D) should be put among the small 'gas molecules' to simulate the Brownian motion. (Note that this is not an exact model as 'buoyancy' and gravity play important parts, but the irregular motions of the large ball do essentially show a large scale version of Brownian motion.)



54 *Optional demonstration*

Brownian motion of carbon particles in water

(On no account should this be substituted for the class experiment 52, showing Brownian motion in a smoke cell. If shown, this must come after experiment 52.)

Apparatus

1 microscope with objective of relatively high power ($\frac{1}{6}$ in)
1 slide with cover slip
1 illuminant (12 v. lamp and lens)
  Aquadag (colloidal graphite, photographic opaque or Indian ink)
1 transformer for lamp – item 27

Procedure

Pupils observe the Brownian motion of small specks of carbon suspended in water. The suspension is made by adding a pinhead size speck of colloidal graphite (Aquadag, photographic opaque or indian ink) to a few cc. of distilled water.

It should be viewed with a microscope with a much higher power objective than the one supplied with the microscope suggested for earlier experiments. Transmitted light should be used. Therefore the experiment should remain an optional one, and may be shown as a demonstration with the pupils taking turns to view it.

It is easier to see the particles if the objective lens is used as a water immersion lens. Although lenses such as a $\frac{1}{6}$ in objective are not designed for water immersion, it is advantageous to use the lens like that, by letting it dip momentarily into the liquid in contact with it.

Note

It is essential to make it very clear that this is Brownian motion in a liquid, not in a gas.

55 Demonstration

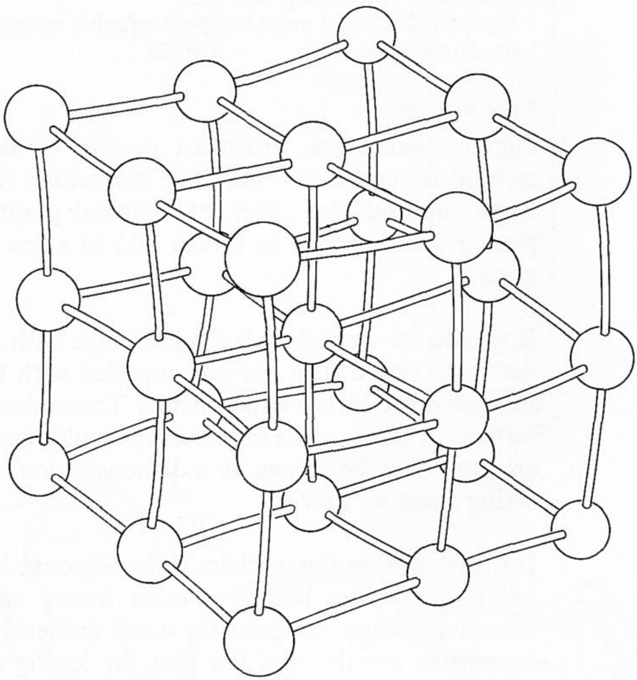
Model of vibrating atoms in solids

Apparatus

Atom model – item 22

Procedure

The model recommended is large and 'wobbly': the more rigid type often used in chemistry departments is not suitable.



The vibrations of the 'atoms' are immediately apparent with this model though the structure retains its basic shape.

At 'higher temperature', the vibrations keep much the same frequency but amplitudes are larger.

56 *Optional demonstration*

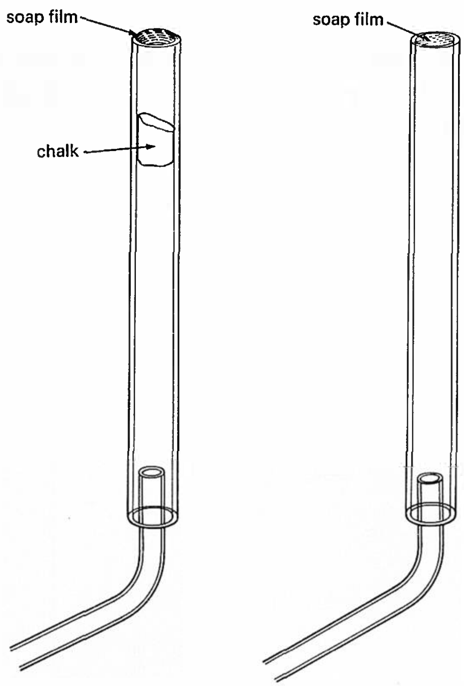
Diffusion of gases

Apparatus

2 6 in lengths polythene tubing
blackboard chalk (soft)
soap solution
hydrogen
carbon dioxide
retort stand, boss and clamp – items 503–506

Procedure

Take a 6 in length of polythene which is slightly too small in diameter to take a $\frac{1}{2}$ in length of *soft* blackboard chalk. Warm it so that it can be stretched and push the chalk a little way into the tubing. Hold this tube in a vertical position using a retort stand, boss and clamp.



Make a soap film at the top end by smearing soap solution across it.

Hydrogen is fed in through a fine tube inserted in the lower end of the polythene tubing. The hydrogen molecules pass more rapidly through the chalk than does the air downwards, so on diffusion the pressure below the soap solution rises above atmospheric and blows a soap bubble.

A control experiment will be necessary to show it is not the hydrogen rising from the fine tube which blows the bubble. This is done by repeating the experiment using another piece of tubing without the chalk.

Notes

1. The hydrogen is best obtained from a cylinder – small cylinders are often available from chemistry departments. Failing that, hydrogen must be obtained from a chemical generator, but in that case it is advisable to pass the gas through a filter of loose glass wool to remove small drops of acid which might spoil the soap film.

2. When the chalk becomes wet with soap solution in repeated experiments, the top layer of chalk can be scraped out with a screw driver.

57 Demonstration

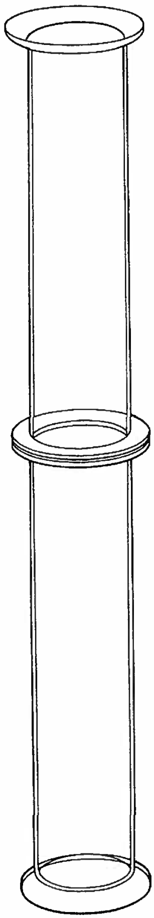
Diffusion of nitrogen peroxide into air

Apparatus

2 gas jars	– item 514
2 cover glasses	– item 515
nitrogen peroxide	
translucent screen and lamp	– items 46/1 and 46/2

Procedure

The diffusion of nitrogen peroxide in air can be shown by taking a gas jar of each, inverting the air-filled gas jar on top of the other. The advantage of nitrogen peroxide is that it is visible and this certainly shows diffusion taking place.



The translucent screen and lamp will make it much easier to see.

Note

The nitrogen peroxide can be manufactured in the bottom of its gas jar beforehand (but it must cool to room temperature), or it may be 'poured' in.

58a *Demonstration*

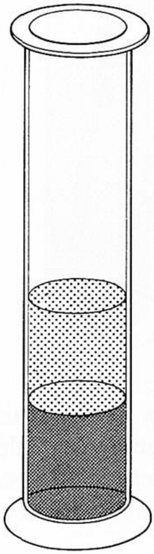
Diffusion of copper sulphate solution in water

Apparatus

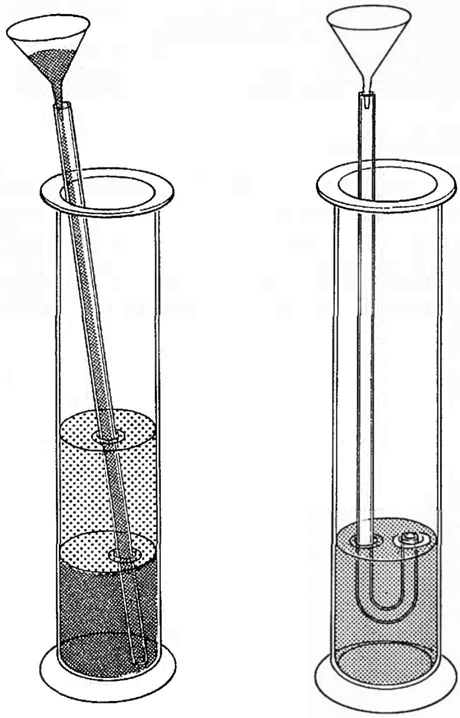
1 gas jar	– item 514
concentrated $CuSO_4$ solution	
distilled water	
funnel and glass tube	– see below

Procedure

The diffusion of copper sulphate in water can be shown by putting a concentrated solution of copper sulphate in the bottom of a tall vessel, such as a gas jar. Introduce carefully some distilled water on top of the copper sulphate. Diffusion in liquids will then be seen in the course of hours.

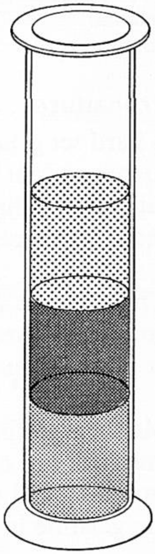


Care must be taken when pouring in the second liquid to avoid disturbance of the first. Pour the water in first and then pour the denser copper sulphate solution down a funnel to which a long tube has been attached with rubber tubing as shown.



Some teachers prefer to use a bent piece of glass tubing as illustrated. The copper sulphate is poured in first in this case, the outlet is kept just *below* the surface as water is poured in and the level gradually rises.

An optional variant is to put a strong sugar solution in the lower third of the vessel. Then introduce the concentrated solution of copper sulphate on top of the sugar to fill the next third. Finally add distilled water on top of the copper sulphate. Copper sulphate will then be seen to diffuse against gravity as well as with it.



58b *Demonstration*

Diffusion of potassium chromate in gelatine

Apparatus

4 boiling tubes
4 retort stands, bosses and clamps – items 503–506
gelatine
potassium chromate

Procedure

A hard set gelatine can be made with gelatine and 10 per cent to 20 per cent hot (not boiling) water. Pour it before setting into four boiling tubes, one tube being filled completely and the other three half-filled. Allow the gelatine to set.

Then fill the three half-tubes to the top with a solution of potassium chromate. Close the tubes with well-fitting corks or bungs in such a way as to exclude air bubbles.

Mount the four tubes in retort stands, one upright, one inverted, one on its side and the gelatine only one (control) in any fashion. Leave for a few hours and observe diffusion into the gelatine in all directions.

If the solutions are then replaced by clear water, it will be possible to observe the reverse diffusion out of the gelatine.

59 *Demonstration*

Diffusion of copper sulphate crystals in water

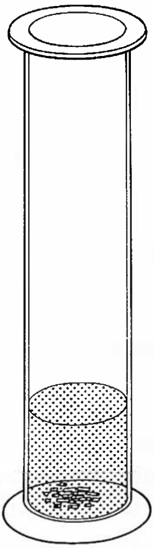
Apparatus

1 gas jar	– item 514
1 cover glass	– item 515
copper sulphate crystals	– item 3N

Procedure

Put a layer of large copper sulphate crystals in a gas jar of water with a cover glass over the top.

Leave it standing for several weeks observing the diffusion.



60 *Optional demonstration*

Diffusion of bromine into air

Apparatus

1 bromine diffusion kit	– item 8
1 retort stand, boss and clamp	– items 503–506
1 translucent screen	– item 46/1
1 lamp	– item 46/2
1 pliers	– item 530

Note

This experiment will be shown in Years III and IV of the Nuffield course. This is merely a preliminary view of an important experiment and it is not essential to show it now.

Esso-Nuffield Film

The details of this experiment are clearly shown in the Esso-Nuffield film for science teachers called *An Approach to Kinetic Theory*. It is available on free loan from Esso Petroleum Company Limited, Victoria Street, London, S.W.1. This is a film for teachers, not for pupils. It should *never* replace the real experiment.

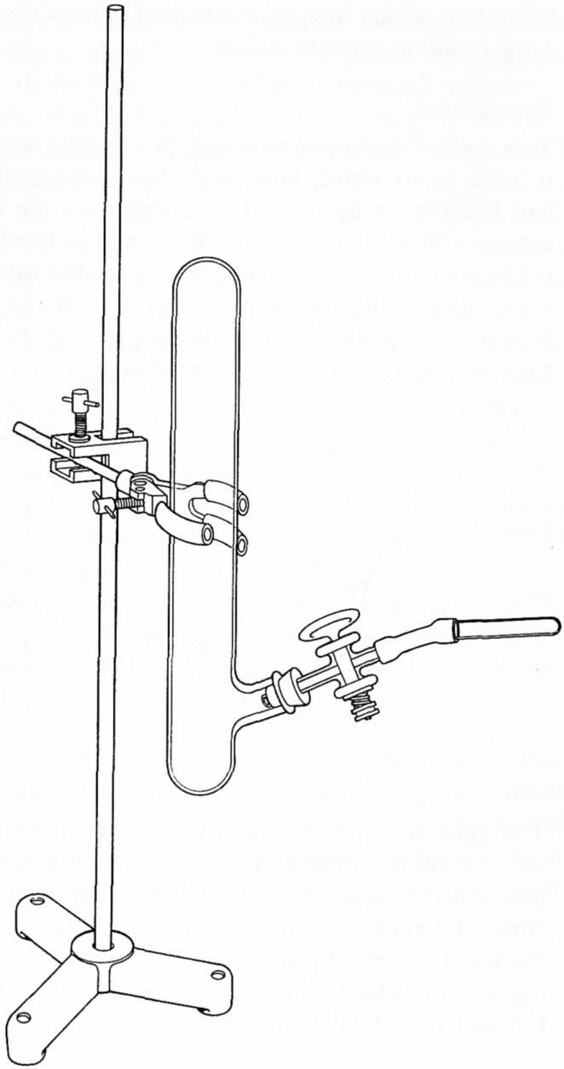
Warning

Bromine is a dangerous substance. If liquid bromine splashes on to the skin it makes a bad blister. Bromine vapour will also attack the skin and will produce a sore throat if used carelessly. In general, bromine attacks almost anything except glass and paraffin wax. Great care should therefore be taken with this important experiment.

The Apparatus

The main diffusion tube is a closed glass tube (18 in long, 2 in diameter) with only one opening. A rubber bung fits into the opening, but the glass tube through it ensures that only bromine vapour and not liquid comes into contact with it. In any case the bung should be replaced by a new one as soon as the bromine has hardened its face. A bung can be used for several experiments in the course of a few days, but if it is then kept for a week or two the rubber will harden and may crack – a new bung must then be used.

The bung must make good contact with the glass side-tube. To ensure that, it may be advisable to moisten it with saliva.

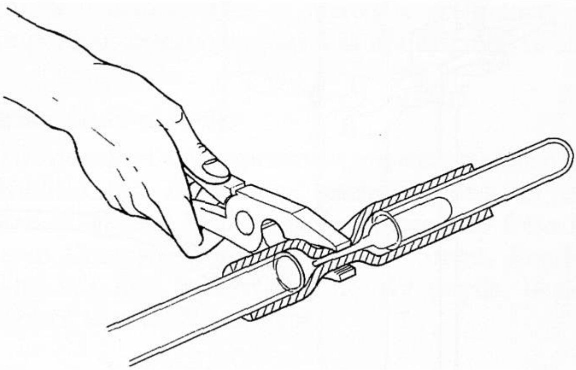


Vaseline should on no account be used, or the bung may slip out of the tube.

A glass stopcock with large bore – 8 mm Interkey stopcock, spring held – separates the main diffusion tube from the region where the bromine capsule is broken. The stopcock is ordinary quality and not a high-vacuum stopcock. To the other end of the stopcock is attached a short length of rubber tubing, to which in turn is attached a glass 'cap-tube' with a 1 ml bromine capsule inside.

Procedure

The main diffusion tube is held firmly in a vertical position using a retort stand, boss, and clamp. A translucent screen and lamp is set up behind it so that the tube is silhouetted against a bright background. The bung is fixed in place and the rubber tubing is fitted tightly on to the other end of the glass tubing. This tubing must be the right size to fit tightly. A bromine capsule is put inside the glass cap-tube and this in turn is connected to the rubber tubing.



The glass tube is raised and tapped until the capsule slides into the rubber tubing. The rubber tubing is squeezed with pliers and the capsule is crushed releasing the liquid bromine. *Note*: the rubber tubing should not be too short otherwise there is a danger of pulling it off the glass tube when squeezing it with pliers. Some will prefer to secure the rubber tubing by wiring it to the glass tubes.

During this process, the stopcock is kept closed. Then the stopcock is turned and bromine is admitted to the main diffusion tube. Leave it for some time so that the pupils can watch the diffusion.

Safety precautions

Both when preparing the experiment and when doing it, the experimenter should have a beaker of strong ammonia solution at hand: ammonia combines with bromine to form harmless ammonium bromide. Strong ammonia solution '0·880', diluted to half or quarter strength, provides an excellent safety precaution. If bromine splashes on table or skin, pour ammonia solution on at once. Ammonia should not of course be used near eyes, for which plenty of cold water is the treatment.

Cleaning the apparatus

After the experiment the whole apparatus should be put into a plastic bucket, previously prepared. The bucket should be half full of a dilute ammonia solution. The apparatus should then be taken to pieces under the solution in the bucket. The lower end of the apparatus should be plunged in first, the bung should be removed from the main tube and the stopcock and other items disassembled. The apparatus can later be washed, dried and reassembled. Some vaseline should be used to lubricate the stopcock. ('Tap grease' should not be used, because it is likely to contain rubber in which case it will become very messy when in contact with bromine. Vaseline, like paraffin wax, is inert. Avoid the modern form of vaseline that has air bubbles in it – that will make the tap leak.)

It is sensible to wear rubber gloves for this cleaning process. Rubber gloves are not necessary during the main experiment and, as explained in the *Teachers' Guide*, this would only invest the experiment with an air of danger which the experiment does not deserve if carried out as suggested above.

61 *Optional demonstration*

Diffusion of bromine into vacuum

Apparatus

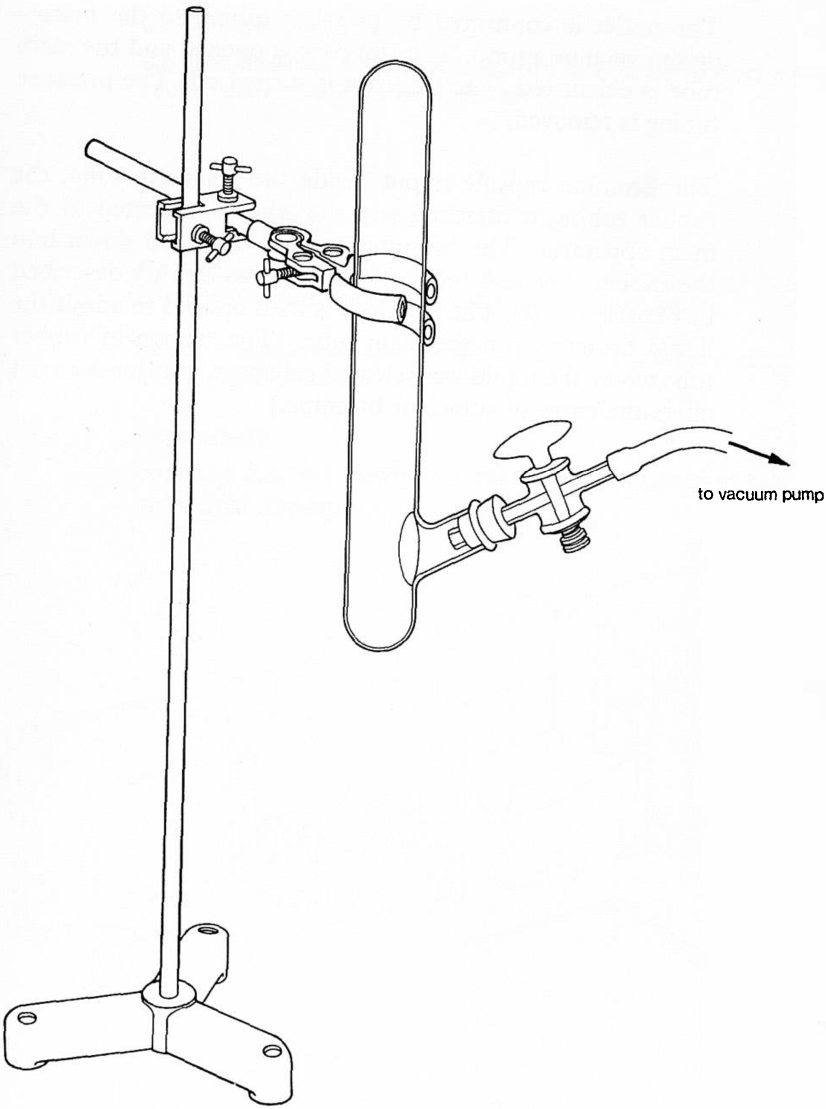
1 bromine diffusion kit	– item 8
1 retort stand, boss and clamp	– items 503–506
1 translucent screen and lamp	– items 46/1 and 46/2
1 vacuum pump	– item 13
1 pliers	– item 530
1 4 ft length pressure tubing	– item 10DD

Note

See Experiment 60 for the warning note, the description of the apparatus, the safety precautions necessary and the details for cleaning the apparatus.

Procedure

A duplicate set of apparatus should be used for this experiment to avoid wastage of time whilst the apparatus in Experiment 60 is being cleaned and reassembled. The bromine diffusion kit (item 6) includes two complete sets of apparatus with some spares.



The main diffusion tube is held firmly in a vertical position using a retort stand, boss, and clamp. The translucent screen and lamp is set up behind it so that the tube is silhouetted against a bright background. The bung and stopcock are fixed in place, but without the cap-tube attached.

The outlet is connected by pressure tubing to the motor-driven vacuum pump. The stopcock is opened and the main tube is exhausted. The stopcock is turned off. The pressure tubing is removed.

The bromine capsule is put inside the glass cap-tube, the rubber tubing is attached and the whole connected to the main apparatus. The bromine capsule is tapped down into the rubber tube and broken with pliers as already described in Experiment 60. The stopcock is then opened to admit the liquid bromine into the main tube. (The section of rubber tube where the liquid was released collapses, but this does not affect the entry of sufficient bromine.)

62 Demonstration

Comparison of pouring marbles, peas, sand and water from one container to another

Apparatus

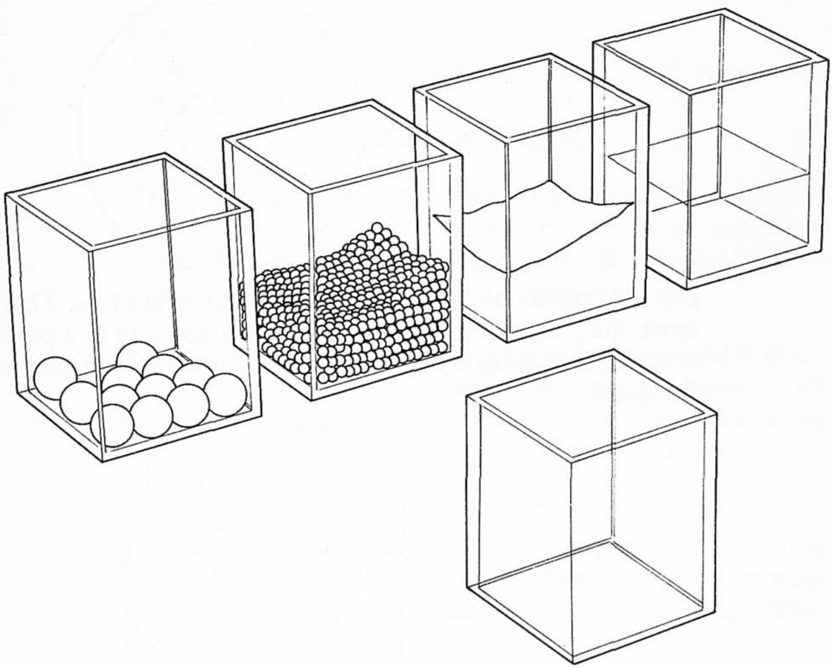
5 Perspex containers – item 26

One container should be empty, the others three-quarters full, respectively, with marbles, dried peas, sand and water.

Plastic containers are used as the marbles might break a glass beaker when poured into it.

Procedure

Pour the marbles slowly into the empty container so that the individual impacts are clearly heard.



Repeat with the dried peas. Then with the sand (though this is obviously discrete it sounds much more like a continuous fluid). Finally pour the water.

63 *Home experiments*

Simple experiments on surface tension

(These experiments are intended for the pupils to do at home.)

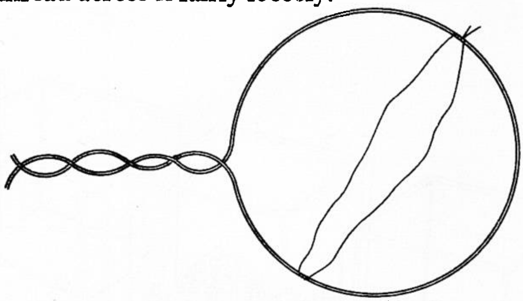
Apparatus

A little household detergent dissolved in water provides a useful substitute for the traditional soap solution in Surface Tension experiments. But, where greasy materials are involved a weak solution of 'Manoxol–OT' is to be preferred.

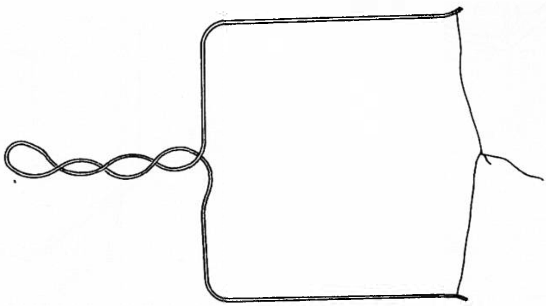
Procedure

a. *Soap Film*

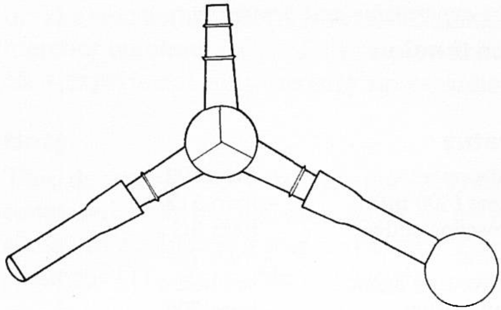
Make a loop of wire about 2 or 3 in across and tie two pieces of cotton thread across it fairly loosely.



Dip the ring into the detergent solution and form a film. Then touch the film between the threads with a hot wire or a piece of chalk. If possible try this with a thread loop loosely held in the frame.



Make a square frame of wire and close its open side with a loose thread as shown. Tie a second thread to the centre of this loose thread. Form a film on the frame and try the effect of pulling on the loose thread.



b. *Soap bubbles*
Borrow a 'T' piece or 'Y' piece, and two short lengths of rubber tubing, and pinch the rubber whilst you blow a second larger bubble on the other piece. Now watch one blow the other one up. Which is which?

c. *A waterproof sieve*
Make a small tray from perforated zinc. Dip it into molten candle grease. Will it float or hold water?

d. *Quick dying*
Take a greasy rag – and make up some dye from ink and water. Open the rag on a sloping sheet of glass and throw some dye over it. What happens? Now add a few drops of the Manoxol–OT solution to the dye and try again.

e. Pour some molten wax on to a scrap piece of wood to give a waterproof surface. Put a drop of water on the surface. Look carefully at it from the side, and touch it with a matchstick which has been dipped into your Manoxol–OT solution. What happens?

f. Float three matchsticks on some water, so that they form an equilateral triangle on the water. Touch the water between the matchsticks with the corner of a cake of soap. What happens?

64 *Class experiment and demonstration*

Surface tension

Apparatus

16 eye droppers	– item 102
16 beakers (400 ml)	– item 512/2
32 microscope slides	– item 3G
paraffin wax	– item 7S
1 bottle wetting agent	– see below
1 Bunsen burner	– item 508
1 2 in soft paint brush	– item 7R
1 can for heating wax	– item 7T

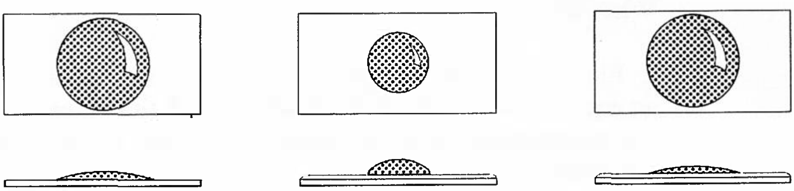
Preparation of Glass Slides

One of the microscope slides must be clean, the other coated with clean paraffin wax. To coat the second slide, heat about ¼ lb of clean paraffin wax in a saucepan. When it has melted and is very hot (almost smoking) either dip the slide in the wax and let it drain or paint some of the liquid wax on the slide with a clean, cheap paint brush.

Procedure

a. Working in pairs, the pupils should make a small pool of water on a clean slide, using fingers or an eye-dropper, and then on the waterproof waxed slide. For the best effect the 'pools' should be about ½ inch in diameter.

The teacher should then produce the beaker of 'wetting agent' and let each pupil dip a matchstick in the solution, to try in the pool on the wax. This will spoil the waterproofing.



After use, the wetting agent must be removed from the waxed slide before it is put away. This is done either by copious rinsing or by removing the wax (which must be thrown away) and rewaxing with new wax.

b. The teacher should then demonstrate the same thing using mercury on clean glass. (This may be done by the pupils as a class experiment, but mercury raises some difficulties.)

Note

This demonstration is a poor one with ordinary detergents compared with the startling effect of a 'wetting agent' designed to act between wax and water. That recommended is Manoxol-OT, obtainable as a powder from B.D.H.

65 Demonstration

Surface tension: aniline dripping in water

Apparatus

1 bottle of aniline	– item 536
1 separating funnel (or tap burette)	– item 516
1 retort stand, boss and clamp	– items 503–506
1 translucent screen and lamp (or projector)	– item 513

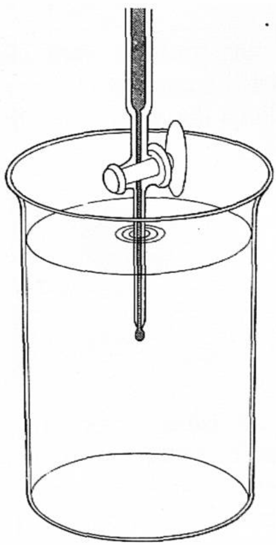
Only about 10 ml of aniline are necessary. Pure fresh aniline is a pale yellow colour. As it ages in a corked bottle, it darkens and the darker the better for this experiment.

A burette can be used in place of the separating funnel.

Procedure

The aniline should be put in a glass separating funnel with a tap, the whole being held in a clamp attached to a retort stand. The end of the funnel should dip into a tall beaker of water.

Aniline is only slightly denser than water at room temperature, so as drops form at the end of the funnel, they hang, buoyed up by the water, as if they had practically no weight at all. A narrow neck forms and then a round drop falls.



Notes

1. The drop that is formed is no bigger than the glass tube at the end of the funnel, where it is formed. Therefore, a large class must either come up and watch it nearby in small groups – for which the time seems hardly justified – or see a demonstration projected with a lantern. It can be shown to a large class by using a flat-sided jar of glass or plastic placed in the beam of an Aldis projector. If plastic is used, place a small glass beaker at the bottom to catch the aniline, because aniline damages most plastics.

2. Aniline is a liver poison which can be taken in through the skin. Contact with it should be avoided. If contaminated, wash immediately.

3. Some teachers prefer the use of other liquids, such as olive oil in alcohol. Aniline, however, is very clearly visible and it works well.

Introductory work for oil film experiment

Apparatus

32 or 48 crystallizing dishes	– item 528
8 lycopodium powder dispensers	– item 7M
1 bottle of olive oil	– item7H
1 bottle of alcohol	
crumbs of camphor	– item 7U
16 eye droppers	– item 10Z
16 8 in lengths 16 swg iron wire	– item 10BB
16 Bunsen burners	– item 508
16 asbestos mats	– item 509
16 heavy iron wires	
16 beakers (400 ml)	– item 512/2
detergent for cleaning	– see below

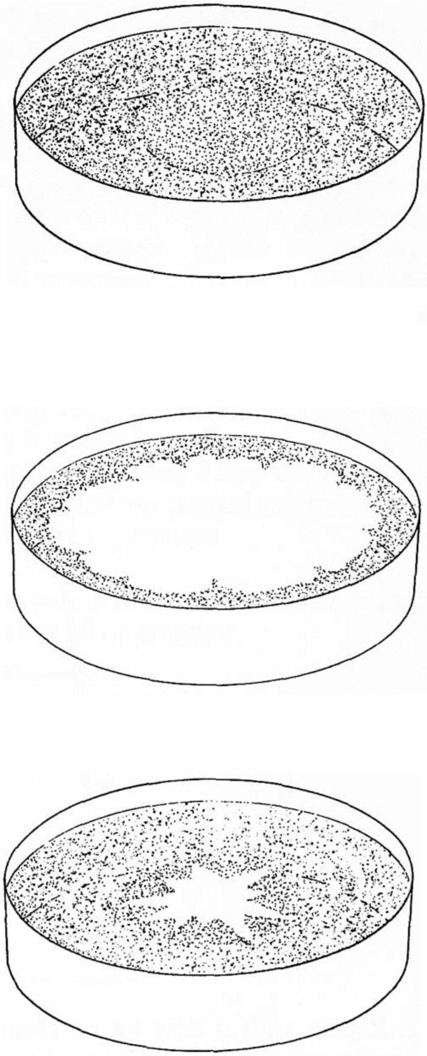
As the dishes become dirty quickly, it is advisable to have thirty-two, or even forty-eight, for a class.

Procedure

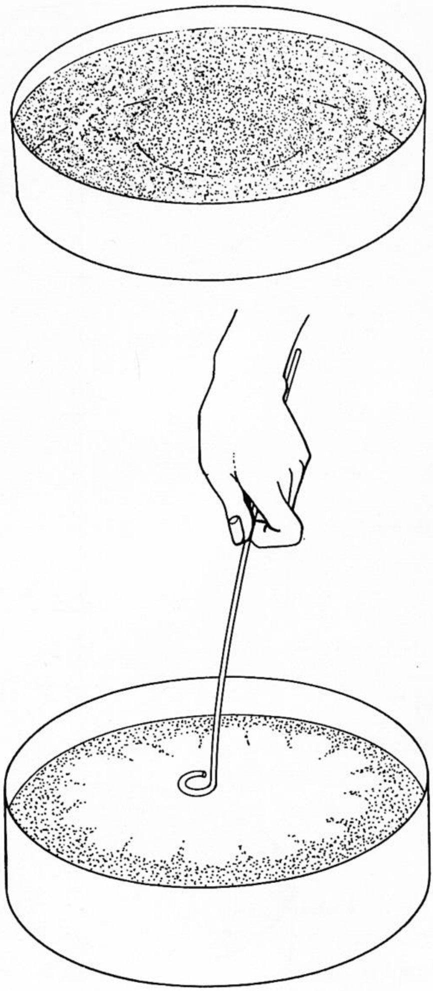
These are important introductory experiments for a proper understanding of the oil film experiment.

Before the lesson begins, the dishes must be cleaned carefully as cleanliness is essential. They should be cleaned with a non-foaming and soda-free detergent (such as Dreft) and then carefully washed to remove all detergent.

a. The surface is very lightly dusted with lycopodium powder. Put a drop of alcohol on the powdered surface. A clean patch appears as the powder is pulled away to the edges (or 'pushed' by the alcohol). The powder returns as the alcohol dissolves in the water or evaporates. The dishes need to be very clean for this. (The teacher can test the cleaning of a dish by putting a drop of absolute alcohol on the water in it with a very little powder. Unless the powder rushes out to the edge, the dish is too dirty to do well.)



b. Repeat with fresh water, again very lightly dusting the surface with lycopodium powder. Bring a red hot iron wire very near the surface. It will be seen that the powdered surface rushes away from that region. (The wire is heated in a Bunsen flame. It must be thick enough to remain very hot when carried to the dish, but not so thick that the heating takes too long. An iron wire 18 gauge or $\frac{1}{16}$ in diameter will do well.)



c. Repeat with a new lot of clean water and lycopodium powder using a very small quantity of olive oil – a matchstick dipped in oil and wiped clean should provide enough. Again the lycopodium powder is pushed aside by the film, but this time it remains and the powder does not return as it did with the drop of alcohol.

d. With a fresh, clean dish try placing crumbs of camphor on a clean water surface. If the camphor seems lazy in its movement, it is a sure sign that the surface is oily. A full re-cleaning is necessary. Then a drop of alcohol may be used as a test.

e. With a very clean dish, a pupil will find it interesting to dip a clean finger in a dusted surface and see the 'grease ring' that forms.

Notes

1. When washing a dish after cleaning it is best to fill it to overflowing. Then hold it with the fingers outside, well away from the rim, tip it sharply to pour out half the water in it. This may help to carry away residual oil. Remember that a monomolecular film of oil will ruin these experiments. That means that 0·00001 gram of oil can spoil a small dish.

2. If the heating and camphor experiments seem unsuccessful, the cause is probably residual oil. The teacher can test against this by administering a drop of alcohol to a powdered surface when the pupil has cleaned and refilled his dish and is ready to repeat the experiment.

3. In storing apparatus, it is essential to keep the lycopodium far away from any oil or camphor.

67 *Demonstration*

Illustration of oil spreading

Apparatus

1 transparent trough	– item 532
drinking straws	– item 4A
Plasticene	

Procedure

The drinking straws are cut into one-inch lengths. A plug of Plasticene is rolled and forced into one end of each of the small lengths, closing that end and making a loaded cylinder.

A handful of about fifty of these loaded cylinders is thrown on to the water surface and the behaviour observed. The straws should float upright and about half immersed in water.

68 *Class experiment*

Estimating the size of a molecule using an oil film

Apparatus

The oil film kit (item 7) includes 8 sets of the following:

1 special tray	– item 7C
1 rubber bung for drain hole	– item 7D
4 rubber wedges for tray	– item 7L
2 metal booms	– item 7J
1 lycopodium powder dispenser	– item 7M
1 cheese cloth cover	– item 7N
1 rubber band for above	– item 7P
1 large sponge	– item 7Q

It also includes 32 sets of the following so that each pupil can have his own:

1 special holder	– item 7G
1 $\frac{1}{2}$ mm graticule	– item 7E
2 mounted wire loops	– item 7F
1 10 ml glass beaker	– item 7K

It also includes:

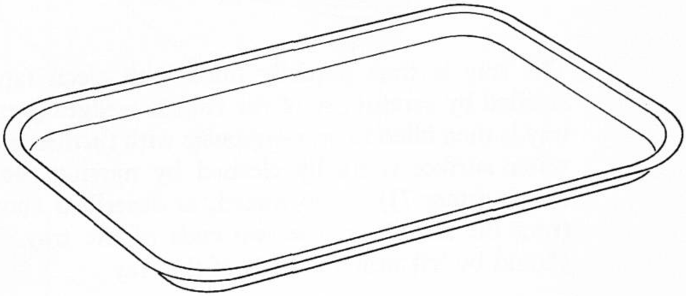
1 250 ml bottle of pure olive oil	– item 7H
1 100 gm bottle of lycopodium powder	– item 7I
1 2 in soft paint brush	– item 7R
1 can	– item 7T
1 $\frac{1}{2}$ lb packet of vegetable black	– item 7B
7 lb white paraffin wax	– item 7S
1 25 gm bottle of camphor	– item 7U

In addition to the above, each pupil will require:

1 retort stand	– items 503–504
1 boss	– item 505
1 hand lens	– item 24

Each group of four will also require:

1 metre rule	– item 501
1 bucket	– item 533



Procedure

Initial preparation of the trays

The trays should have a layer of molten paraffin wax painted on the bottom, the sides and – especially carefully – the top rim. The booms also should be coated with wax. This should be done at least a day prior to use.

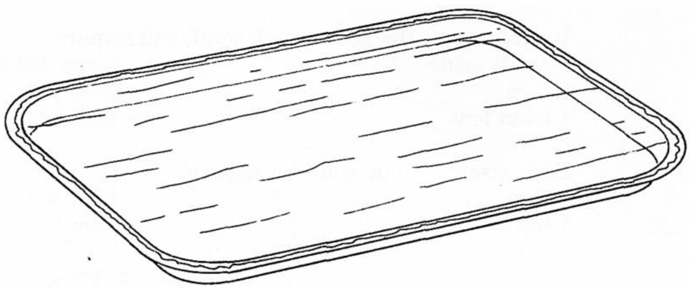
Melt paraffin wax in the can provided in the kit (item 7T). Add a little of the vegetable black (item 7B). When the liquid is hot – almost but not quite smoking – paint it on to the tray with the soft 2 in paint brush (item 7R).

Any thick blobs of wax which form on the rim can be dispersed by repainting with a brushful of very hot, molten wax. (It is *not* advisable to use a Bunsen flame, though that is tempting. A flame playing on the wax surface may add grease, a flame under the tray will melt the unwanted blobs but may also do unexpected damage.)

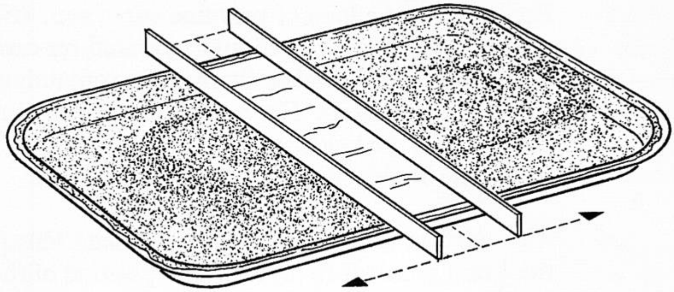
If any difficulty in waxing the tray is experienced, it is almost certainly due to not having the wax hot enough.

Setting up the trays

The prepared tray is placed on the bench with the corner with the drain hole hanging over the bench edge. The hole is closed with the rubber bung (item 7D) from below.

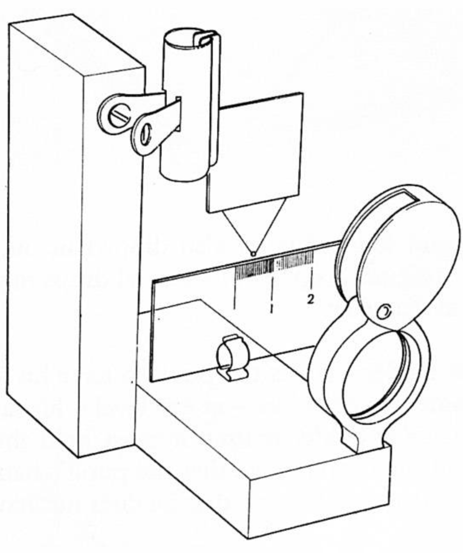


The tray is then partially filled with clean tap-water and levelled by careful use of the rubber wedges (item 7L). The tray is then filled to *over-brimming* with further levelling. The water surface is finally cleaned by moving the two metal booms (item 7J) – also waxed, as described above – slowly from the middle to the two ends of the tray. The booms should be left near the ends of the tray.



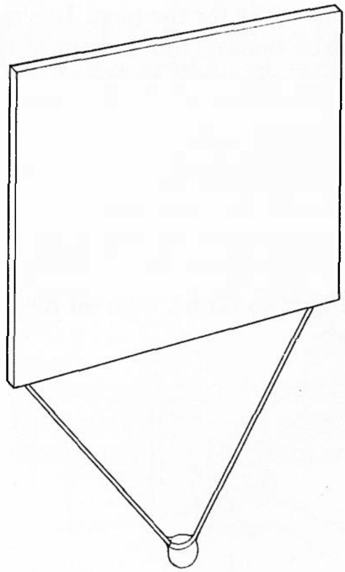
The advantage of this arrangement is that it makes it very easy to prepare the water surface after one oil film experiment ready for the next. It is merely necessary to take up the waxed booms, move them to the centre and sweep the surface as described above.

Preparing the oil drop
It is important that each pupil should do his own experiment. Whereas the trays are shared in groups of four, each pupil should prepare his own small drop of olive oil. Because of the ease with which the water surface can be cleared, he will also be able to do his own oil film experiment on the water surface.



Each pupil has a loop of very fine wire (item 7F) – steel wire, diameter 0·003 in, looped and mounted on card – which he dips in his small beaker (item 7K), containing olive oil, to catch a small drop. He suspends the loop in the special holder, fixes the holder rigidly to his own retort stand using a boss. The holder should be level with his eye.

Also fixed in the special holder is a hand lens (item 24) and the $\frac{1}{2}$ mm graticule (item 7E). The position of the loop should be adjusted so that the drop is clearly seen against the $\frac{1}{2}$ mm graticule when viewed through the hand lens.



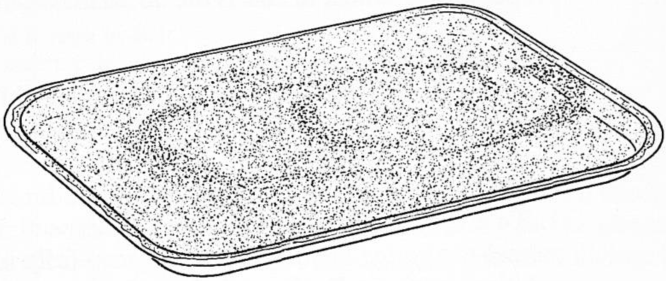
With a second loop of wire, also dipped in oil, the pupil 'teases' the original drop or runs several drops together until it is $\frac{1}{2}$ mm in diameter.

The special holder enables the pupil to have his hands free. Without some sort of holder – at eye level – his task is much harder. Whatever holder is used it must hold the loop, the graticule and the hand lens so that the pupil's hands are free and it must be at eye level so that he does not have to strain his neck.

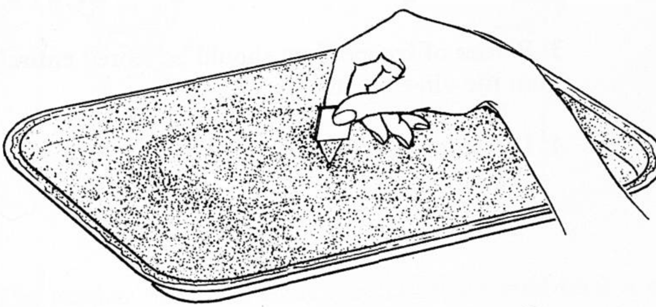
If there is an excess of oil on the loop, the pupil can wipe this off with filter paper.

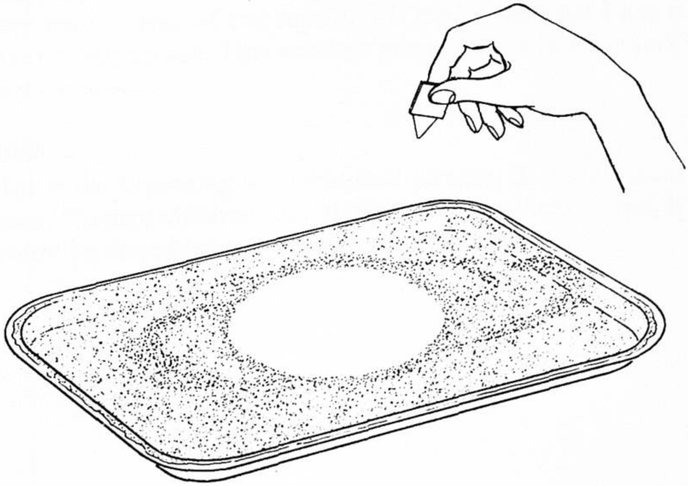
Doing the experiment

Having cleaned the water surface by moving the waxed booms across it, the pupils lightly dust the surface with lycopodium powder.



When he has adjusted his drop of oil to $\frac{1}{2}$ mm diameter, he brings it to the tray and dips the loop with the drop into the water. The metre rule is used to measure the maximum diameter of the patch produced.





(With some water supplies, the patch contracts to a smaller size soon after it is formed. This is probably due to water-softening agents attacking the oil, though this is not certain. Whatever the cause of such a contraction, we believe the proper measurement to take is the initial maximum diameter.)

Calculation of the estimate
See the *Teachers' Guide* for the simplification which should be used.

Notes

1. To empty the tray, put a bucket underneath the hole and release the bung. Then wash the tray carefully in a detergent solution, such as Dreft, and flush for a considerable time before storing.

2. Since effective waxing of the edges of the tray is essential, it is advisable to store the trays very carefully using, for example, corrugated card to separate tray from tray.

3. Bottles of lycopodium should be stored entirely separately from the olive oil stock.

4. It is important in this experiment to use *pure* olive oil.

69 *Demonstration*

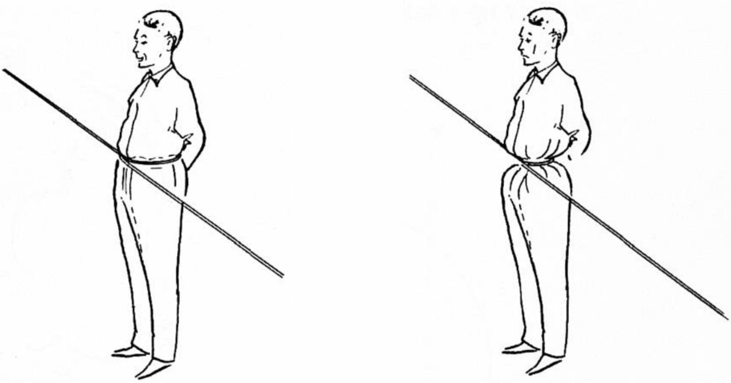
Dependence of 'size' on 'method of measurement'

Apparatus

1 4 ft rope or belt
1 metre rule – item 501

Procedure

The teacher uses the rope or belt as a tape measure, putting it round a pupil's waist. He removes the rope, holds it straight and, with the aid of the metre rule, measures the circumference. He asks how to get the diameter and then divides by 3·14.



The teacher then asks what the diameter would be if a wire were used instead of the rope and if pulled very hard like a wire cutting cheese. This extreme measurement is, of course, only discussed.

Note

This is the beginning of operational physics, in its technical sense. Though children may think this experiment trivial, it should be done here to start an important idea.

70 Class experiments

Things to do for a discussion of 'jobs' needing food

Apparatus

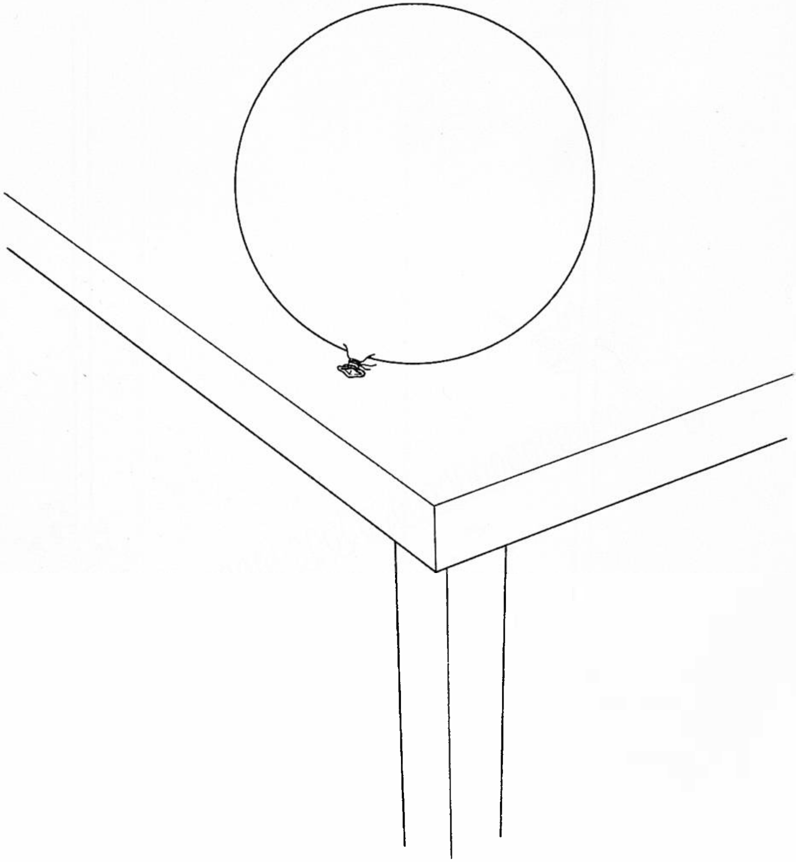
balloons	– item 57C
steel springs	– item 2A
bricks or wooden blocks	
pulleys on clamps	– item 40
cord	– item 10A

Procedure

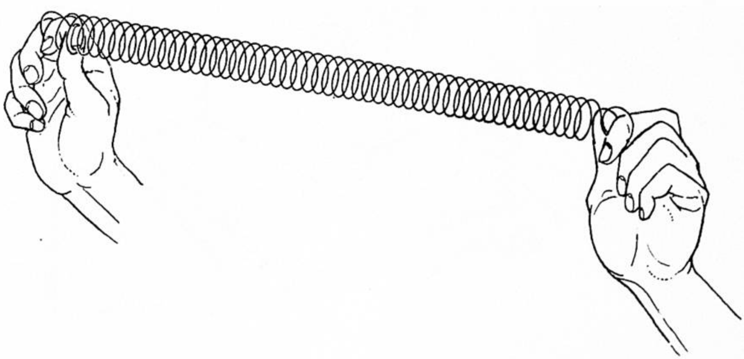
Simple examples of 'jobs' to be done for quick discussion whether food is necessary for each, directly or indirectly:

a. Blow up a balloon.

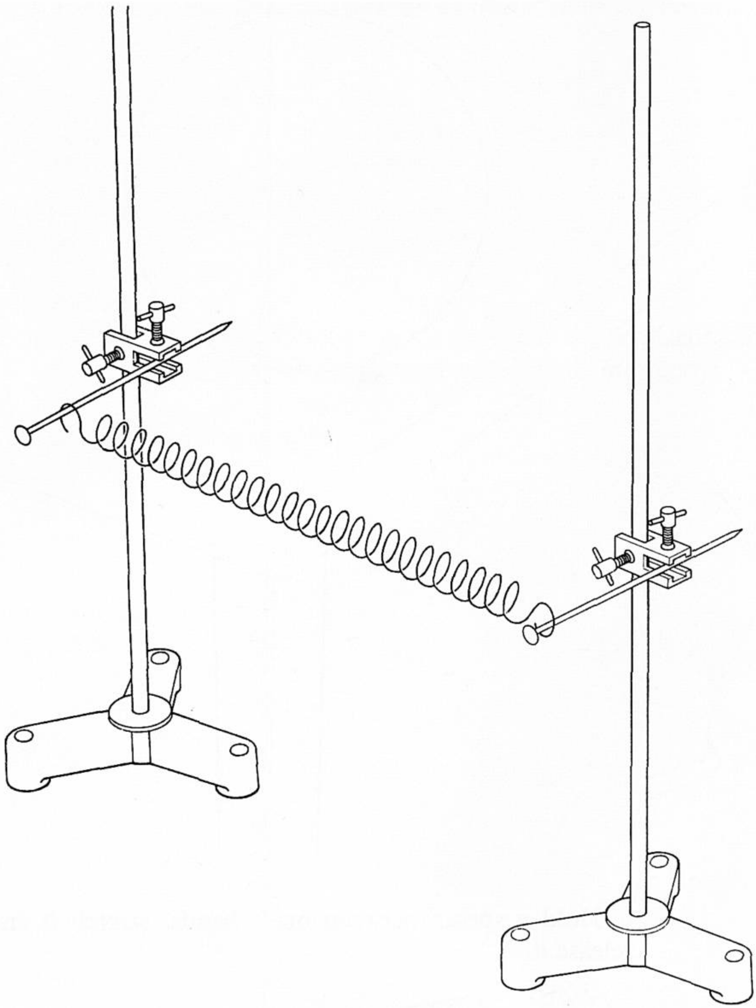
b. Put the blown-up balloon on a table and sit and watch it.



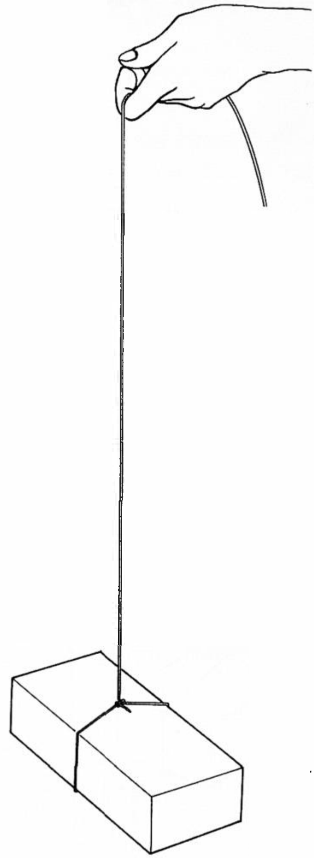
c. Hold a spring between one's hands, stretch it and then release it.



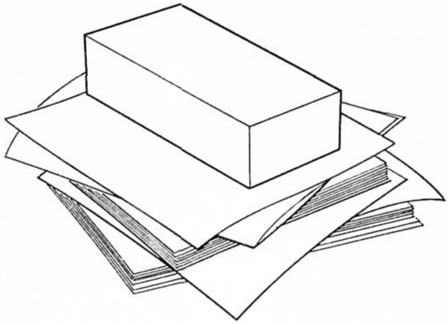
d. Keep a spring stretched permanently between two pegs.



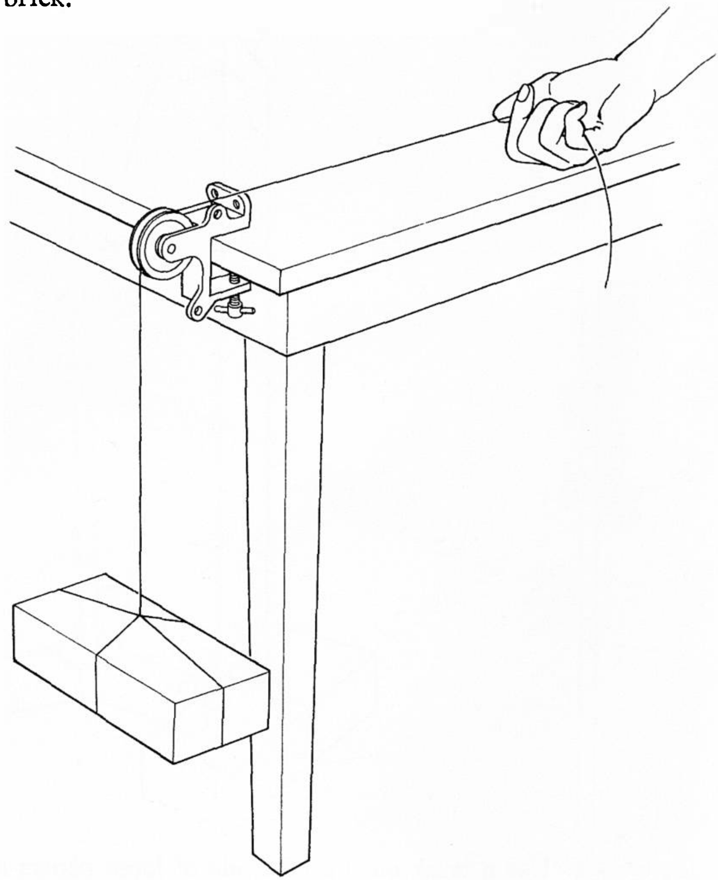
e. Raise a brick (or block of wood) from the floor to a table by pulling on a string tied to the brick.



f. Use a brick on top of a pile of loose papers as a paper-weight.



g. Finally fix the pulley to the edge of the table and run the string over it and raise the brick by pulling the string horizontally along the table with the other end attached to the brick.



71 *Wallchart*

Human energy - food supplies and activity demands

The following information might be displayed:

1. Energy from food

Some idea can be gained of the energy available from different sorts of food if we work out the number of kilocalories liberated per ounce.

Food	*Energy value*	*Food*	*Energy value*
Butter	211 kilocal/oz	Margarine	226 kilocal/oz
Sugar	108 kilocal/oz	Beef	91 kilocal/oz
White bread	73 kilocal/oz	Fried fish	58 kilocal/oz
Potato	21 kilocal/oz	Boiled fish	20 kilocal/oz
Oranges	10 kilocal/oz	Cheese	120 kilocal/oz
Turnip	5 kilocal/oz	Oatmeal	115 kilocal/oz
Lentils	84 kilocal/oz	Eggs	46 kilocal/oz

2. Human energy demands

How much energy do we need each 24 hours? The answer depends very much on the sort of people we are, particularly our age and our occupation. Some average figures are as follows:

Children (either sex)

0–1 yr	1,000 kilocal/day
2–6 yrs	1,500 kilocal/day
7–10 yrs	2,000 kilocal/day

Teenagers

	Males	*Females*
11–14 yrs	2,750 kilocal/day	2,750 kilocal/day
15–19 yrs	3,500 kilocal/day	2,500 kilocal/day

Adults (20 years and over)

	Males	*Females*
Lying in bed	1,750 kilocal/day	1,500 kilocal/day
Light work	2,750 kilocal/day	2,250 kilocal/day
Heavy work	3,500 kilocal/day	3,000 kilocal/day
Extremely heavy work	5,000 kilocal/day	

Pregnancy	
first half	2,500 kilocal/day
second half	2,750 kilocal/day
lactation	3,000 kilocal/day

The energy needed by an adult to perform various tasks has been estimated as follows (the data were obtained from a coal miner who was 32 years old, 5 ft 9 in tall and weighed 10 stone 8 lb. The data were obtained over the period of one week).

Resting in bed	0·94 kilocal/min
Washing, shaving, dressing	3·3 kilocal/min
Walking	4·9 kilocal/min
Standing	1·8 kilocal/min
Cycling	6·6 kilocal/min
Hewing coal	6·7 kilocal/min
Loading coal	6·3 kilocal/min
Walking (in mine)	6·7 kilocal/min

Generally speaking, energy consumption by an adult man ranges from 12·5 kilocalorie/min for the heaviest work to 2·5 kilocalorie/min for the lightest. Such estimates are, of course, only average. Just as our body temperature varies from one person to another, so do our energy needs for the same rate of work.

Available charts

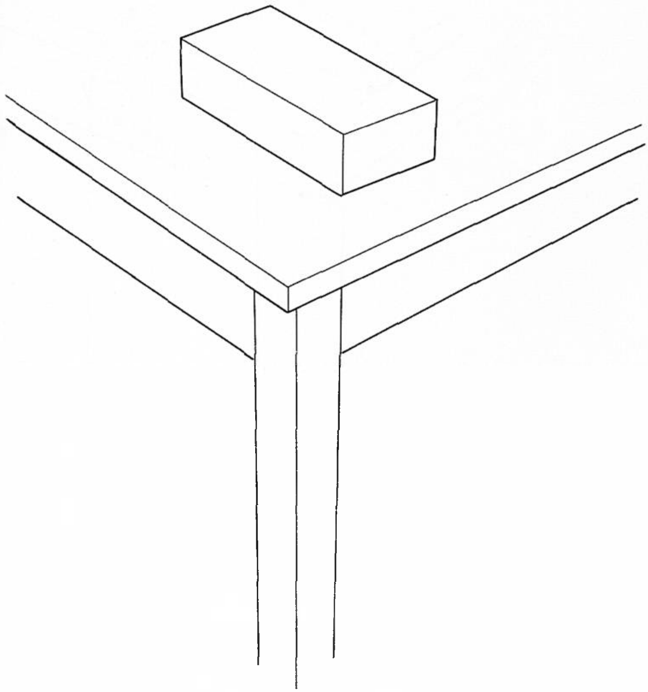
A series of wallcharts on energy are available from Esso Petroleum Company. One of them incorporates the data given above.

72 Demonstration

Use of a brick to introduce some forms of energy

Apparatus

1 brick	
1 pulley on clamp	– item 40
1 large compression spring	– item 88
1 motor/generator unit	– item 9A
1 line shaft unit	– item 9F
1 lamp unit	– item 9D
3 G-clamps	– item 44/1
cord	– item 10DD
1 retort stand base	– item 503
1 long retort stand rod	
1 1 lb weight	– item 36
1 L.T. variable voltage supply	– item 59

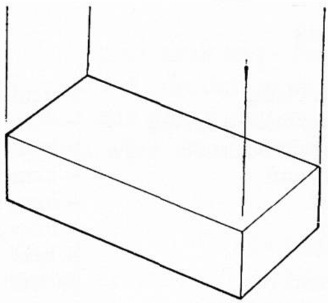


Procedure

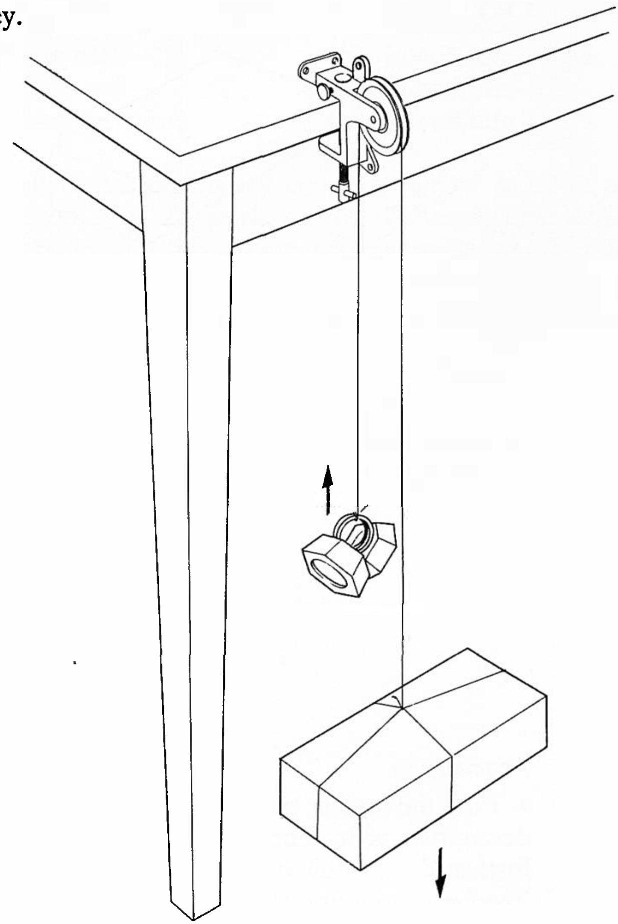
a. First the teacher puts the brick on the bench and invites a description of it. Then the brick is put on the floor and a further description is asked for. See the discussion in the *Teachers' Guide* how the pupils should be led to the idea that a brick higher up can 'do a job'.

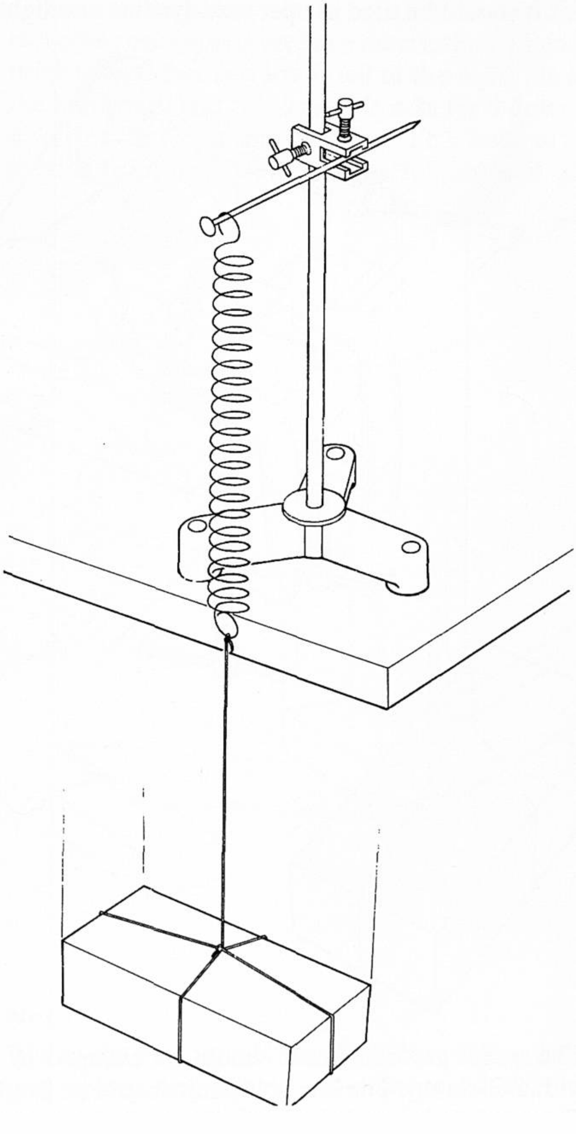
b. Then the brick is used in various ways to do 'a job' as it falls:

(i) It should accelerate by falling vertically.



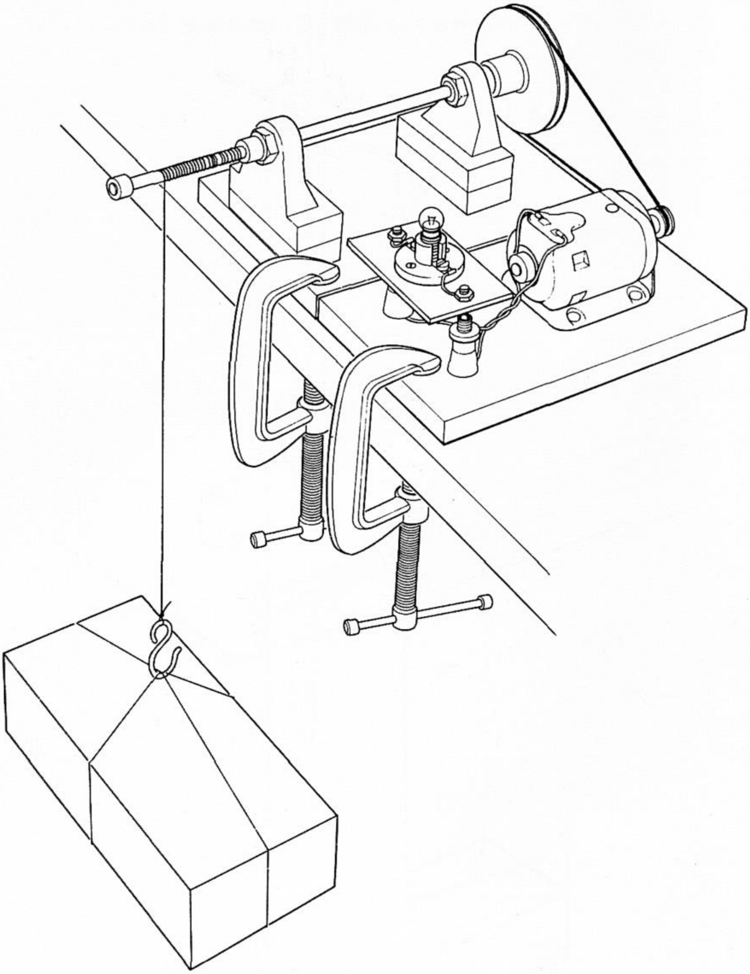
(ii) It should be allowed to lift another load, by a cord and pulley.





(iii) It should be used to stretch a horizontal or vertical spring.

(iv) It should be used to operate a dynamo and light a lamp.

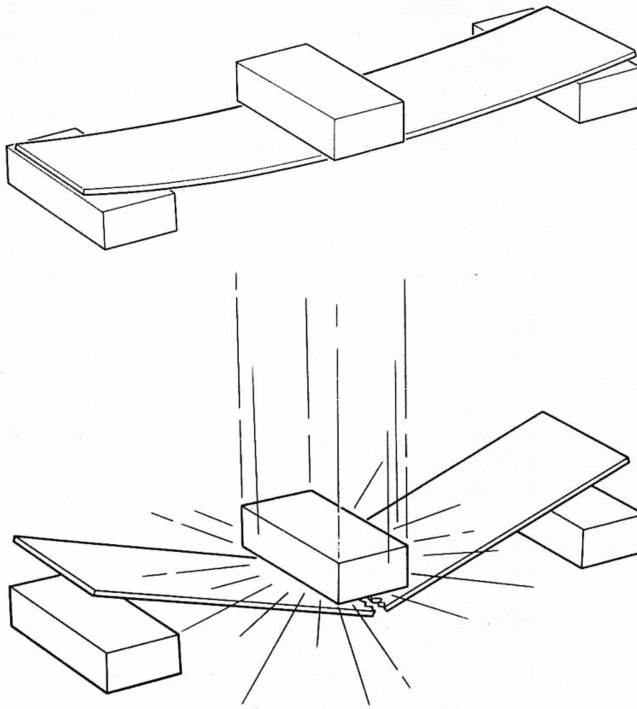


The motor/generator unit should be clamped to the bench with a G-clamp. The line-shaft unit should be fixed next to it. The cord tied round the brick is wrapped round the axle of the line shaft.

The output terminals of the generator are connected to the lamp unit.

When the brick is released it will turn the dynamo which in turn lights the lamp, or several lamps in parallel.

c. The teacher places a brick on a hardboard 'bridge' (across two other bricks) and invites a description. Then he raises the brick several feet and lets it fall to the floor. He lets it fall on the hardboard and breaks it. He asks for a description of the brick just before it hits the floor. This leads to the idea of a moving brick being able to do useful jobs as it comes to rest.



Note

Where the floor may be damaged by a falling brick, teachers may wish to wrap the brick in newspaper before letting it fall.

73 *Demonstration*

Discussion of work

Apparatus

Experiments 1 and 3

2 1 lb weights	– item 36
1 3 ft wooden lath	– see below*
3 shelves	– see below†
1 motor/generator unit	– item 9A
1 line shaft unit	– item 9F
1 L.T. variable voltage supply	– item 59
2 G-clamps (2 in)	– item 44/2

Experiment 2

1 set of accessories for model lift	– see (b) below
1 metre rule	– item 501

Experiment 4

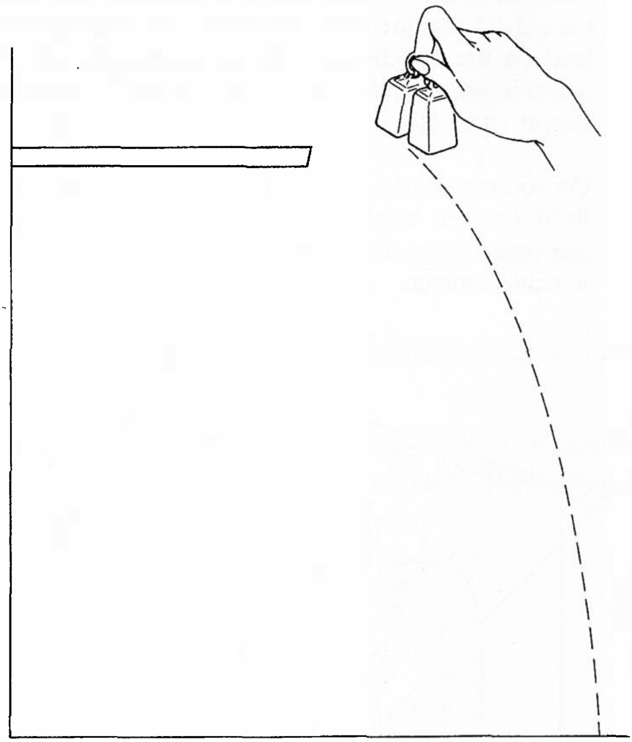
2 retort stands and bosses	– items 503–505
1 6 in nail	– item 10H
1 S-hook	– item 35
1 compression spring	– item 88
2 G-clamps (4 in)	– item 44/1
1 single pulley on clamp	– item 40

*The 3 ft wooden lath should be marked in feet as a foot rule and is left to the teacher to provide.

†The shelves are also left to the teacher to provide. In 1 only one is used and this should be arranged 3 ft above the bench-top. In 3 all three are used, supported respectively 1 ft, 2 ft and 3 ft above the bench-top.

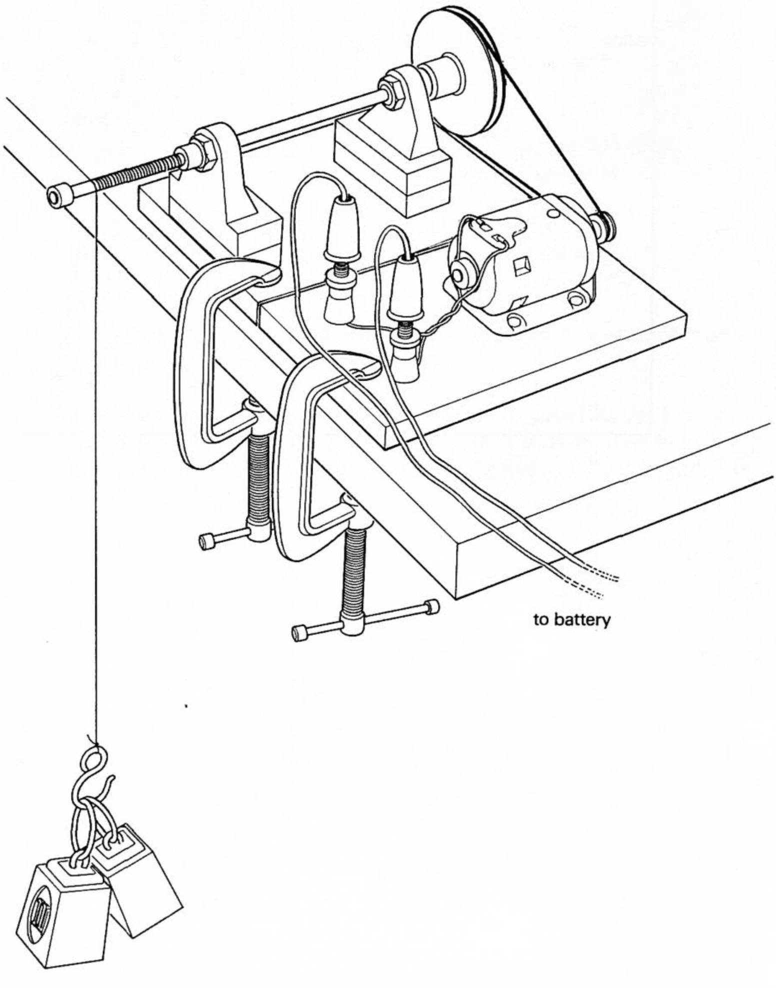
Procedure

a. The teacher raises the 2 lb load from the bench to the 3 ft shelf as part of his discussion of work.



An optional additional experiment is to use the electric motor to transfer the same amount of energy. The motor/generator unit should be clamped to the shelf with the line shaft unit clamped beside it. One end of a length of cord is secured to the axle of the line shaft, the other end is attached to the 2 lb load on the bench-top. The motor requires 6 volts d.c. to drive it. A suitable supply is the L.T. variable voltage supply (item 59).

On connecting the motor to the supply it will wind up the 2 lb to the shelf height. It is about the limit for this motor and the speed drops as the layers of thread increase the effective winch diameter.



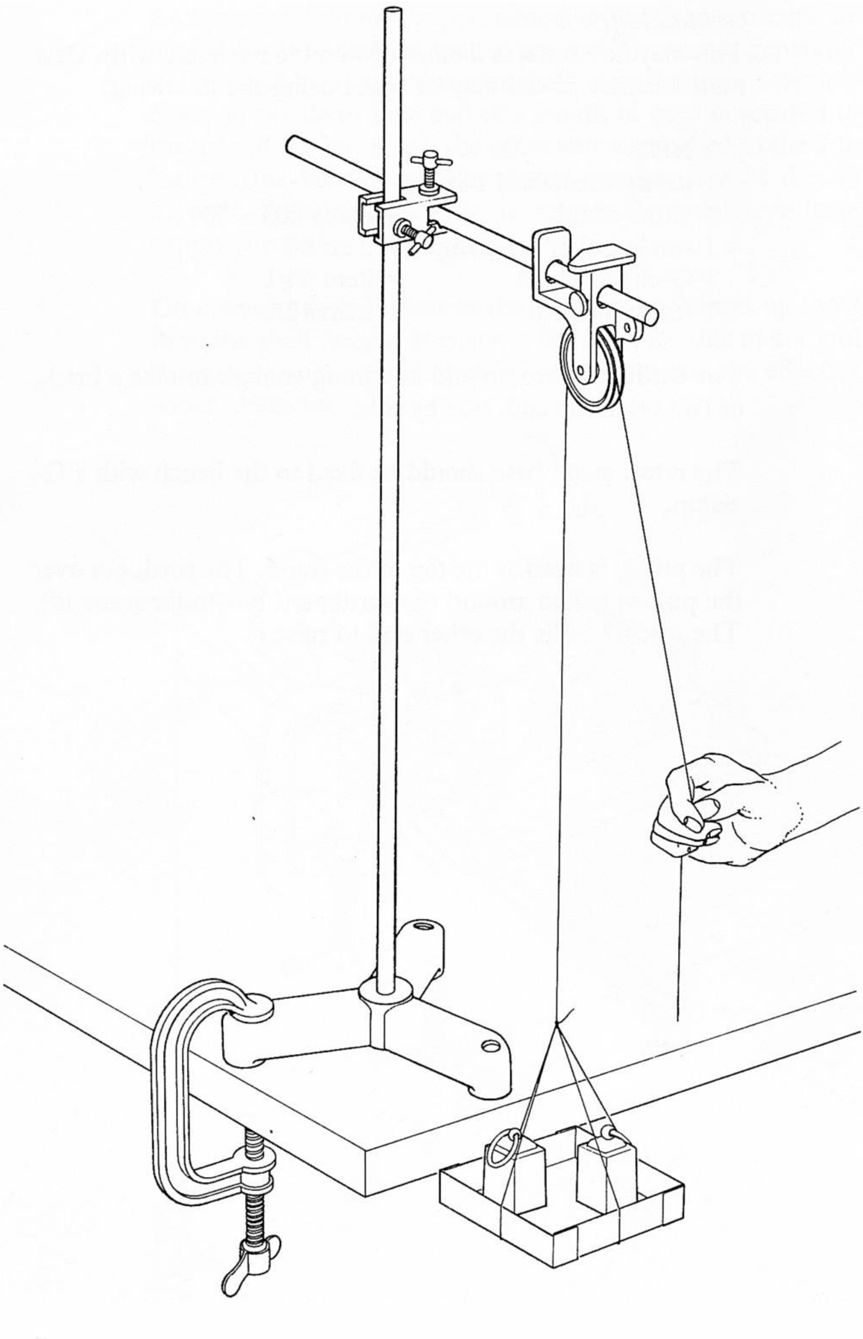
b. *Model lift*
This may be a brick or a block of wood to represent a lift. Or a more realistic model may be made using the following:

2 bricks	
1 strong cardboard box	
1 retort stand	– items 503 – 504
1 single pulley on clamp	– item 40
1 G-clamp (4 in)	– item 44/1
1 length of cord	– item 10A

The cardboard box should be strong enough to take a brick, or two bricks on end, side by side.

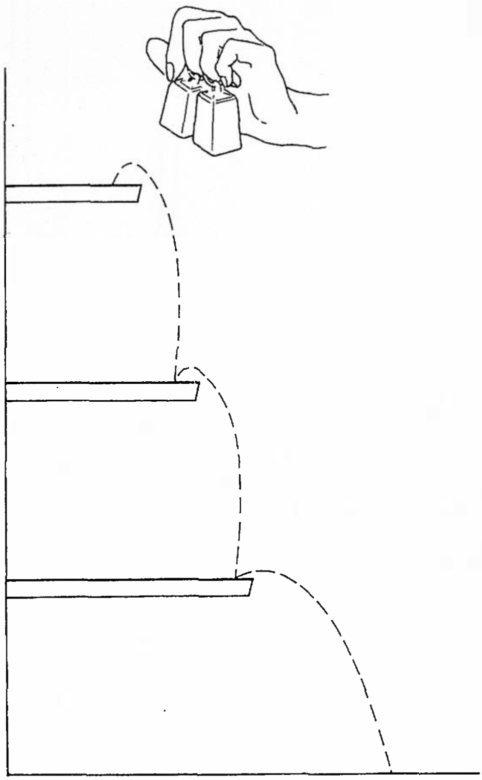
The retort stand base should be fixed to the bench with a G-clamp.

The pulley is fixed at the top of the stand. The cord, put over the pulley, is tied around the cardboard box to form the lift. The teacher pulls the other end to raise it.



c. The three shelves should be arranged side by side at heights of 1 ft, 2 ft, and 3 ft above the bench-top respectively.

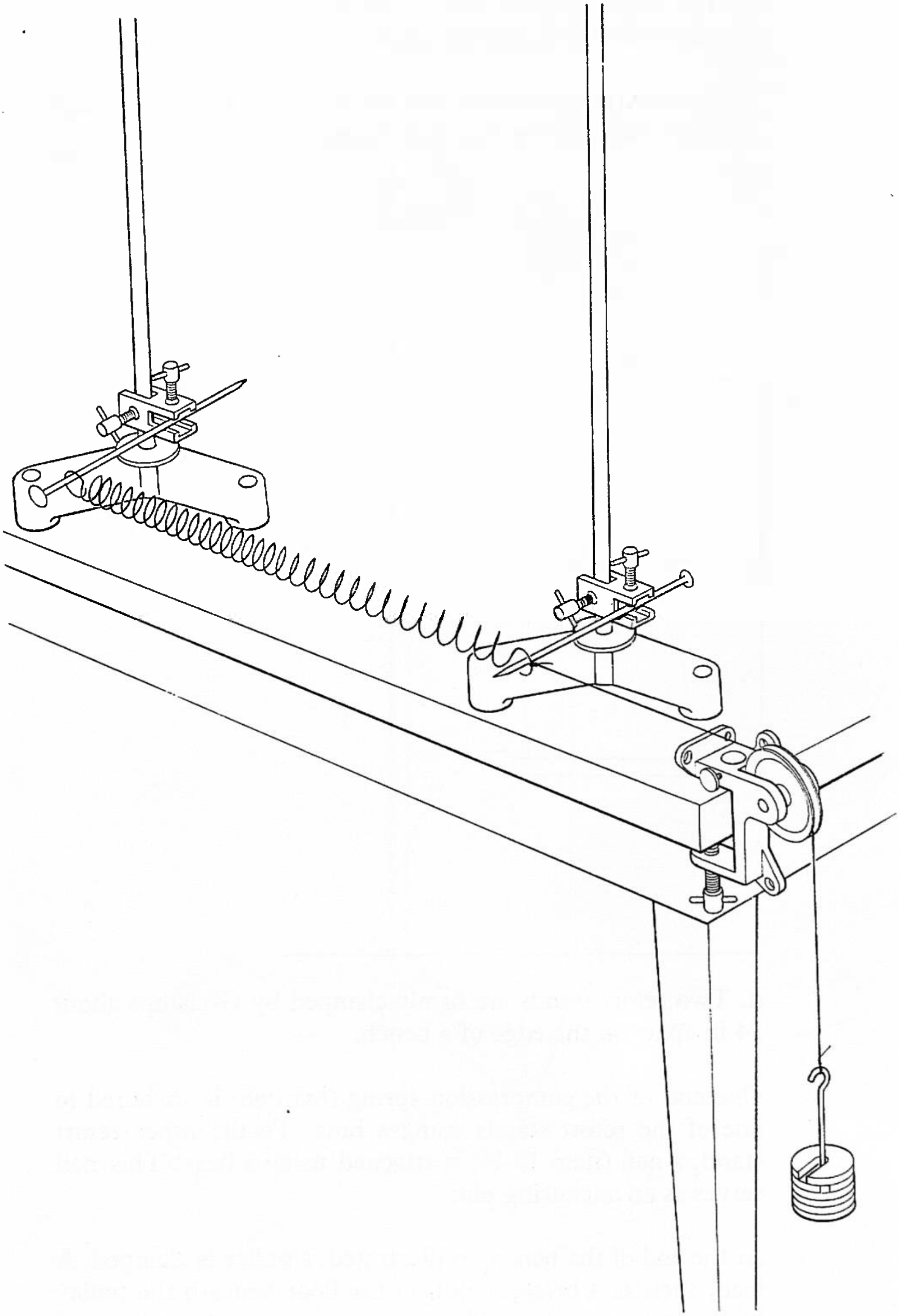
As in the first experiment, the teacher raises the 2 lb through 3 ft, but this time he does it in stages.

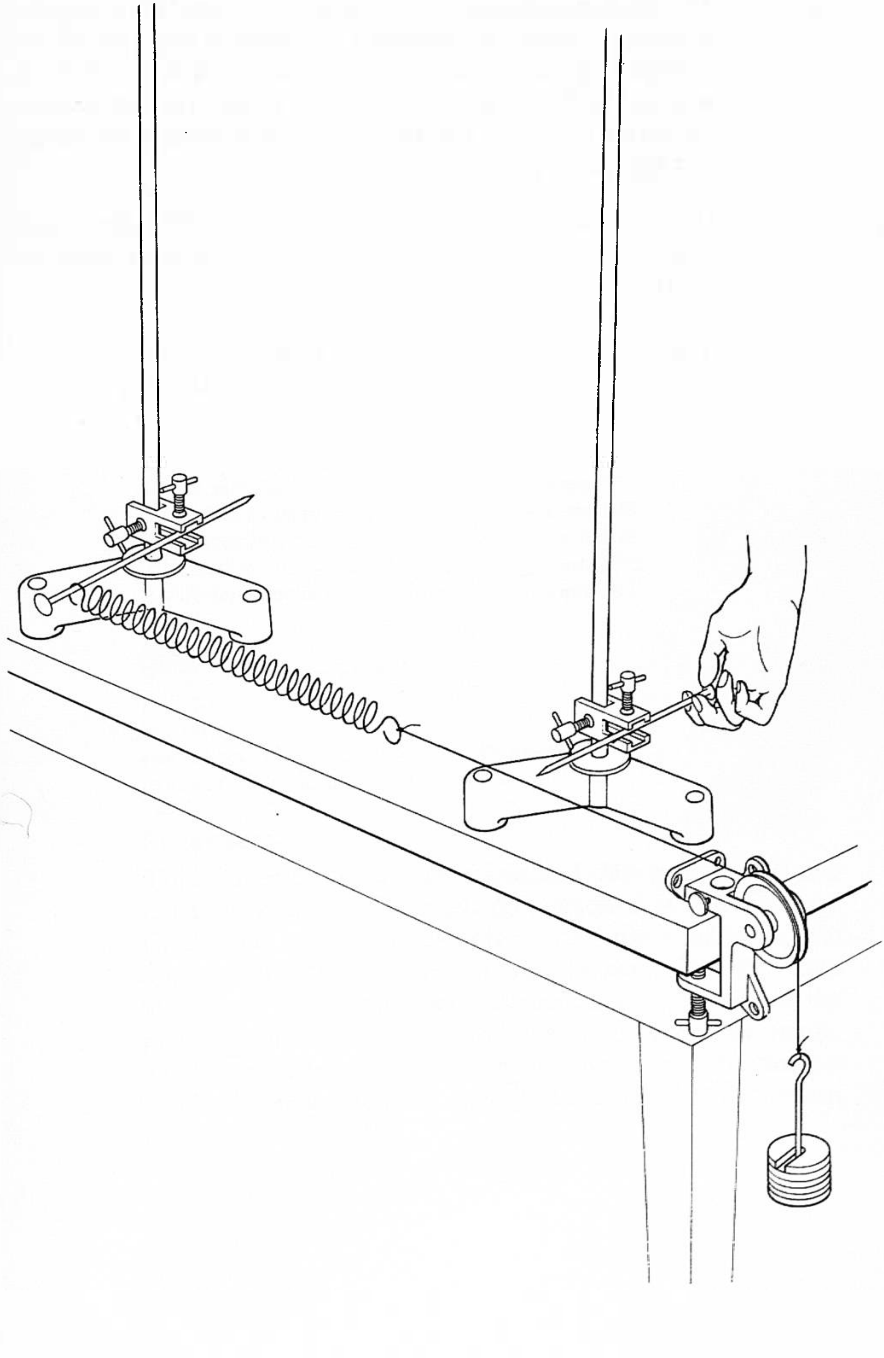


d. Two retort stands are firmly clamped by G-clamps about 24 in apart on the edge of a bench.

One end of the compression spring (item 88) is anchored to one of the retort stands using a boss. To the other retort stand, a nail (item 10 H) is attached using a boss. This nail serves as an anchoring pin.

At the end of the bench, as illustrated, a pulley is clamped. A load, such as a brick, is put on the floor beneath the pulley with a string attached. The string passes over the pulley and terminates in an S-hook near the second retort stand.





The teacher stretches the spring horizontally. While pausing to discuss what has happened he anchors the end of the stretched spring to the nail. He then connects the S-hook, attached to the string and load, to the spring. He then releases the spring (which he was holding, whilst attaching the string) and the load is pulled up some distance.

Obviously the spring and load must be such that the tension when the spring is stretched is a good deal more than the weight of the load.

The fact that the spring does not pull all the way back to its original unstretched length does not spoil this experiment: this is part of an important illustration.

Illustrations of energy changes

Apparatus

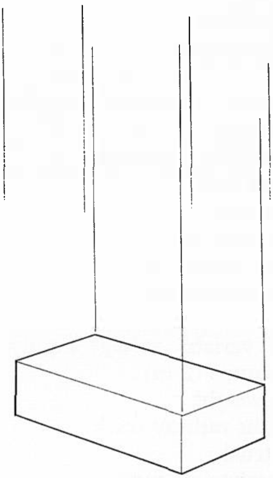
1 Malvern energy conversions kit	– item 9
including:	
1 motor/generator unit	– item 9A
1 switch unit	– item 9C
1 lamp unit	– item 9D
1 line shaft unit	– item 9F
1 steam engine unit	– item 9I
1 turbine/pump unit	– item 9J
1 L.T. variable voltage supply	– item 59
2 G-clamps (2 in)	– item 44/2
1 1 lb weight	– item 36
5 lengths railway track	– item 10R
2 flat trucks	– item 10S
2 horseshoe magnets	– item 50/2
2 wooden blocks with buffers	– item 10T

also:
block of wood (or brick)
pulleys
hammers
lead sheets (1–2 sq. in, $\frac{1}{16}$ in or thinner)
iron wire (1 ft long, 20 gauge)

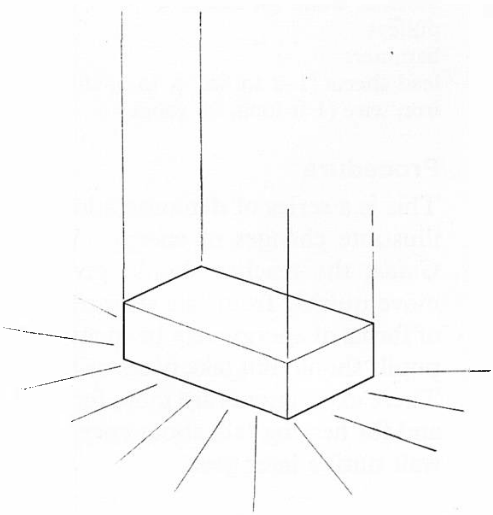
Procedure

This is a series of demonstrations and class experiments that illustrate changes of energy. As suggested in the *Teachers' Guide*, the teacher should give very little discussion, but move quickly from one example to the next. Though names of forms of energy may be mentioned, it is suggested that the pupils should not take notes or be asked to learn those names. These experiments are more for the fun of seeing the changes and for hearing talk about energy; definitions and details can wait until a later year.

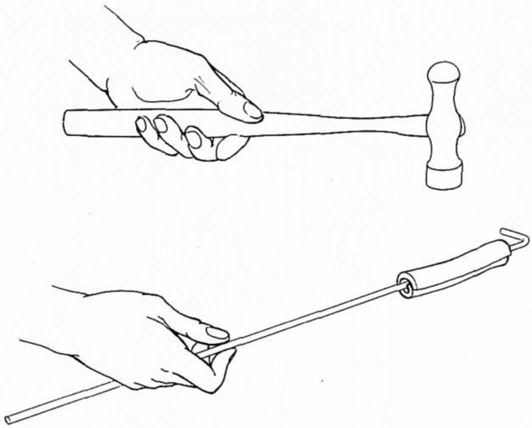
a. Block of wood, brick or heavy book falling – an example of P.E. changing to K.E.



b. Block of wood, brick or heavy book hitting the ground – an example of K.E. changing to heat.

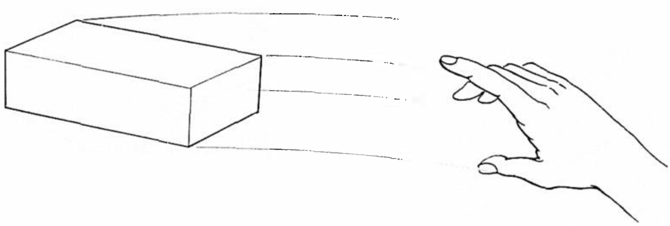


c. Moving hammer hitting lead – an example of K.E. changing to heat.

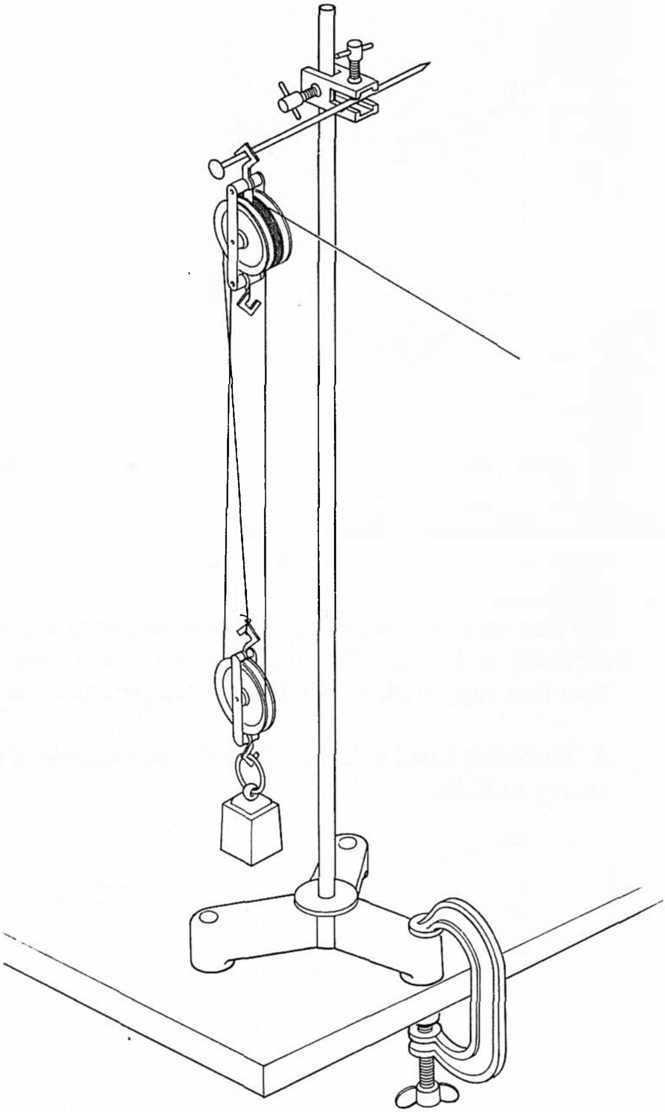


A small piece of lead sheet, one or two square inches by $\frac{1}{16}$ in or thinner, is wrapped round a piece of thin iron wire (say, 1 ft long and 20 gauge) which acts as a handle. The pupil holds the other end of the wire with the lead on an anvil (an iron kilogram weight will serve for this) on the floor and hits the lead several times in rapid succession with a hammer, as violently as he can. Provided the lead is not more massive than that suggested, he will feel the temperature rise.

d. Throwing a ball or block of wood – an example of chemical energy to K.E.

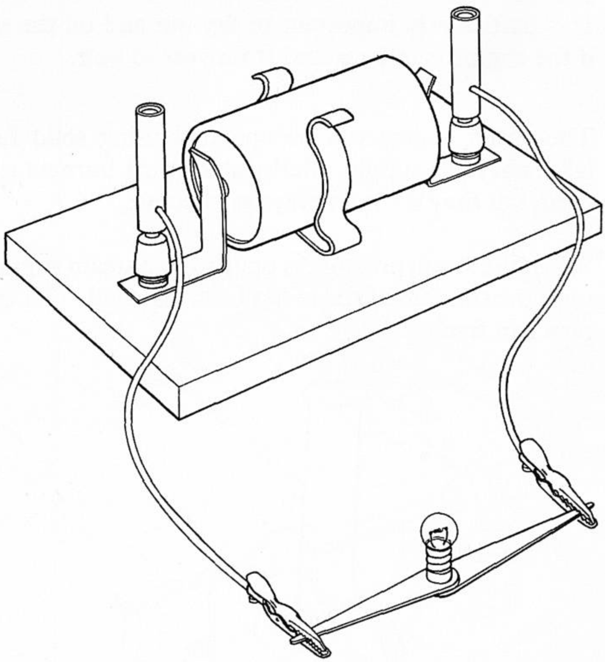


e. Hauling up a load by pulleys – an example of chemical energy to P.E.



f. (optional). Lighting a firework rocket.

g. A battery lighting a lamp – an example of chemical energy to electrical energy to heat and light.

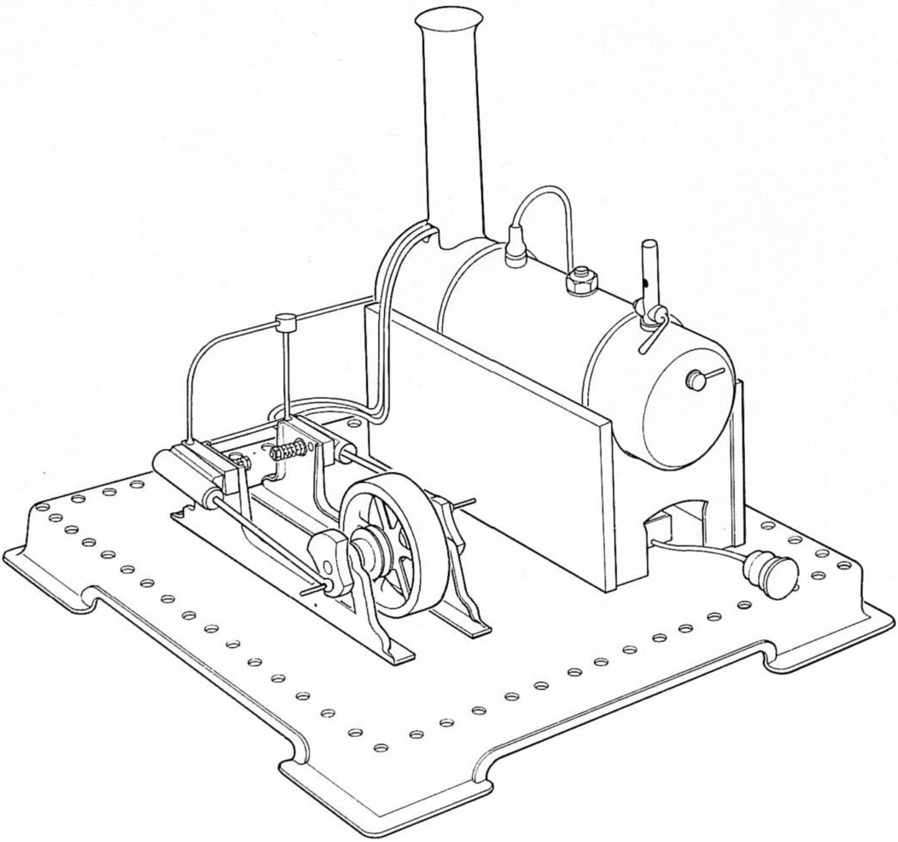


h. Model steam engine.

A model steam engine is included in the Malvern energy conversions kit (item 9I). The makers' instruction for use and care of the engine should be read and carefully observed. It is particularly important to dry out and oil the machinery if the engine is to be stored from year to year.

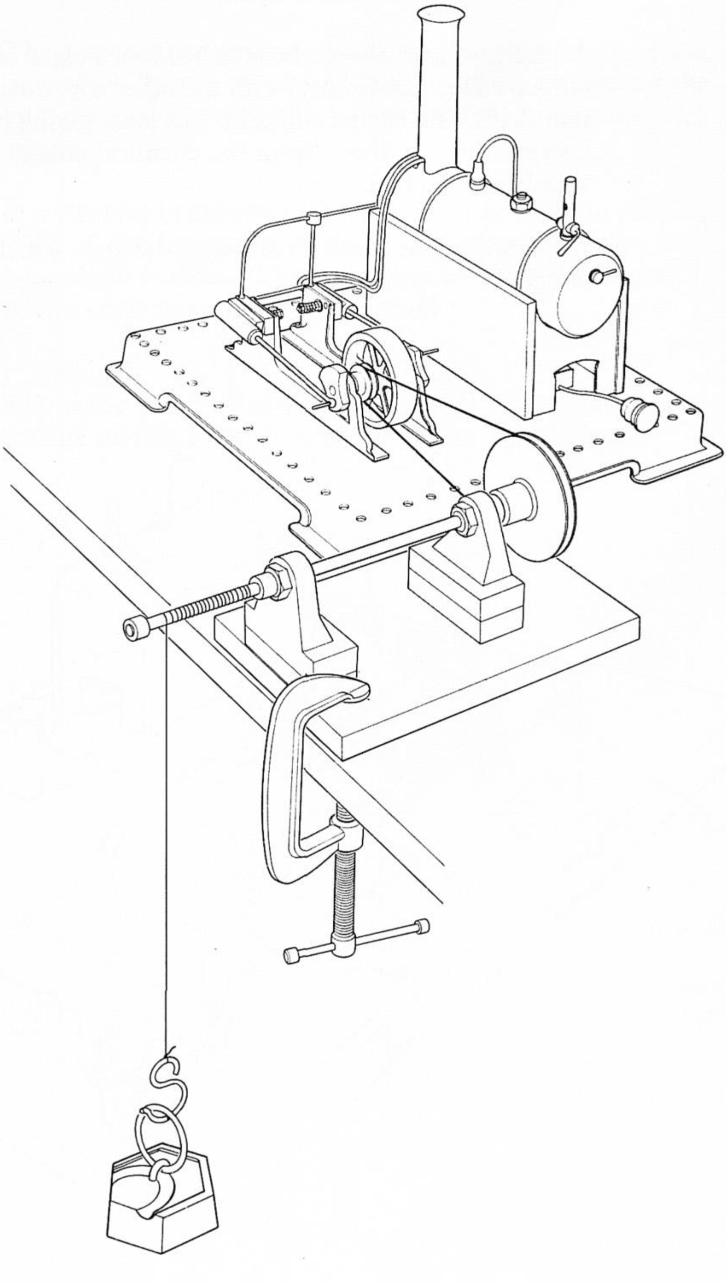
The steam engine can be operated using solid fuel or the laboratory gas supply. Methylated spirit burners can also be used, but they are not always as effective.

When the steam pressure is up, turn the steam engine by hand until the condensed steam has been expelled. The engine will now run freely.



i. Steam engine used to raise a small load.

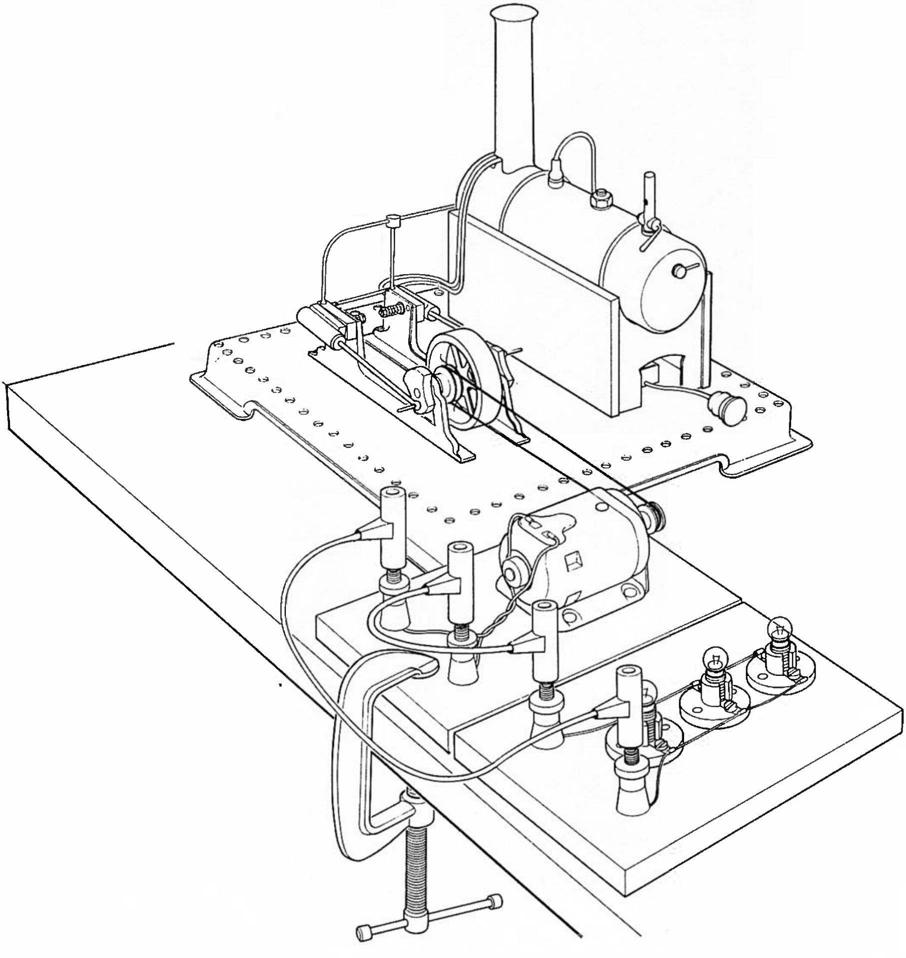
The steam engine is operated as described in 8.



The engine should be clamped to the bench with a G-clamp and likewise the line shaft next to it. The small pulley on the engine should drive the large pulley on the line shaft by means of a belt or rubber band.

A length of cord should be attached to a weight on the floor (about 1 lb is satisfactory) with the other end attached to the line shaft. The engine will raise this load, giving it potential energy which is drawn from the chemical energy of the gas supply or solid fuel.

j. Steam engine used to drive a dynamo which lights a lamp.

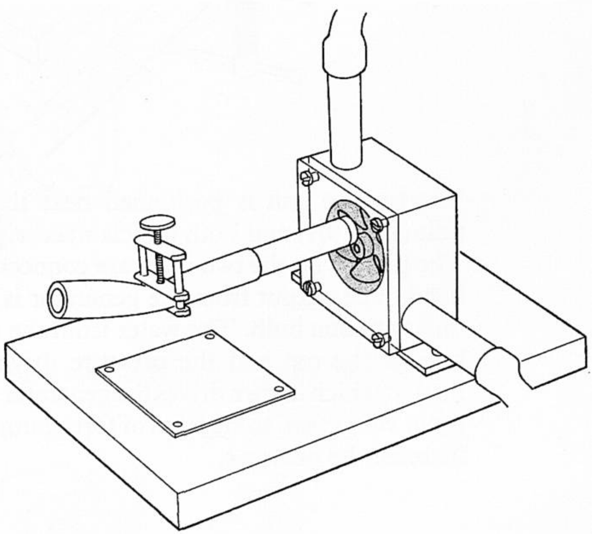


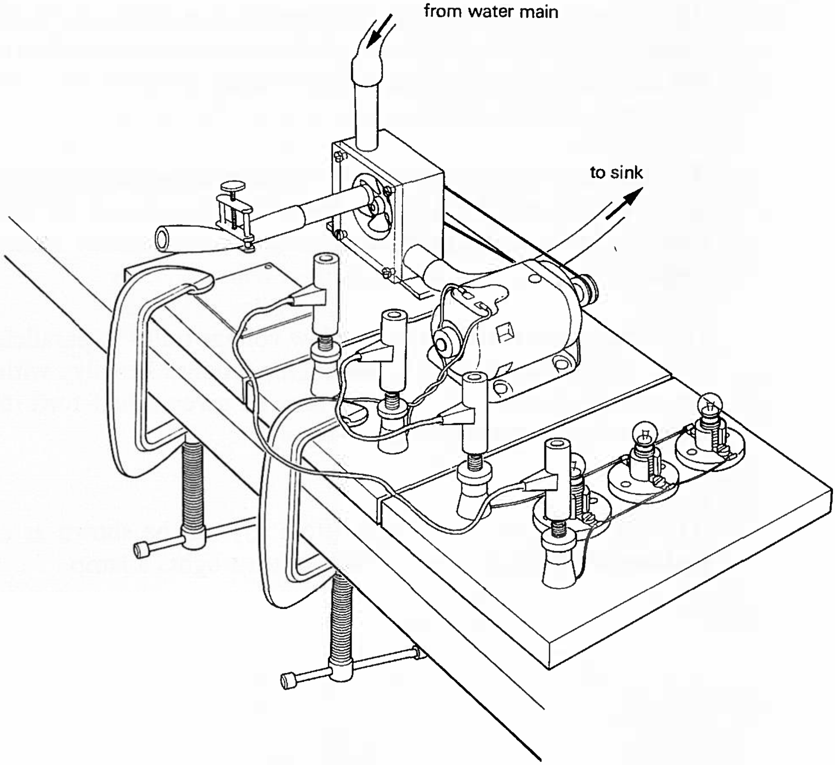
The steam engine is used as in 9, the belt or rubber band now being used to drive the motor/generator unit (item 9A). Both the generator and the steam engine should be firmly fixed to the bench with G-clamps.

The output of the generator unit is connected to the lamp unit (item 9D). It will be noticed that switching on and off the bulb produces a change in the mechanical load on the steam engine.

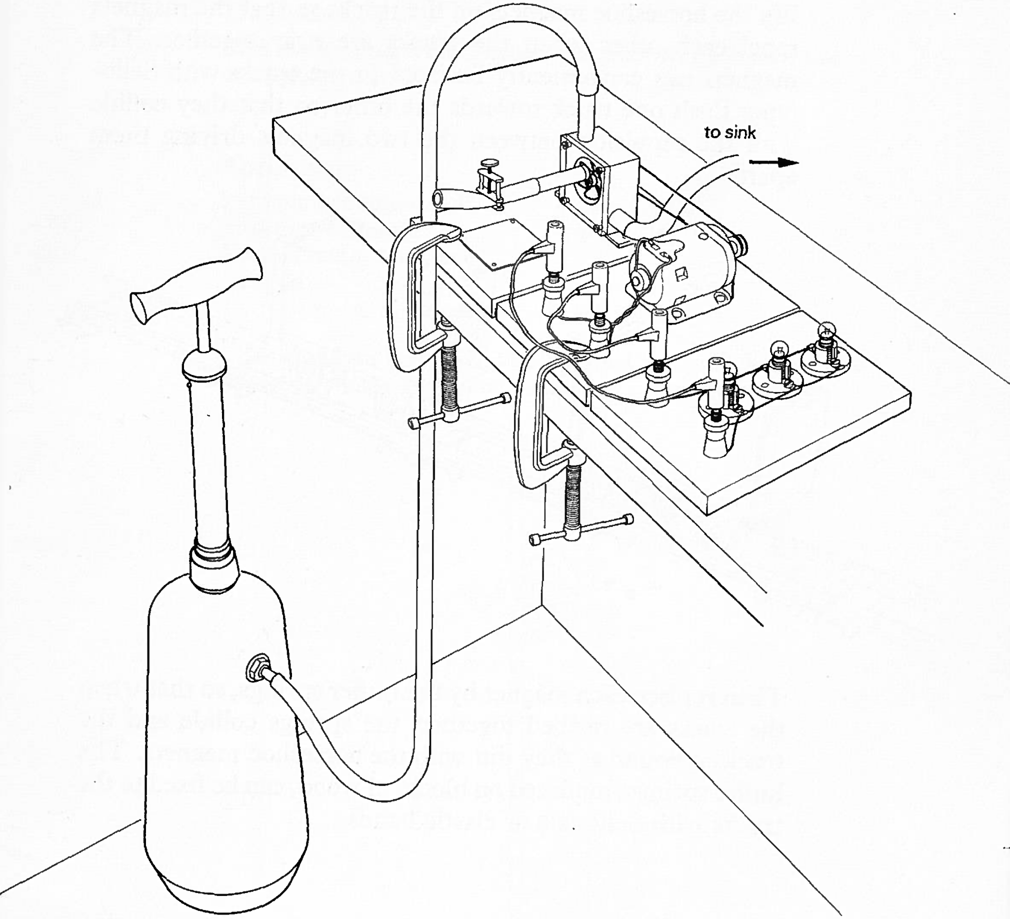
It is effective to use two or three low voltage bulbs in parallel. With all the lamps alight, the engine labours heavily; with none alight it races. (The bulbs may be given a half-turn in their sockets to switch them on or off.)

k. Optional
The water turbine/pump unit (item 9J) can be shown as a turbine driving a dynamo, which in turn lights a lamp.

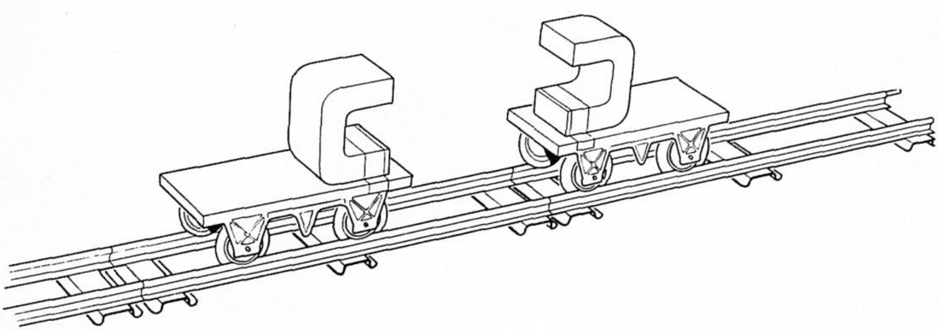




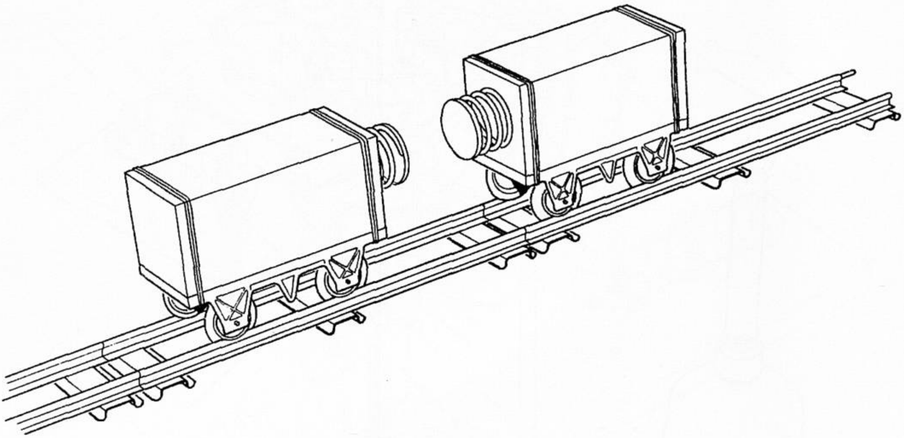
The turbine unit is positioned next to the motor/generator unit (item 9A) and both are clamped rigidly with G-clamps. The pulleys on the two units are connected with a 3 in rubber band. The output from the generator is connected to a lamp unit with one bulb. The water from the mains enters the turbine at the top and the pressure drives round the turbine blades, which in turn drives the generator. If the water pressure is not very great, some form of force pump will be necessary to increase the pressure.



1. A moving truck striking elastically an equal stationary one.



Fix the horseshoe magnets on the trucks so that the magnets repel each other when the trucks are near together. The magnets can conveniently be fixed to the trucks with Sellotape. Push one truck towards the other so that they collide with the repulsion between the two magnets driving them apart.



Then replace each magnet by the buffer springs, so that when the trucks are pushed together, the springs collide and the trucks rebound as they did with the horseshoe magnets. The buffer springs, mounted on blocks of wood, can be fixed to the trucks with Sellotape or elastic bands.

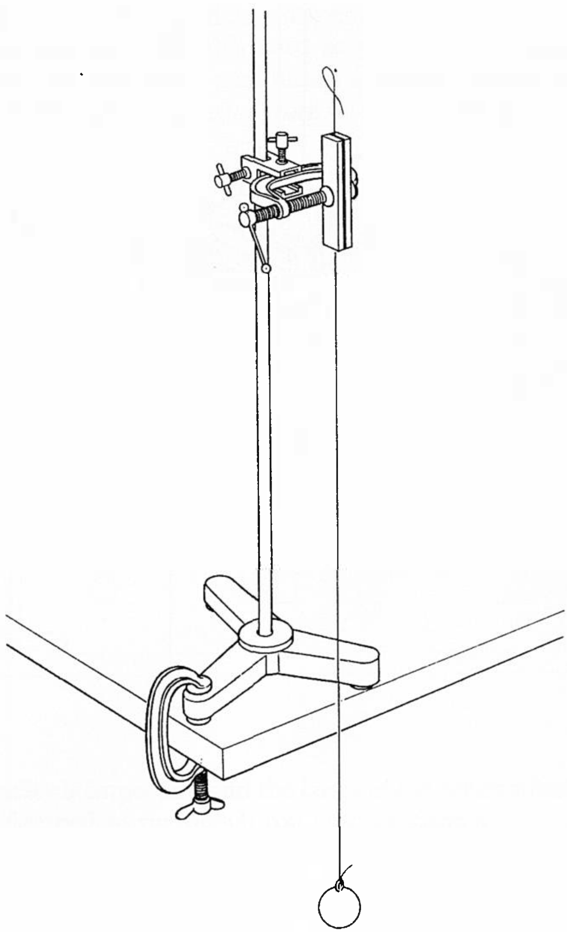
75a *Demonstration*

The swinging of a simple pendulum to illustrate energy changes

Apparatus

1 simple pendulum bob	– item 527
cord for pendulum	– item 10A
1 retort stand, boss, and clamp	– items 503–506
2 bits of metal or wood	– see below

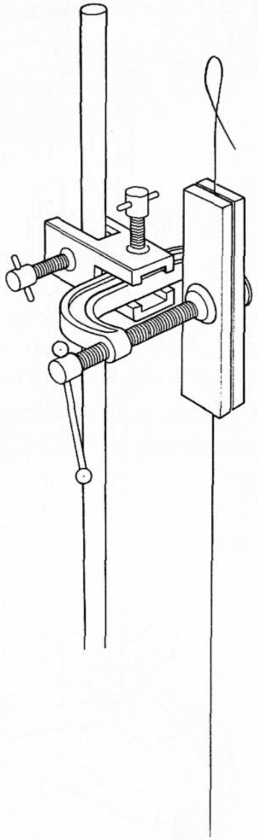
The pendulum bob should be $\frac{1}{2}$ in to $1\frac{1}{2}$ in lead, iron or brass. The cord should be 3 ft or more long.



Procedure

Suspend the simple pendulum from the clamp which is connected by a boss to a rigid retort stand (or, better, to the ceiling). Let the pupils watch the simple pendulum without any attempt to do any timing and discuss the energy changes.

The more massive the support the more successful the demonstration. A light support allows energy to leak away. So does a loose support. Therefore the pendulum cord should be firmly clamped at the top between two bits of metal or wood with their lower edges flush.



75b *Demonstration*

Coupled pendulums to shuw energy transfers

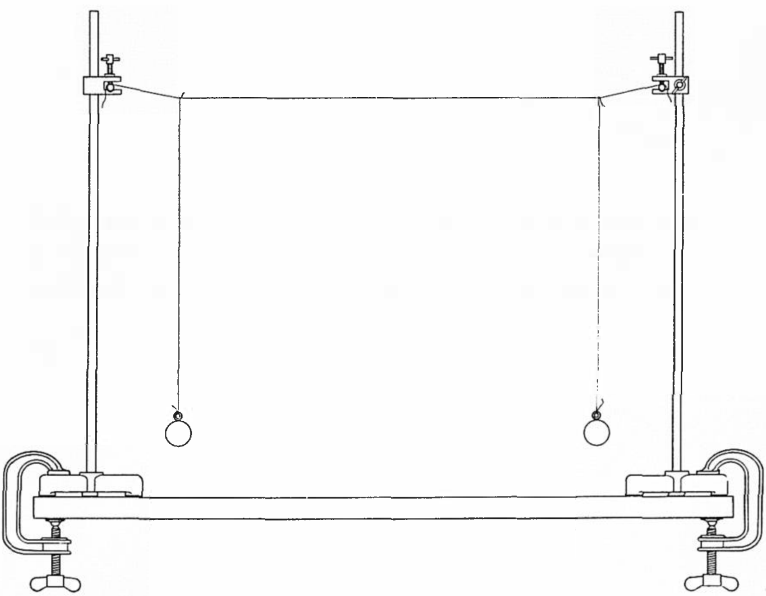
Apparatus

2 retort stands and bosses	– items 503–505
2 simple pendulums	– item 527
cord for pendulum	– item 10A
2 G-clamps	– item 44/1

The pendulum bobs should be $\frac{1}{2}$ in to $1\frac{1}{2}$ in lead or iron.

Procedure

Two retort stands are placed about 30 in apart and a light cord is fastened between them. Suspend two identical pendulums symmetrically from this cord so that they are about a foot apart. Set one of the pendulums swinging and let the pupils watch the energy transfer from one to the other.



Rigidity is important and the bases of the retort stands should be clamped to the bench top with G-clamps.

76 *Class experiment*

Feeling the Earth's gravitational field

Apparatus

1 brick or heavy book (minimum 2 lb) for each pupil.

Procedure

As discussed in the *Teachers' Guide*, the pupil stands holding the brick and, following special instructions from the teacher, 'feels' the pull of the Earth's gravitational field.

77 Demonstration

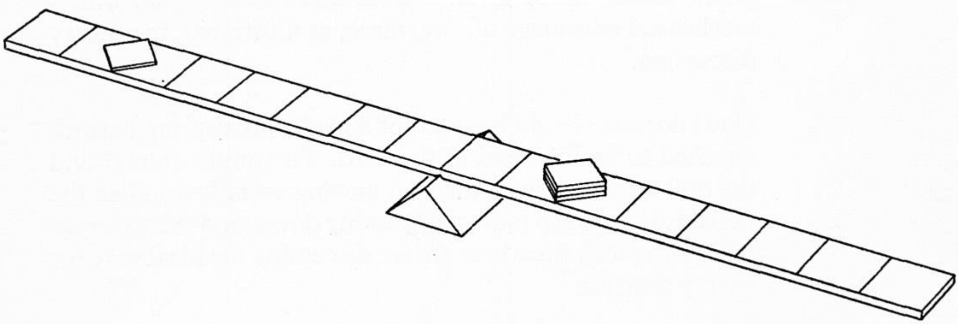
Model see-saw to show that a machine does not multiply energy

Apparatus

1 wooden beam	– item 5A
1 fulcrum	– item 5B
16 special square pennies	– item 5C
1 metre rule	– item 501

Procedure

The model see-saw should be set up as done by the pupils in class experiment 32a, using the same wooden lever.



Balance a large pile of the brass pennies on one side against a small number on the other. Discuss the distances moved and show thereby that the machine does not multiply energy.

78 *Class experiment*

Investigation of a pulley system (block and tackle)

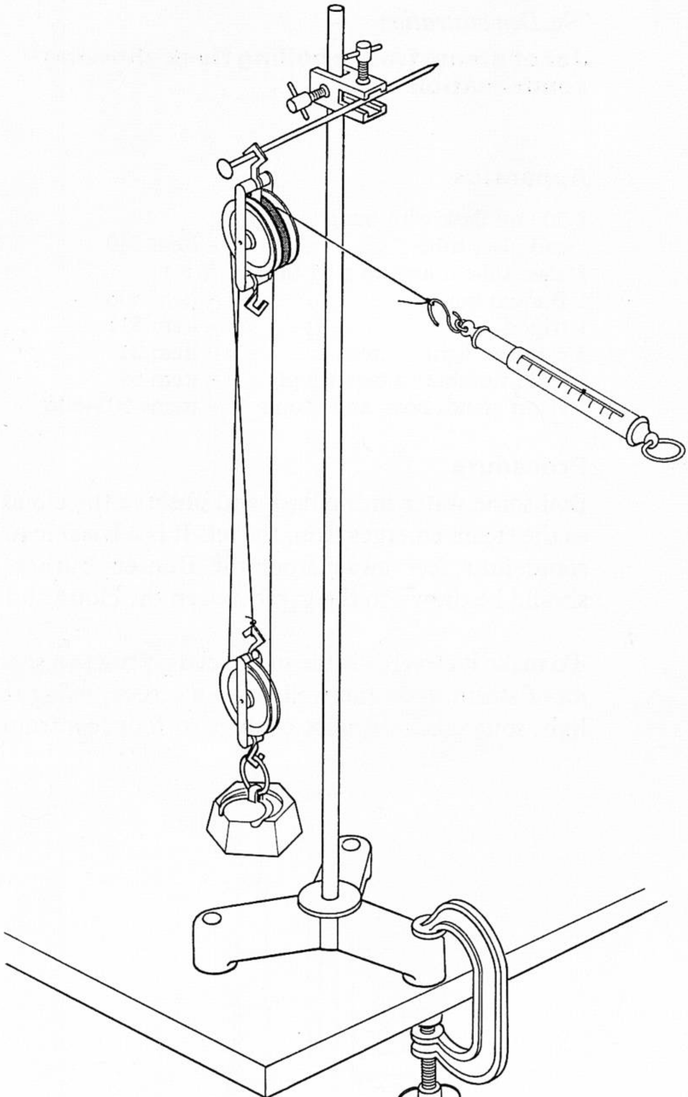
Apparatus

16 double pulleys	– item 39
16 single pulleys	– item 38
16 spring balances	– item 43
16 1 kg weights	– item 32
16 retort stands, bosses, and clamps	– items 503–506
cord	– item 10A

Procedure

Pulley systems are not studied in detail in this course, but the pupils should all be given a block and tackle system with a mechanical advantage of, say, three, as illustrated, for energy discussion.

One kilogram should be used for a load, and a spring balance attached to the free end of the cord. The pupils should find the pull needed to keep the load moving steadily up, then the pull needed to keep it moving steadily down, and then average these two pulls, since here we are discussing the ideal case for energy changes.



79a *Demonstration*

Jet of steam from a boiling flask showing condensation

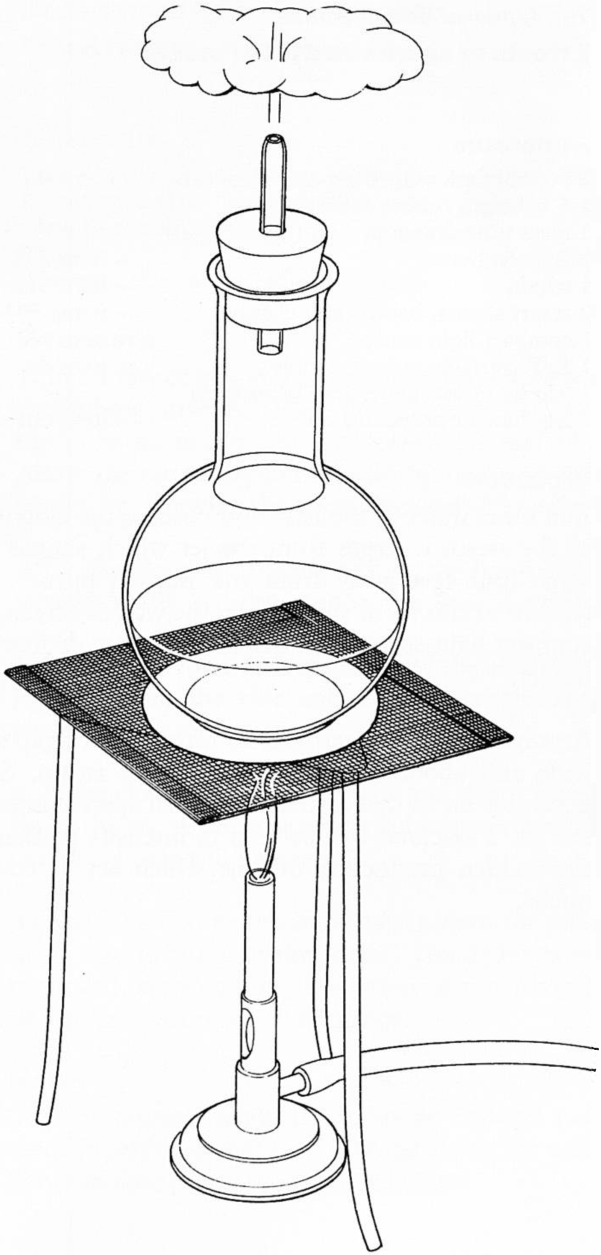
Apparatus

1 500 ml flask with bung and glass tube	– item 540
1 glass tube drawn to a jet (about $\frac{3}{32}$ in)	
1 Bunsen burner	– item 508
1 tripod	– item 511
1 compact light source	– item 21
1 L.T. variable voltage supply	– item 59
1 retort stand, boss, and clamp	– items 503–506

Procedure

Boil some water in the flask and observe the cloud formation as the steam emerges from the jet. It is advisable to put the jet some four feet away from the Bunsen burner. Attention should be drawn to the gap between the cloud and the outlet.

To make it clearly visible to the class, project a shadow of this jet of steam upon the wall or on a screen, using the compact light source at a distance of three or four feet from the jet.



79b *Optional demonstration*

Effects of sparks on a jet of steam

Apparatus

1 500 ml flask with bung and glass tube	– item 540
1 5 ft length rubber tubing	
1 glass tube drawn to a jet (about $\frac{3}{32}$ in)	
1 Bunsen burner	– item 508
1 tripod	– item 511
2 retort stands, bosses, and clamps	– items 503–506
1 compact light source	– item 21
1 L.T. variable voltage supply	– item 59
1 van de Graaff generator, Wimshurst machine or induction coil	– item 601

Procedure

Boil some water in the flask and observe the cloud formation as the steam emerges from the jet which should be placed some four feet away from the Bunsen burner. Project a shadow of this jet of steam upon the wall or screen, using the compact light source at a distance of three or four feet from the jet.

Arrange two wire electrodes to form a spark gap about $\frac{1}{4}$ in wide and about $\frac{1}{8}$ in above the jet of steam. Switch the generator on so that a stream of small sparks passes through the jet. The cloud will be seen to intensify markedly due to the sudden production of ions which act as condensation nuclei.

80 *Demonstration or class experiment*

Cloud formation in a large flask

Apparatus

1 aspirator (10 litres) or large flask	– item 523
1 bung with glass tube and short length of rubber tubing	
1 lamp	– item 46/2
1 bung to close lower outlet of aspirator	

Procedure

1. Put a few cc of water in the aspirator. Close with the bung and tubing attached. Blow down the rubber tubing to raise the pressure inside and then pinch the end of the tubing. Allow the air to expand rapidly by releasing the tubing or, better, by removing the bung. A cloud will be seen.

After the cloud is formed, replace the bung and tube. Blow into the bottle in order to show the cloud disappearing.

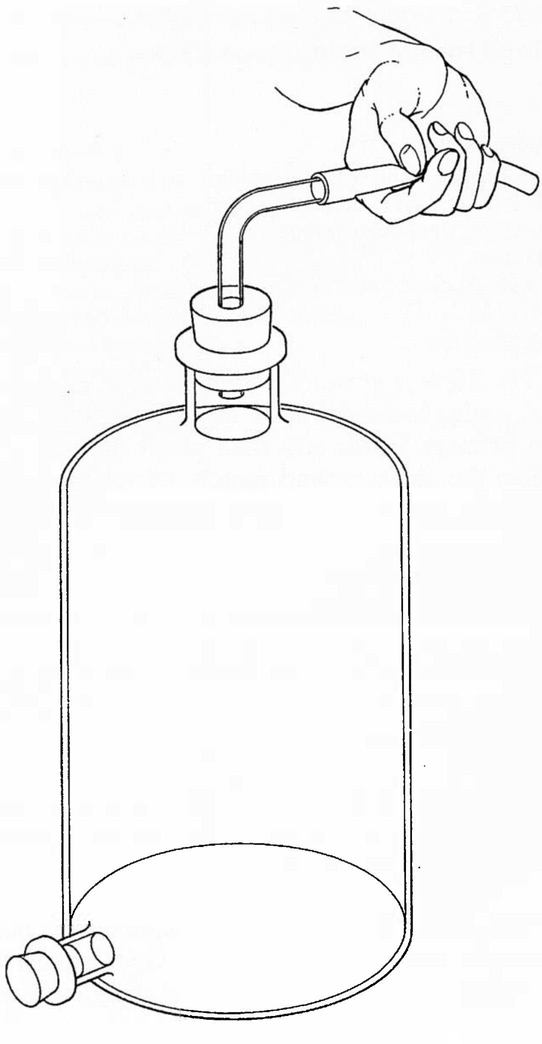
For the cloud to be clearly visible by the class, it needs bright lighting from the side and a very dark background, in a partially dark room.

2. If the cloud is allowed to settle and this is repeated several times the air in the aspirator will become relatively dust free and the clouds will be poorer.

Throw a lighted match into the aspirator (or poke a Bunsen flame into the neck of the bottle). Good clouds will again be produced, showing the great effect of providing smoke-dust or ions as centres for cloud drops.

Note

This experiment might profitably be done as a class experiment if sufficient 500 (or 1000) ml flasks are available. One between four pupils would be adequate.



81 *Demonstration*

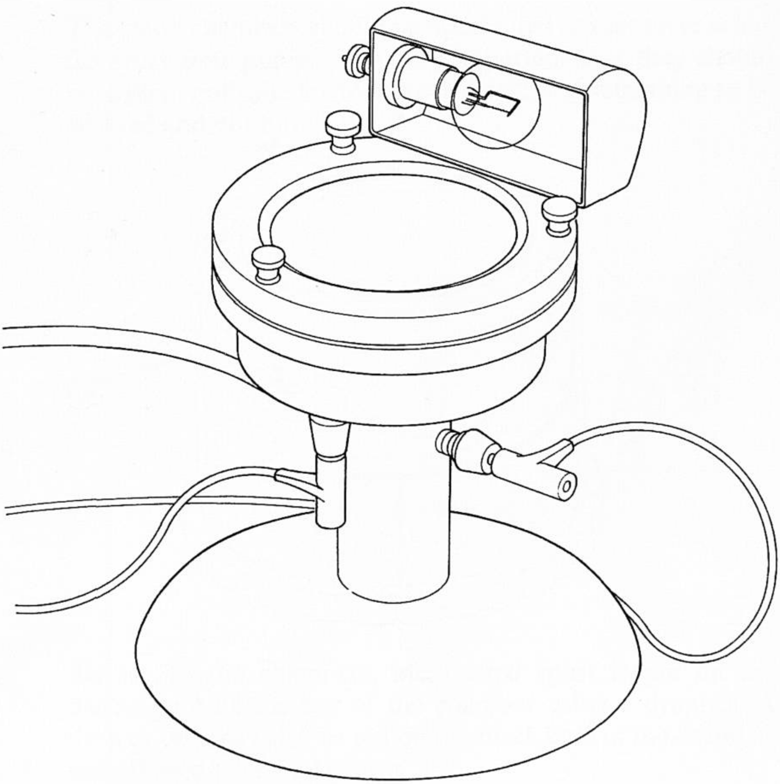
Expansion-type cloud chamber

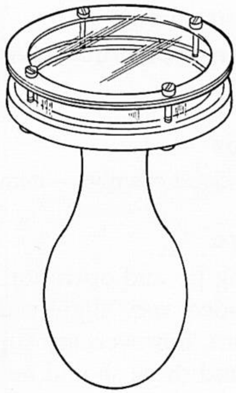
Apparatus

Expansion cloud chamber – item 18

Procedure

The setting up and operation of each of the cloud chambers recommended vary slightly depending on the type chosen. Instructions, however, are supplied with each, by the manufacturer, and these should be followed for the best results.





82 *Class experiment*

Taylor diffusion cloud chambers

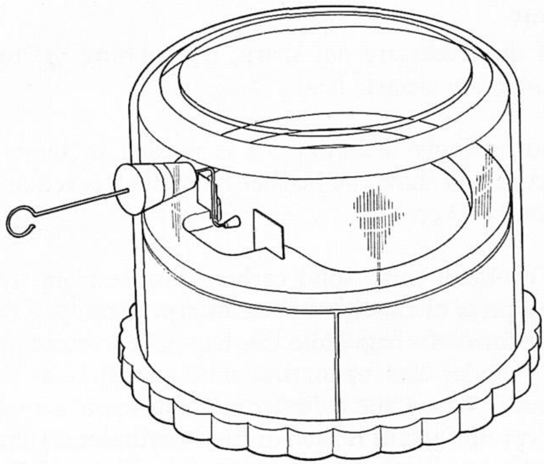
Apparatus

8 Taylor cloud chambers	– item 28
8 illuminants	– item 47
1 CO_2 cylinder	– item 19/1
1 dry ice attachment	– item 19/2
8 transformers	– item 27

See the notes below on the supply of dry ice.

Procedure

The cloud chambers should be distributed so that there is one for every four pupils. It is very important that they should have plenty of time for this experiment: it is something to be enjoyed and not hurried.



To set up the chambers, methylated spirit is put on the padding inside the top of the chamber using a dropper. A drop or two may also be put on the black base of the chamber and allowed to spread over it.

The base of the whole apparatus is unscrewed and a little dry ice from the special CO_2 cylinder put in contact with the base plate. The foam is put back to keep the dry ice in contact with the plate and the base cap screwed on again and the chamber inverted.

It is important that the cloud chamber be level: it should be placed on the three wedges provided, which can be adjusted to get it level (if it is not level, convection currents moving in the chamber will be seen and these can be used as guides in levelling).

The top must be put back on the chamber. Rubbing it with a handkerchief will charge it sufficiently to provide an adequate electric field inside the chamber to sweep away old ions.

Illumination is important and the illuminants provided should be used and adjusted so that there is a layer of illumination a few millimetres above the base plate.

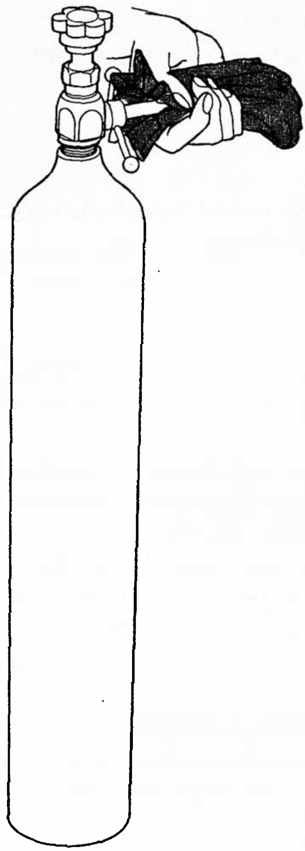
Alpha tracks will be seen coming from the weak radioactive source, inserted in the side of the chamber, usually within 30 seconds of setting it up.

Notes

1. If the tracks are not sharp, try rubbing the top again to improve the electric field.

2. Surprisingly little dry ice is needed in these chambers. Practice will show the teacher how much is required, usually about 2 or 3 cc.

3. To obtain some solid carbon dioxide from the cylinder, fold a piece of closely woven cloth (preferably of dark colour) in the form of a bag. Hold this bag tightly round the nozzle of the cylinder and open the valve at full blast for 5 to 10 seconds. Where the cylinder is of the syphon type it should be kept upright. If it is an ordinary cylinder it should be held upside-down during this process. See also 4 on following page.



4. In schools where several classes are following the Nuffield programme, it may not be feasible to manufacture the supply of solid carbon dioxide from the cylinder. It will be necessary to order a block from the suppliers. Such blocks are easily obtainable, delivered by railway. See Section C of the *Nuffield Guide to Physics Apparatus* for details on the availability of solid carbon dioxide in block form for use in schools.

5. It is possible to make the solid 'snow' by expansion before the lesson begins and to store it in a wide-necked Thermos flask.

83 *Demonstration*

Collection of photographs of alpha particle and other tracks for display

Procedure

These can be passed round the class and later posted on a board for continuous display.

84 *Optional class experiment*

The spinthariscope

(This is an additional luxury experiment for those schools which have the spinthariscopes.)

Apparatus

4 spinthariscopes with 0·5 μ C sources
4 spinthariscopes with 0·02 μ C sources

Procedure

If time and place permit, the spinthariscopes should be passed round the class for pupils to see scintillations themselves.

The spinthariscopes recommended are perfectly safe and have their own optical system built in, which leads to ease of viewing. As the eye must be light adapted to see the scintillations, it is not possible to use them in a daylight-lit room. If, however, the room is blacked out and a limited amount of artificial light is used, it is relatively easy for the pupils to see scintillations quickly.

Two strengths are recommended: one gives a shower, the other makes it easier to see the random nature of the process The pupils should see both if possible.

85 *Demonstration*

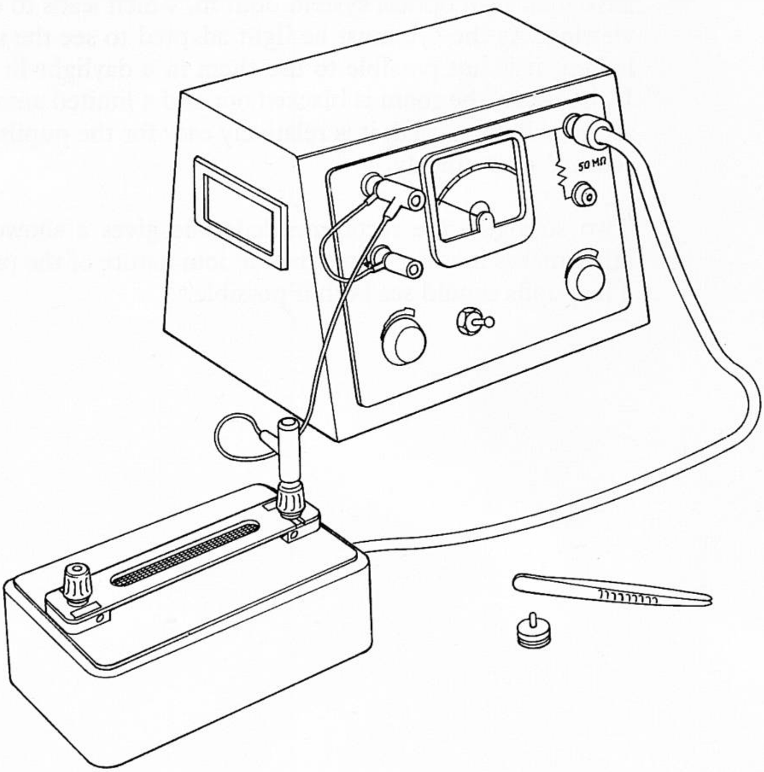
The spark counter

Apparatus

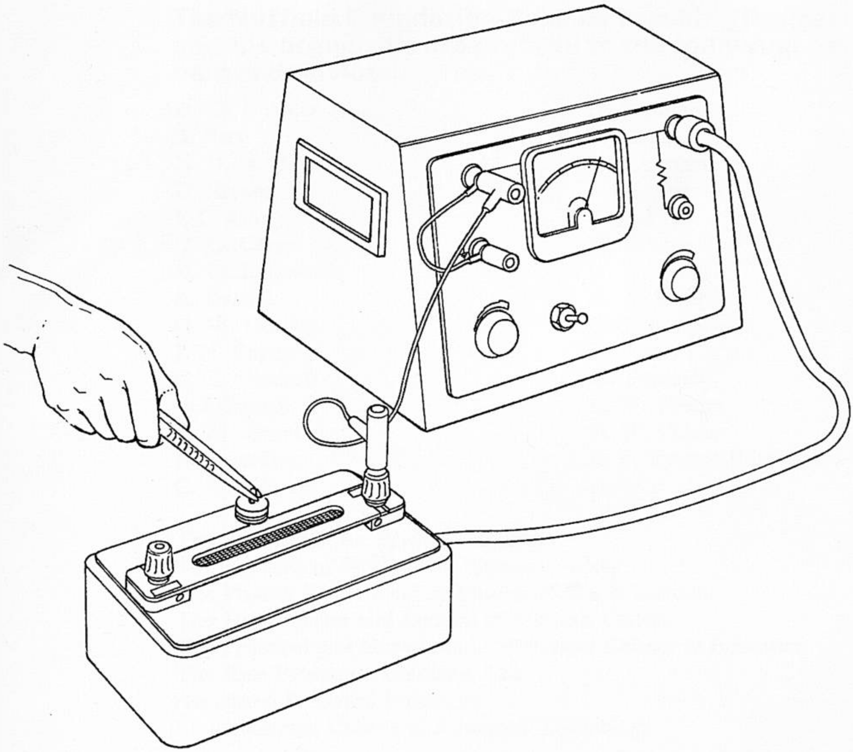
1 spark counter	– item 17
1 E.H.T. power supply	– item 14
1 radium source	– item 16

Procedure

The high voltage lead of the spark counter is plugged into the positive terminal of the E.H.T. supply recommended (without the 50 Megohm safety resistor). The other terminal on the counter is connected to the negative terminal of the supply, which in turn is earthed.



The voltage is turned up slowly until it is just below the point of spontaneous discharge. Usually about 4,500 volts is necessary.



If the radioactive source is held over the gauze, sparks will be seen and heard. Paper can be put between the source and the counter to show the radiation is stopped by it. Then try a piece of cigarette-paper if available. Finally, try thin aluminium leaf.

The random nature of the process should be appreciated.

Notes

1. Any kink or bend in the wire in the counter is liable to cause a spark discharge at that point. If that happens the wire should be replaced.

2. A continuous spark (which will very soon damage the wire) shows the voltage is too high.

3. The counter should be dust free. Dust around the stretched wire can often be blown away.

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NUFFIELD FOUNDATION SCIENCE TEACHING PROJECT PHYSICS SECTION

The physics programme was inaugurated in May 1962 under the leadership of Donald McGill. It suffered a severe setback with his tragic death on the 22nd March 1963, but those who were appointed to continue the work have done so in the spirit in which he initiated it, and in the direction he foreshadowed.

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Bartley Green Girls' Grammar School
Batley Grammar School for Boys
Batley High School for Boys
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Other Nuffield Physics publications

Teachers' guide I
Teachers' guide II
Teachers' guide III
Teachers' guide IV
Teachers' guide V

Guide to experiments II
Guide to experiments III
Guide to experiments IV
Guide to experiments V

Questions book I
Questions book II
Questions book III
Questions book IV
Questions book V