ASE Lab Books

PHYSICS & THE EARTH SCIENCES FOR MIDDLE SCHOOLS

Compiled by Eric Deeson

Published for the Association for Science Education
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ASE Lab Books

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ASE Lab Books

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PHYSICS and THE EARTH SCIENCES FOR MIDDLE SCHOOLS

Compiled by
ERIC DEESON

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Contents

Preface to the Middle School books ix

Introduction xi

The Earth Sciences

Introduction 1

The teaching of astronomy in Middle Schools
B. NICHOLL 2

A use for series and parallel circuits in the teaching of astronomy
M. S. BARRETT 5

Introduction to the concept of time, with the second as a standard unit
J. LOVESEY 7

Polishing and varnishing rock specimens for use in school
P. J. PERKINS 9

Artificial rain making
W. LLOWARCH 11

Light

Introduction 13

Experiments on the eye
L. J. ROWSE 13

Daylight smoke chamber
VED RATNA 14

Adjustable focal length converging mirrors
A. R. GLOVER 16

Pinhole camera without a dark room
J. M. WILSON 16

Heat

Introduction 18

Land and sea breezes
R. L. PAGE 18

Black objects absorb radiant heat more readily than shiny bodies
R. L. PAGE 19

A model to illustrate the kinetic theory of solids, liquids and gases
D. G. SMITH 20

Is heat heavy?
D. P. NEWTON 23

Polyethylene as a material for showing thermal expansion effects
R. H. MORRIS 23

Calorimetry of the hand
R. L. PAGE 24

A beam engine for use in junior work on air pressure
C. A. BUNKER 27

A pure heat engine
W. K. MACE 28

Mechanics

Introduction 30

Force, weight and mass
M. F. JAMES 30

'Jet propulsion'
W. E. PEARCE 33

Simple illustration of Newton's third law
T. J. ERICSON 34

The densities of aniline and water
C. G. HANSON 34

'Blowing up' a girl
ALAN WARD 35

Some elementary demonstrations of pressure phenomena
MURIEL WHITTAKER 35

Low pressure in a 'mini-chamber'
ALAN WARD 37

Vacuum at the top
J. C. SIDDONS 38

A 'squeeze pump' from plastics bottles
ALAN WARD 39

Experiments on surface tension
J. HOWARD BROWN 40

A direct illustration of Hooke's law
I. G. HOLT 42

Aeroplane wings: a simple laboratory demonstration
R. W. JOTHAM 45

Electromagnetics

Introduction 46

Some simple experiments in electricity
J. C. SIDDONS 46

Uses for the overhead projector in the teaching of electrostatics
P. C. F. PORTER 51

A simple Leyden jar
ALAN WARD 54

Mr Coulomb
W. C. HALL 55

Resistances in series and parallel
G. I. JONES and J. POWELL 55

A simple voltameter for class use
M. J. LONG 56

Electrolysis
J. C. SIDDONS 58

First lessons in magnetism
L. J. ROWSE 59

Combined magnetizer and demagnetizer for use on alternating current light mains
F. A. MEIER 70

The disappearance of magnetism
T. E. NICHOLSON 71

Demonstration of a magnetic field pattern in three dimensions
G. AUTY 72

Three-dimensional magnetic fields
M. J. HANSON 74

The magnetic 'gun'
ERIC DEESON 74

A model motor
H. G. F. MICKLEWRIGHT 75

Miscellaneous

Introduction 76

Experiments with balloons
C. J. ROBINSON 76

Activated graphs
J. A. CLARK 80

Middle School field work: the physical science of a stream
T. WARD 82

Preface to the Middle School books

It is not much more than a decade since the Association for Science Education (ASE) appeared from the reorganization of the Science Masters' Association and the Association of Women Science Teachers. The change in name symbolizes changes in attitudes and approach which are still continuing. Outwardly these changes may be observed in the new presentations of the Association's publications—*The School Science Review* (*SSR*), which has evolved through a number of 'new looks', and *Education in Science*, the old 'Bulletin', in particular—as well as in the modern buildings which house its headquarters in Hatfield. The 1960s have, of course, been times of great upheaval in British (and overseas) science teaching generally, so that what has happened to the ASE is really only symptomatic of bigger things. The Nuffield Foundation has poured hundreds of thousands of pounds into new teaching schemes, syllabuses and approaches of all kinds have been reorganized, and hard looks are being given to practically everything that science teachers are involved with—concepts and equipment, ideas and experiments.

Educationally a most exciting development for the science teacher has been the appearance and proliferation of the Middle Schools. These have the potential—indeed, the intention—to be a valid and essential link between the best aspects of the first school and the best of secondary education. As far as science is concerned, the Middle School teacher has the opportunity of giving important assistance to the rather traumatic transition between the free and informal work of the primary sector and the highly directed, examination-based work that follows. There have been major problems with primary science, caused mainly by lack of space and money, and by the inadequate scientific knowledge of the hard-pressed teachers. Middle School science does not normally suffer in these ways, and already some really excellent work is being done.

How can the ASE help? Its members have, of course, been very active and encouraging in the developments of the pivotal Schools Council 5/13 project and Nuffield Combined Science. Many teachers at secondary and higher levels have had much useful contact, formal and informal, with their colleagues in the First and Middle Schools—sharing equipment and ideas and trying to formalize overall progress. But there can and should be more. The ASE as a body is very keen on being recognized by science teachers at the more junior levels as an organization which can assist their work in many ways. That this is already coming to be the case is shown by the membership figures and the breakdowns of attendance at meetings and functions.

Therefore, when the Association mooted the idea of replacing its excellent but rather outdated *Science Masters' Books* with a new series of little *Lab Books*, great efforts were made to provide something of value to the primary and Middle School teachers. There has, however, been much difficulty. It has—correctly—always been the intention that the *Lab Books* should contain only reprints of teaching material published in the Society's own pages. So far, however, the increasing momentum towards full assimilation of scientific work at the lower levels has not yet provided enough such ideas worthy of presentation in this way for the first schools. As far as the Middle School work is concerned, we felt that the production of two books would be a viable proposition. We hope you agree!

Thus, this book and its companion cover the large range of scientific activities concerned in the following way. Note that the classification is, of course, one of administrative convenience rather than a hangover from the old formal times. The first book deals with material broadly coming under the umbrellas of biology and of chemistry; the second covers physics and the earth sciences of geology, meteorology and astronomy. It is not so long since those days of nature study, mechanics and electricity, in the atmosphere of which so many contemporary teachers were raised, so perhaps it is natural that biology and physics make up the significantly larger fractions of their corresponding books. Let us hope that by the time new editions are called for, this situation will not still obtain. It is up to you!

Introduction

Although this book is designed to cover physics and the earth sciences, the former area takes up by far the larger proportion of its pages. This is perhaps a pity, but the fact arises naturally from the realities of the development of British science education generally in the last half-century. Also, physics is certainly of more direct importance in the lives of our pupils than the other sciences concerned, and anyway it is a much wider field. All the same, the trends towards increased teaching of astronomy, geology and meteorology are strong ones, and it is certain that in the future a more balanced treatment will be possible.

Culled almost entirely from the pages of *The School Science Review*, with just a few notes from the old Science Masters' Books, the material here falls into two types. First there is the detailed discussion, with or without experimental detail, of the teaching of quite large areas of the work. The introspection that has characterized much of the philosophy of British science teaching in the last decade or more is clear here—old ideas and concepts are questioned; new approaches and principles are justified. In general these revisions are of basic introductory fields, so it is to the middle school teacher that we turn to see if they are valid.

The second type of material in the book consists of 'wrinkles' for the presentation of individual experiments and lessons. The *SSR* is perhaps unique among the specialist subject teaching journals for the space given over to thoughtful correspondence and the publication of new ideas and approaches. We have therefore a very rich and imaginative field to draw on, and indeed this is one of the major ways in which science teaching is able to progress. The flow should, of course, be two-way, and every encouragement exists for the middle school teacher to submit accounts of novel work of his own to the journal for the benefit of his colleagues elsewhere. Long may the situation remain that our teachers are each thinking individuals, able to develop and test their own bright ideas before passing them on to a wider audience.

It should finally be noted that the subdivisions of the material in this book have been chosen for obvious administrative reasons. Crossing the inter-subject boundaries is an excellent characteristic of middle schools science teaching, and we would not wish at all to discourage this.

The Earth Sciences

Introduction

The first section of this ASE Lab Book is concerned with what can be called 'Earth Sciences'—astronomy, geology, and meteorology. It is certainly sad that it is such a thin section, especially in view of the fact that the whole book claims to deal with these subjects as well as with physics. The treatment of such matters in the pages of *SSR* has long been rather meagre, and what there is has tended to be at a somewhat higher and more academic level than is suitable for our purposes.

However, things are changing fast now. Most of the new science syllabuses developed in the last few years include a good selection of material in these fringe areas (as they seem so often to be considered)—and this is true of every level of science teaching. Advocates of these fields should be grateful for the appearance of the Middle School, for, with its freedom of approach and yet comparatively high conceptual standards, it is well designed for good work of a kind that rarely appears in the more formal secondary schemes. It is felt that already most Middle School science teachers will include a gratifyingly large quantity of study of astronomy, geology, and meteorology; perhaps they will be able to impress their secondary colleagues to do more themselves.

The material included in this section cannot be called at all comprehensive. Yet it should help the uninitiated to form their thoughts somewhat, as well as providing 'old hands' with a few useful novel ideas. The section opens with discussions by Brian Nicholl and Mrs Barrett on models in the teaching of astronomy (this being a subject which lends itself very well to such a valuable approach), continues with some notes on the preparation of rock and fossil specimens for display, and closes with description of an intriguing model of rain production. Meteorology does seem rather to be under-treated but, as is pointed out at the end of the piece included, there is more of relevance in the section on heat later on.

The teaching of astronomy in Middle Schools

B. NICHOLL

The subject of astronomy is often neglected in Secondary Science schemes, and yet it has many claims for inclusion in the syllabus. Within its scope are some of the most obvious natural phenomena; it offers good examples in the History of Science and in Scientific Method, and it also appeals to the child's imagination (hence the many journeys to imaginary planets made by heroes in children's comics). Perhaps this neglect of the subject is sometimes due to the apparent lack of demonstration models suitable for use with this type of child. Illustrated below are some of the models I have used.

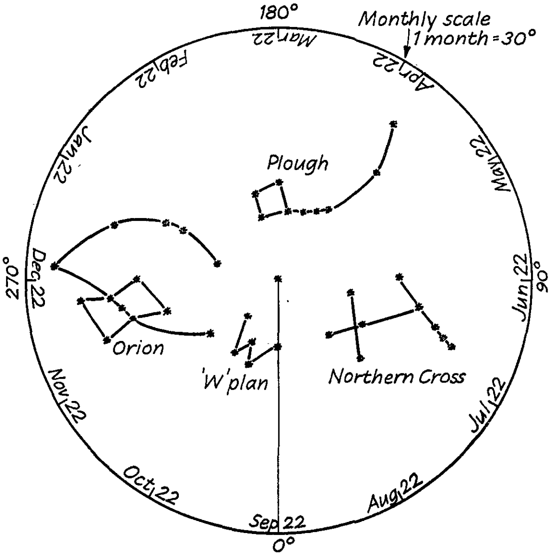


Fig. 1. Star chart to scale. 8 cm diameter

KEY TO STARS

1. Polaris or Pole Star
2. Arcturus
3. Spica
4. Vega
5. Altair
6. Betelgeuse
7. Aldebaran
8. Sirius
9. Pollux
10. Castor
11. Capella

Star Group

	W. Plan	*Orion*	*N. Cross*	*Plough*
Angle (°)	0	280	55	195
Radius (to centre) (cm)	1.3	2.6	1.8	1.3

The subdivision of the chart into months is only approximate, but gives a near enough guide to the position of the main star constellations in the Northern hemisphere throughout the year.

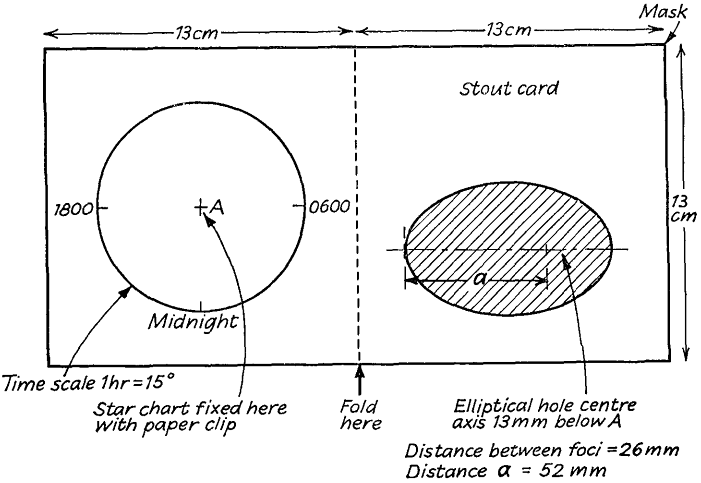


Fig. 2. Simple star chart

PHASES OF THE MOON AND ECLIPSES

The apparatus consists of a hockey ball representing the Earth and a table-tennis ball representing the Moon as these give approximately scale values of the sizes of Earth and Moon.

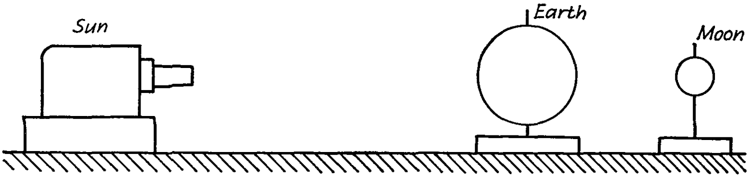


Fig. 3

The Sun is represented by a film strip or other projector placed as far away as possible from the 'Earth'. It is not very practical to give scale values of distances but this can be stressed to the class. The Earth and the Moon are both painted a dull black and are fixed to wooden bases by steel knitting needles inserted through the centres of the balls. The bases should be clearly labelled 'Earth' and 'Moon' and the film strip projector labelled 'Sun'.

By viewing the 'Moon' from different angles, the phases of the Moon are clearly illustrated.

ALTITUDE OF THE POLE STAR

The purpose of the apparatus is to show how the Pole Star can be used to find latitude. It consists of a plywood disc, 60 cm in diameter, representing the Earth, fitted with a wooden adjustable radius pivoted at the centre and carrying protractors as in the diagram. The whole is fixed to a retort stand

Three pieces of equipment have been prepared, representing Orion (Fig. 1), Cygnus (Fig. 2), and the Plough (Fig. 3). Each comprises a piece of hardboard 45 cm × 30 cm to which $4\frac{1}{2}$ V lampholders have been fixed in the positions of the stars of the respective constellations. Two studs project from each board to which the connections from the battery and switch are brought, and from which the circuits of the lampholders are taken. A battery, bulbs, a push-button switch and suitable insulated wire are provided. The pupil is given an instruction card as detailed below, and by wiring the stars of first magnitude in parallel, and the stars of second magnitude in pairs in series, can obtain the required variation in brilliance. The difficulty of the exercise could be increased by introducing larger constellations, or, with the use of higher voltages, stars of third, fourth or fifth visual magnitude could be included, and the variation in brilliance obtained by the use of resistances in the circuits.

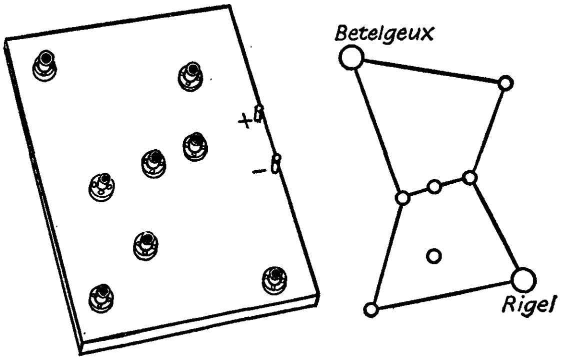


Fig. 1

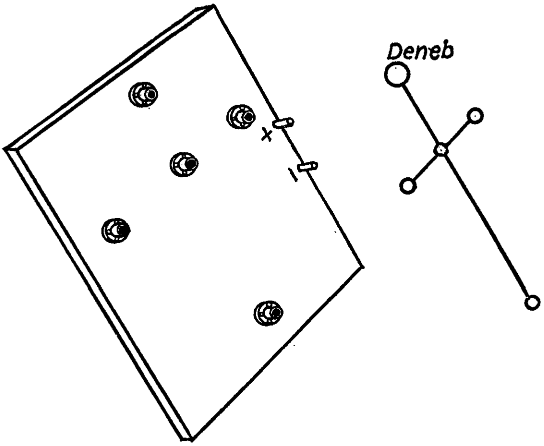


Fig. 2

An instruction card is given to the pupil containing a diagram of the constellation and the following information.

ORION

In the constellation ORION the stars Rigel and Betelgeux are very bright, each having a visual magnitude of approximately 1. Each of the other stars has a visual magnitude of approximately 2 and appears only half as bright as the two named. Wire the lampholders to give this effect.

CYGNUS

The star Deneb in the constellation CYGNUS has a visual magnitude of 1+. All the other stars in the constellation are less bright, with a visual magnitude of 2+. Wire the lampholders to give this effect.

THE PLOUGH

In the PLOUGH each of the three stars shown (Fig. 3) with a large circle has a visual magnitude of 1+, and appears twice as bright as the other four stars, each of which has a visual magnitude of 2+. Wire the lampholders to give this effect.

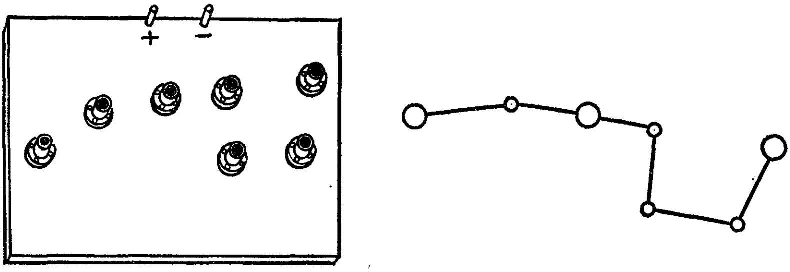


Fig. 3

Introduction to the concept of time, with the second as a standard unit

J. LOVESEY

The sundial has obvious relevance to the natural temporal divisions of night and day. As such it may provide a stimulus for dealing with the rotation of the Earth and other simple astronomical facts.

Pupils construct their own sundials from 'kits' duplicated on thin card (see Fig. 1) and use clock time to position them correctly, making the necessary correction for BST. If the dial is set up in September a discrepancy of about

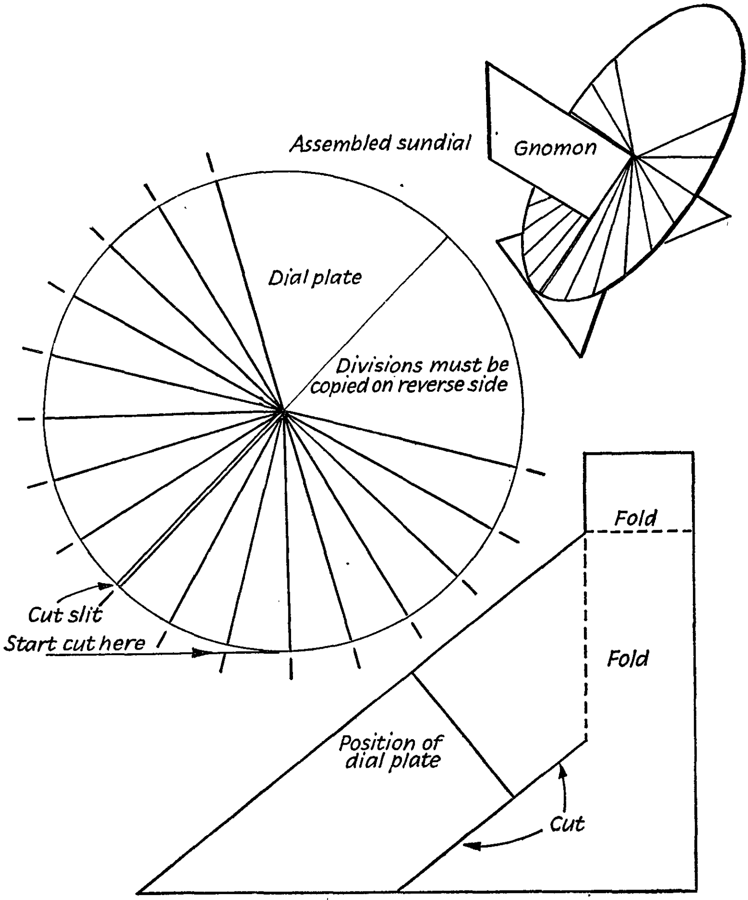


Fig. 1. Plan for simple equatorial sundial

15 minutes will be noticed by mid October, clearly demonstrating its unsuitability as a standard measuring device.

The less common equatorial dial was selected as our model since it has the advantage of equal hour-divisions with obvious relevance to the 24-hour clock.

The name 'equatorial' derives from the fact that the dial plate must be set up in the same plane as the equator, with the gnomon perpendicular to it. Thus the gnomon must make an angle with the horizontal equal to the latitude, whence it will point to the pole star.

Pupils proceed to investigate the properties of the simple pendulum using the apparatus described below.

The apparatus consists of a piece of fairly thick mild steel plate, approximately 15 cm long and 2 cm wide, through which a small hole has been drilled near one end. An opened-out paper clip is tied to one end of a length of

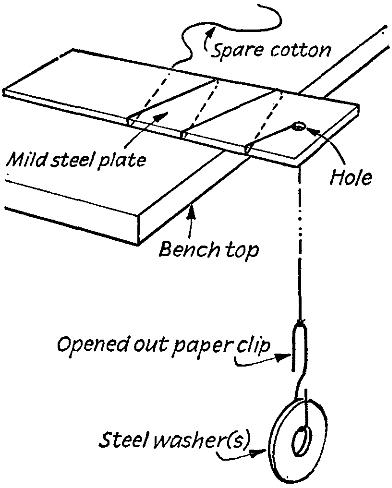


Fig. 2. Apparatus for investigation of the simple pendulum

cotton. The other end of the cotton is passed through the hole in the plate and the spare wrapped around the plate. In use, the cotton is anchored by the weight of the plate, yet the length is easily changed. Washers hung on the paper clip allow the mass of the bob to be changed.

The second may be defined in terms of pendulum length, and pupils experience no difficulty in realizing that the choice of any other standard of time would demand an impossibly long pendulum. The fact that a pendulum 1 m long has a period of approximately 2 seconds provides a useful reinforcement of the pupils' grasp of the standard unit for length.

Polishing and varnishing rock specimens for use in school

P. J. PERKINS

Geology is not the only school subject in which the attention of pupils should be drawn to the nature of rocks. In geography there is a need to describe the main types of rock and to show how they determine land forms. In general science and chemistry, reference should be made to the different rocks from the point of view of their chemical composition. Certainly, in all three subjects, actual rock specimens should be looked at rather than just referred to, but all too often the specimens available rarely show the details of their composition and texture well enough for their use to be worth while. Usually rocks collected from the field have suffered from weathering and in consequence evidence of their composition is largely obscured. Very often a weathered surface gives a completely false impression of the nature of the rock and all such specimens should be broken to produce a fresh surface. Those rocks which contain fossils and which are wanted for the demonstration of types of extinct animal will often be of little value even when a freshly broken surface is used.

Faced with a specimen of crinoidal limestone, will the pupils be able to see and recognise the fragments of crinoid stems and will it really look different to them from a sandstone or a coarse, even-grained igneous rock? This is the difficulty that many teachers must be confronted with. All the details of a fossiliferous rock can be seen only if the rock specimens have first been ground and polished.

EQUIPMENT

The best results are obtained if the polished surface is flat and this can best be produced by grinding and polishing on a piece of sheet glass (about 35 × 45 cm). This sheet of glass (or glass lap) should be kept on a flat surface and it is most convenient to have this as the base of a tray. Without a flat clean surface under the glass the pressure used in grinding is likely to cause breakage of the glass. Having sides to the tray helps when storing the glass when it is not being used. Satisfactory results have been obtained with silicon carbide (carborundum) abrasive powders which are prepared and sold for this use. They are produced by The Carborundum Company Ltd, Trafford Park, Manchester 17, and can be obtained from their agents. The grain sizes that the author has used are: Nos. 80 and 220 for grinding and No. 600 for polishing. Pepper pots are very useful for the careful sprinkling of the powder on to the glass lap.

GRINDING AND POLISHING

Before starting to grind a rock specimen, it is advisable to obtain as flat a surface as possible by trimming with a hammer and cold chisel. Coarse-grained abrasive powder (e.g. grain No. 80) should be used first to obtain a flat surface. A small amount of the powder (equivalent to a pinch) is sprinkled over the centre of the glass and a little water added. A circular motion should be used and all of the glass lap covered so as to maintain even wear over the surface. If the specimen seems to stick, a little more water should be added. A medium-grained powder (e.g. grain No. 220) is then used, but only to smooth down the coarse scratches of the coarser powder. It is important to scrub the specimens after each stage so that no stray grains of coarse abrasive spoil the surface whilst grinding with the medium powder, and especially when polishing with the fine-grained powder. In order to avoid this mistake, it is helpful to have a glass lap for each grade of abrasive used, but even so specimens should be scrubbed to remove coarse powder from cracks in the specimens. Having one glass lap for each grade of powder used will also allow work to be done simultaneously, by pupils if necessary, on specimens at different stages of treatment. It is possible to use waterproof carborundum paper in place of powders for grinding but this tends to produce a slightly convex surface on the specimen. Strips of the paper can easily be pinned on to panels of wood but must frequently be renewed if hard rocks are being ground.

Polishing is done with the finest of the powders (e.g. grain No. 600) and great care must be taken to ensure that there are no scratches on the polished surface resulting from stray grains of coarser powder on the glass lap being used for this last stage of the treatment.

VARNISHING

The polished surface of a rock specimen, when dry, does not show the details of its structure as well as when wet. It is sufficient to moisten the surface whenever it is to be studied. It may be more convenient, however, to varnish the surface. If a hard varnish is used this will also protect the polished surface. Care should be taken to avoid the excessive use of varnish, to keep the surface horizontal when allowing the varnish to dry and to do the varnishing in an atmosphere which is as free from dust as possible.

NOTES

1. This work is an introduction to lapidary, a subject which is now becoming a very popular craft activity. It is likely that your pupils will also find that the beauty of rocks and fossils treated in this way can lead to possibilities for making brooches and other ornaments for presents.
2. A number of people now coat the treated specimens with PVA emulsion rather than varnish. This material dries to produce a robust transparent film. It may of course also be used for mounting, being a good adhesive.

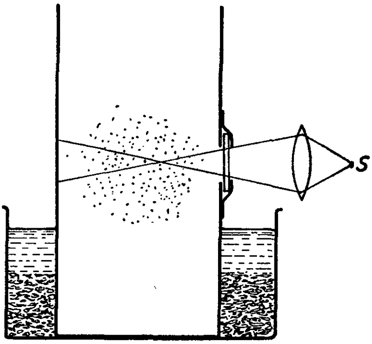
Artificial rain making

W. LLOWARCH

An experiment to demonstrate this principle was included in the exhibition on 'Weather' at the South Kensington Science Museum in the early part of 1950. The catalogue of that exhibition did not state who was the originator. The present note describes a successful attempt to repeat the demonstration on a reduced scale and with simplified cooling arrangements which bring it within the scope of any school laboratory.

A cylindrical tin, 40 cm high and 20 cm in diameter approximately, stands in a tin of height 15 cm and diameter 30 cm. The annular space between the tins contains a cooling bath of paraffin oil and solid carbon dioxide. The two tins must be soldered together or otherwise fastened to counteract buoyancy. The middle portion of the taller tin is illuminated transversely through a celluloid window by a concentrated beam from a 24 W motor headlamp bulb. The celluloid may be stuck with 'Sellotape' over a slit 2.5 cm high and 15 cm wide cut in the side of the tin. The inside of the inner tin is painted matt black.

Breathe into the tin. A cloud forms in the cold air. This cloud consists of *supercooled water* drops, extremely small, so that they remain suspended and cannot fall as rain. If the cloud is cooled below about −40 °C the drops will freeze, grow by collision with other drops and fall as ice crystals. This is achieved by holding a piece of solid carbon dioxide *in the gloved hand* over the tin and scraping a few particles into the cloud. A miniature snow storm develops and the cloud is precipitated. The demonstration may be repeated at frequent intervals.



After a time the inside of the tin becomes covered with a film of ice crystals, forming a white background which spoils the effect and must be wiped off. This might be avoided by smearing the lower half of the inner surface with glycerine or 'antifreeze'. It is possible to dispense with the somewhat messy paraffin bath and merely pack the annular space with lumps of solid CO_2, but this soon causes excessive cooling so that the cloud begins to form ice crystals as soon as it is produced and without the necessity for 'seeding'.

NOTE

There are other experiments which may be considered to be part of the subject of meteorology in Section 3 in this booklet—that on heat—namely those on pages 18 to 29.

Light

Introduction

This section is like the first—remarkably thin. Light, however, tends far too often to be treated as a formal and academic study, and a perusal of the pages of *SSR* seems to bear this out, though again attitudes are clearly freshening fast. What we reprint here then is simply a selection of little experiments from the field, all ones which nevertheless deserve wide propagation.

An important area in the teaching of light in Middle Schools nowadays is that of photography; readers will like to know therefore that there are several useful papers on this subject reprinted in the Lab Book *Biology and Chemistry for Middle Schools.*

Experiments on the eye

L. J. ROWSE

TO SHOW THAT THE IMAGE ON THE RETINA IS INVERTED

The illuminated object is a single pinhole in a piece of paper held up to the light. Take another piece of paper, about 5 cm square, and at the centre make three small pinholes forming an equilateral triangle of about 1.5 mm side. The holes must be close enough to be included within the area of the pupil of the eye.

Hold the paper bearing the three holes as close as possible to the eye so that the eye can see through all three at once. Now hold the paper bearing the single hole about 8 cm from the paper near the eye so that, looking up to the light, the light will come through the single hole, then through the three holes and finally form a pattern on the retina. So long as the single hole is too near to be in focus, the pattern of the images on the retina must be the same way up as the three holes. Since they appear to be inverted, the brain must carry out the inversion; therefore since the cow in the field appears to stand feet downwards, her image on the retina must be feet upwards.

TO FIND THE NEAR POINT OF THE EYE

Repeat the above experiment and slowly take the paper bearing the single hole further away from that with the three holes. The three images move closer together until, at the near point, they become a single image.

Daylight smoke chamber

VED RATNA

If it is desired, in an experiment in optics, to demonstrate the light beam by a smoke chamber without darkening the room, the visibility of the beam is completely marred by the background illumination. The problem would be specially serious in a country where daylight is strong and there are no facilities for darkening the room.

The two sources of background illumination are the following:

(*a*) Stray light entering the chamber through the glass front is scattered by the inner surface of the back of the chamber. Whatever substance may be used to paint the back black, it must scatter back about 5 to 10 per cent of light.

(*b*) Stray light is reflected by the glass front.

The essential feature of this apparatus is to provide a surface which absorbs light almost 100 per cent. For this purpose the principle of the black body of thermodynamics has been applied. The inner surface of the back of the chamber is lined with horizontal strips of black paper 12 mm broad with a spacing of 4 mm among them. The greater their breadth: spacing ratio, the better it is. But a ratio of 3 : 1 is quite sufficient.

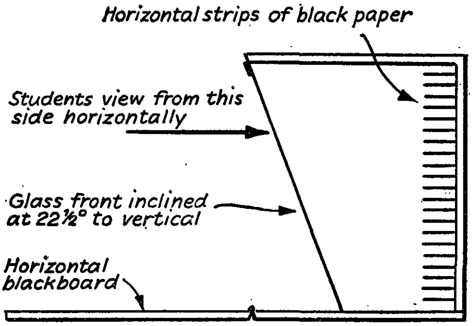


Fig. 1. Side elevation

To reduce the stray light reflected by glass, a horizontal blackboard is placed in front of the apparatus and the glass is inclined at such an angle that the virtual image of this board seen in reflection from the glass fills the whole background. This board is made in the form of a lid so that when closed it is also a protection for the glass. The larger the board, the better does it enable all students see its image filling the background. To reduce further any stray light, the horizontal blackboard can also be lined with black strips.

There is a drawback in this arrangement. Strips of paper are quite brightly illuminated near the edges. As long as the lines of sight of students are horizontal, these illuminated areas are not seen and do not produce an illuminated background. Thus this arrangement is all right in a classroom in which all the seats are on the horizontal floor, seats at the back not being higher than those in the front.

If the seats at the back are higher, some advantage will be obtained by inclining the strips upwards so that they are parallel to the plane of lines of sight of the students in the middle row. But much better results will be obtained by making the strips of metal and painting them glossy black. Glossy black strips will produce a little higher but regular reflection. Illuminated edges will no doubt reflect a lot of light but none at all back into the eyes of the students. Ratio of breadth to spacing should, however, be increased to about 6: 1.

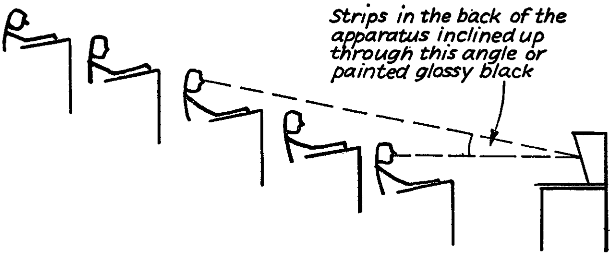


Fig. 2

NOTE

Although smoke boxes are not very fashionable nowadays (either in the commercial variety or home-made ones like this), they have a great deal to offer for demonstration work in introductory treatments of light. Now that the laser is beginning to appear in schools (perfectly adequate instruments of this kind are available for £50 or £60), it is worth remembering that laser light in a smoke box is extremely effective. The Editor has tried this a number of times at this level.

Adjustable focal length converging mirrors

A. R. GLOVER

Concave mirror strips can easily be made from sheet zinc. Strips of the zinc can be cut with tin snips or stout scissors, and a highly polished surface that reflects light well is produced by rubbing with 'Duraglit'. The strip can then be moulded into a circular shape around a beaker or other cylindrical object. By using a set of parallel rays from a ray-box, the focus of the mirror can easily be seen and marked. The focal length can be measured and it can be shown that $2f = r$ by measuring the radius of the cylindrical object round which the mirror was bent. The result can be verified by rebending the strip around other cylindrical objects so as to produce mirrors of different focal lengths. The experiment works well as a class experiment.

NOTES

1. The same approach can, of course, be used also to prepare adjustable-focus diverging mirrors, although it is not so simple to involve the pupils in a quantitative approach.
2. Many teachers find the little strips of mirror squares used for shop decoration useful for introductory work in this area.

Pinhole camera without a dark room

J. M. WILSON

A simple version of the pinhole camera can be made by any pupil in a few minutes from a tin (with lid), a piece of tissue paper, a newspaper and a piece of string. A small hole is made in the bottom of the tin with a nail. The lid is removed and replaced by the tissue paper tied with string. The folded newspaper is rolled round the tin with one edge close to the tissue paper and the other edge pressed against the face, as shown.

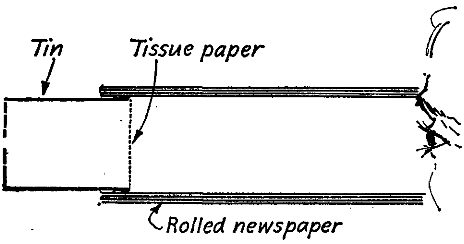


Fig. 1

A 'dark room' for a standard pinhole camera may be made from an open cardboard box. A flap is cut in one side into which the camera fits (if the flap is left in place it helps to seal the 'dark room'). A peephole is cut in the opposite side. Pupils must realize that the peephole through which they look is not the 'pinhole'.

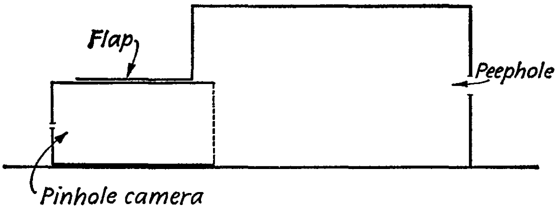


Fig. 2

NOTE:

The Editor wishes to go on record as believing that the simple pinhole camera described in the first part of the above note is by far the best construction he has ever met!

Heat

Introduction

The area of physics vaguely called 'heat' in the traditional classification covers a wide selection of important subjects. Even of its more elementary topics, many are closely relevant to everyday life and experience. Yet teaching can often be rather dull, perhaps because it is not a field in which great strides are being reported each week in the press. Often lessons tend to be taught from a Victorian ivory tower, with oodles of rather dreary mathematics to add insult to injury.

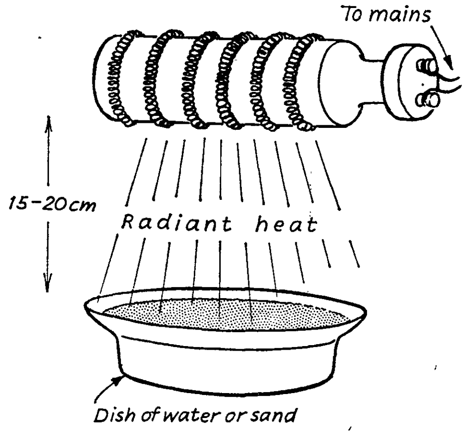
Yet there is much of interest here, and every item in this section of the book shows this fact clearly. Nothing here is new as such—the fields of transmission, expansion, calorimetry, and engines are all represented—but the approaches are fresh, appealing, and relevant.

The section opens with a couple of pieces which nicely link the ivory castle of heat with the study of the weather (and this links it therefore with material in the first section). We then have a novel model approach to the concepts of the thermal behaviour of atoms, it being always important to encourage understanding and acceptance of this fundamental theory of the nature of matter. Some unusual views of the teaching of expansion are followed by a neat approach to calorimetry, with some biological significance. The section is completed with two models of heat engines, for many pupils a closed book because of the difficulties of putting across the relations between heat and the work involved.

Land and sea breezes

R. L. PAGE

One of the foremost examples of air convection is the occurrence of land and sea breezes as a result of the land heating up more quickly than the sea during the day and cooling more rapidly than the sea at night. A simple demonstration of the quicker heating of land than sea is shown in the figure below. Two dishes of the same shape and size are filled to an equal depth with sand



and water respectively. An electric fire filament is suspended above one of the dishes. The temperature of the sand or water (whichever is in the dish) is taken. The filament is turned on for a given time and the temperature is retaken. The other dish is then placed in the same position and the operation repeated. It is found that a greater rise is detected in the dish containing sand than in the dish containing water. If it is a sunny day the dishes can be exposed to the sun for, say, half an hour side by side and the difference is quite pronounced.

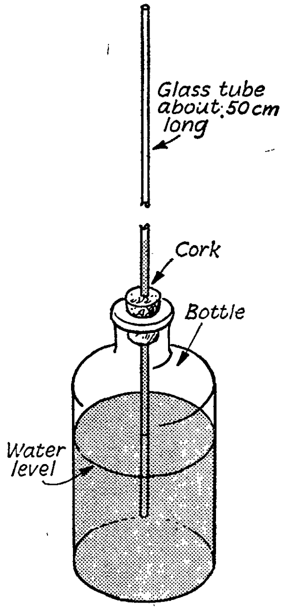
NOTE

An interesting project is to attempt to irradiate both sand and water in an arrangement of this kind in order to investigate whether breezes are actually set up.

Black objects absorb radiant heat more readily than shiny bodies

R. L. PAGE

For this demonstration two identical bottles or flasks are fitted with corks. One of the bottles is blackened over a candle and then both are filled to an equal depth with coloured water. The levels should be about halfway up the bottles. Each cork is bored and fitted with a narrow length of glass tubing about 50 cm long. The corks are then fitted into the necks of the bottles so that the glass tubing reaches below the surface of the coloured water and pressed home until water appears in the glass tubing above the corks. The corks are adjusted till the levels of the water in each tube are the same. The bottles are then placed in the sunlight to get equal quantities of sunlight and the levels of the water noted after an hour or so. Alternatively the bottle can be placed in front of the filament of a bar electric fire about 20 cm away from the filament. The water level in the blackened bottle will be found to be higher than in the other bottle, showing that the air has expanded in the blackened one more because it has absorbed more radiant heat.



A model to illustrate the kinetic theory of solids, liquids and gases

D. G. SMITH

While analysing the content of lower school physics we encountered the need for a working model which would demonstrate that a molecular model of the structure of matter explains the following.

1. Manifestation of 'heat' as energy.
2. Rigidity of solids.
3. Crystalline and non-crystalline structure.
4. Expansion of solids with rise in temperature.
5. Relationship between kinetic energy of vibration of the molecules in a solid and temperature.
6. Change of state—solid to liquid.

7. Random nature of molecular motion in a liquid.
8. Flat surface of a liquid and conservation of its volume at a given temperature.
9. Relationship between mean kinetic energy of translation of molecules of a liquid and temperature.
10. Expansion of liquids with rise in temperature.
11. Existence of an associated vapour with a liquid.
12. Various volatilities of liquids.
13. Dependence of saturation vapour pressure on temperature.
14. Change of state—liquid to gas.
15. Relationship between mean kinetic energy of molecules of a gas and temperature.
16. Distinction between boiling and evaporation.
17. Increase of pressure exerted by a gas when its temperature is raised at constant volume.

Eventually, we used a discarded electric razor to vibrate a cell containing the 'molecules'. These were 4.8 mm ball bearings in a single layer between parallel glass plates. Glass was used because Perspex and other plastics materials are prone to scratching. The cell was bonded with 'Araldite', bound with adhesive tape and finally stuck to the vibrator on the razor with 'Araldite' (Fig. 1).

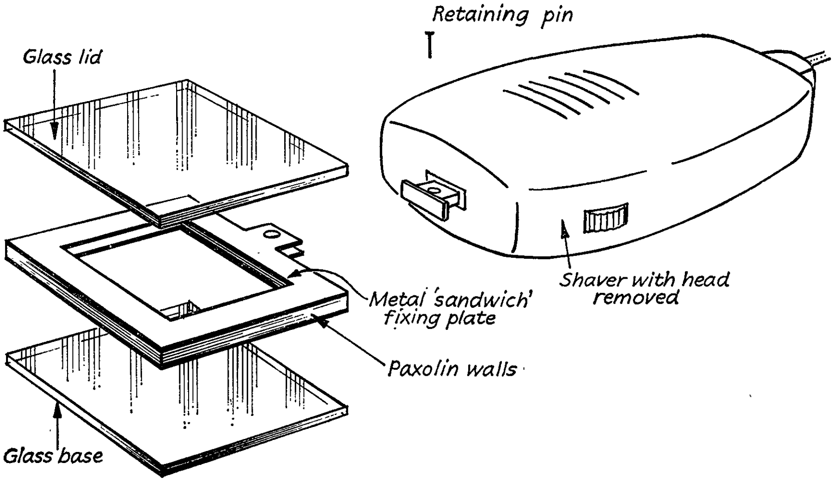


Fig. 1. Construction of model

In position it is tilted about 2° to the horizontal since this allows the 'molecules' to remain in the gas phase for a noticeable length of time. A greater tilt produces a less volatile 'liquid' with a raised boiling point and melting point.

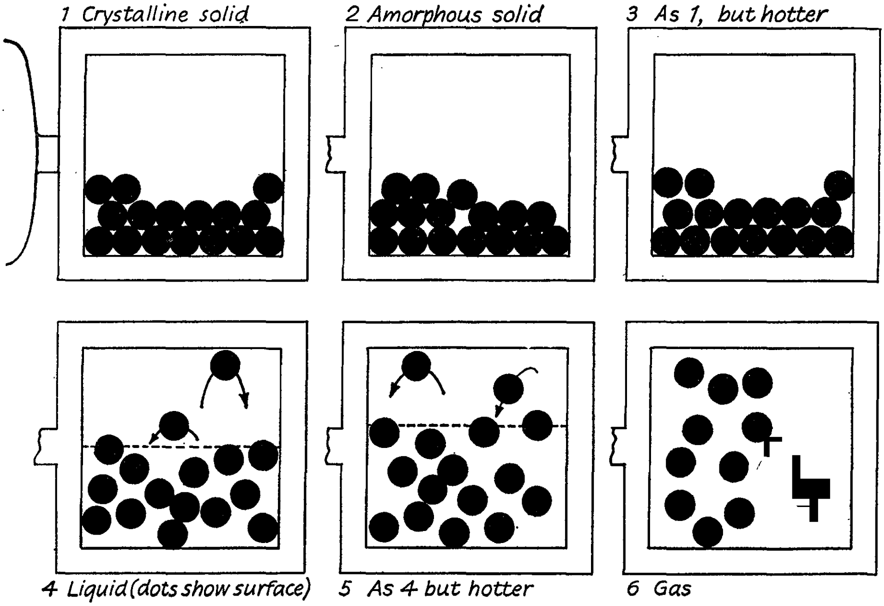


Fig. 2. Examples of projected images

The shaver is clamped so that it can be rotated about three mutually perpendicular axes while positioning it (Fig. 3).

The amplitude of the vibrations is varied by adjusting the voltage supplied to the razor by means of a variable transformer or a *large* resistance; a voltmeter registers the 'temperature'.

A conventional projection device produces a final image 60 cm square

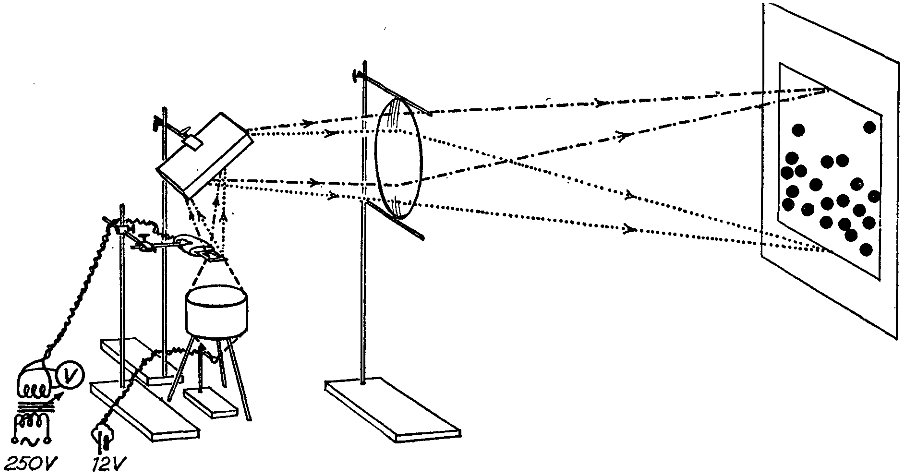


Fig. 3. Method of projection

which is readily seen from any position in the laboratory, although close inspection is necessary to observe the vibrations in a 'solid' at low temperatures (Fig. 3).

We have improved the illumination by adapting an old 8 cm × 8 cm slide projector and using a reflecting prism.

The cell has also been modified so that it may be mounted on an Advance electromagnetic vibrator driven by an Advance signal generator.

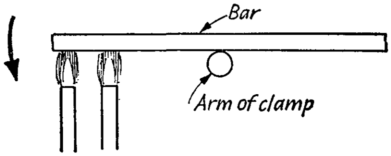
NOTE

There is, of course, now available a large number of different kinds of device intended to show some or all of the effects analysed in this particular piece. Various designs also exist for do-it-yourself teachers, some of which are able to be used on the overhead projector. A useful project for those with somewhat more time available is to make films or loop films of the effects produced in such equipment.

Is heat heavy?

D. P. NEWTON

The following problem experiment is an intriguing example of expansion which lends itself to discussion by the class.



The long bar of a clamp is unscrewed from its base and balanced on the arm of a similar clamp. One end is strongly heated and after a minute or two the bar falls in the direction shown by the arrow.

Polyethylene as a material for showing thermal expansion effects

R. H. MORRIS

The writer, in a search for materials with high coefficients of expansion, narrowed the field to gutta-percha and high melting point waxes. It occurred to him that synthetic wax might give useful results and also be consistent, and this has been found to be so. The average coefficient of expansion per kelvin between 20 and 100 °C proves to be about 0.000 35 (cf. 0.000 018 for brass). In a simple experiment, a piece of polyethylene about 30 cm long expanded by more than 1 cm on heating from room temperature to 100 °C. The expansion is, in fact, so great that in a demonstration it should be emphasized that the behaviour is not typical of all solids. 'Bi-metallic' elements incorporating the material show extraordinary sensitivity.

The following figures may be of interest to those in search of materials for demonstration. (Is it a coincidence that the materials showing high thermal expansion are very bad electrical conductors?)

Material	*Melting point* (°*C*)	*Mean temperature coefficient to* 100 °*C or m.p.* (K^{-1})
Brass	—	0.000 018
Paraffin wax	40–55	0.000 15
Hard wax	40–60	0.000 3
Polyethylene	*c.* 115	0.000 35
Ebonite	—	0.000 08
Perspex	80–105	0.000 09
Gutta-percha	65–75	0.000 2–0.000 6

Polyethylene is available in various extruded sections, and in the form of a moulding powder. For demonstration, the 30 cm × 1.26 cm-diameter rod, marketed as a standard article, is extremely convenient. 'Alkathene Grade 2' should be specified, as this is the hardest variety available. Another convenient form for demonstration is the 'Alkathene Film Grade 70' which is available in any reasonable length in thicknesses from 0.076 mm to 0.3 mm and widths from 1.25 to 7.6 mm.

The material is normally used, of course, as a low-loss dielectric, and 'everytime' static electricity experiments are certain with its aid. The rod mentioned above should replace the ordinary ebonite rod of the textbooks, while a continuous length of the ribbon forms the basis of a simple but efficient friction machine.

Calorimetry of the hand

R. L. PAGE

One of the difficulties of teaching calorimetry is to make it relevant to the class's experience. The following experiment overcomes this difficulty in part, by measuring the heat lost/min/cm² by the hand. The hand is a reasonable heat source—on average it gives out about 8.5 kJ (2000 cal) in ten to fifteen minutes. Placed in a 1000 cm^3 beaker it can be covered normally, by about 400 cm^3 of water, and thus over a period of ten to fifteen minutes a temperature rise of 4 to 5 °C can be obtained. A cut-away diagram of the apparatus is shown in Fig. 1. The jacket is made of corrugated cardboard, and the base on which the beaker stands, of asbestos sheet or enamel tile. For slightly more accurate results a $\frac{1}{5}$ °C thermometer can be used, but for many groups an ordinary thermometer will be good enough.

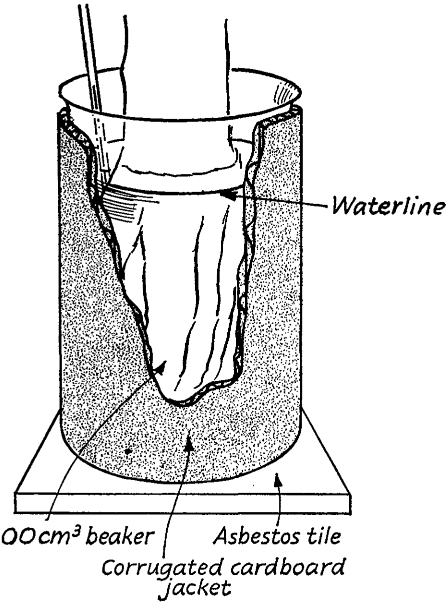


Fig. 1

A typical set of results was as follows.

Mass of water to cover hand = 400 g
Temperature before = 15.4 °C
Temperature after = 20.4 °C
Temperature rise = 5 °C
Heat gained by water and given out by hand = 8.4 kJ (taking specific thermal capacity of water to be 4.2 J/g °C)
Time taken = 15 minutes
Heat given out/minute = 560 J/min

To find the surface area of the hand to a fair degree of accuracy, take a sheet of fairly thick cardboard. Draw an outline of the open hand on it up to the water line, and cut it out. Then cut a separate square 10 cm × 10 cm. Weigh both of them, m_1 and m_2, respectively (Fig. 2).

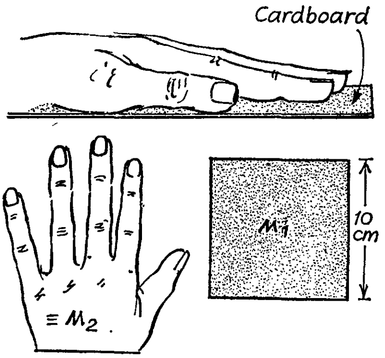


Fig. 2

Mass of square (m_2) $= 4$ g
Mass of cut-out hand (m_1) $= 7$ g

$$\text{Area of hand} = 2 \times \frac{m_2}{m_2} \times 100 \text{ cm}^2$$

$$= \frac{2 \times 7 \times 100}{4} \text{ cm}^2$$

$$= 350 \text{ cm}^2$$

Hence heat output rate 1.6 J/cm²/min

I have found so far results ranging from 0.8 to 2.5 J/cm²/min. After strenuous activity (a PE lesson or some other athletic activity) this value can rise by as much as 0.8 J/cm²/min. This experiment is quite a useful introduction to heat loss from the body, which in turn can lead to heat production to keep the body temperature steady, dieting, etc.

It should be pointed out that this experiment measures heat loss in water which is more than heat loss in air. That is, the experiment approximates to heat loss while swimming rather than walking, etc. None the less, I think it brings calorimetry a little nearer to a child's experience.

NOTE

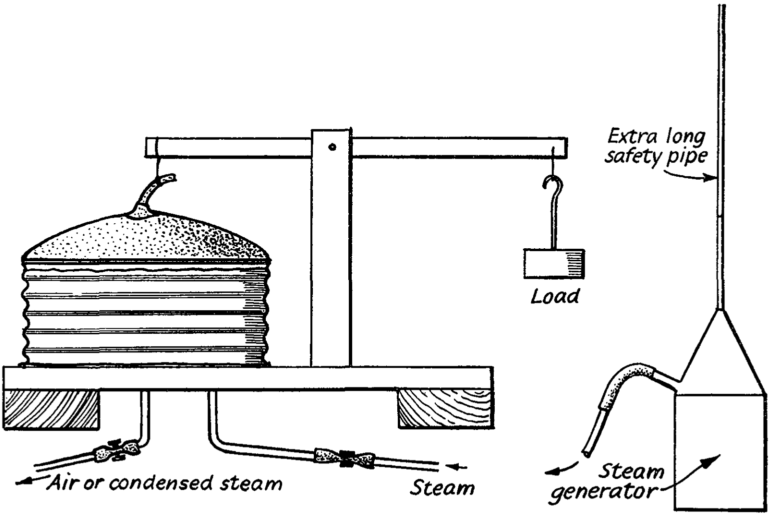
The mathematics involved in this piece is the most advanced of any quoted in this book (practically the only mathematics in the book in fact). Although the computations and concepts are not involved, many Middle School teachers will naturally hesitate before going to this depth.

A beam engine for use in junior work on air pressure

C. A. BUNKER

It has always struck me that there has been a need for a simple demonstration to show that (*a*) steam possesses a store of energy due to having displaced air from the space occupied by the steam, (*b*) that this energy is available to do work, and (*c*) that a simple machine can make this energy available. The collapsing tin experiment is not repetitive, nor is the energy available in a useful form; a simple beam engine seems to me to satisfy all the requirements (*a*), (*b*) and (*c*).

The chief difficulty experienced in constructing the apparatus lies in the piston and cylinder; however, the arrangement shown is found to work very well. The cylinder consists of a cut-down 3 kg jam tin, the sort with corrugated sides being most suitable. The piston is a section from a football bladder, the neck being blocked off and used to attach the bladder to the beam. The bladder is attached to the top of the cylinder with 'Araldite', which seems to be able to resist the action of low-pressure steam very well, and is wired with heavy gauge copper wire into one of the corrugations of the tin. The tin is screwed to the base of the apparatus before the bladder is fitted, 'Araldite' again being used to seal the joint. The base of the tin is fitted with two rubber bungs, to which are fitted glass tubes. The boiler consists of an ordinary steam generator, to which has been added an abnormally long safety tube; one about 60 cm long is satisfactory. Though the largest load I have used has been one kilogram, there seems to be no reason why larger loads should not be used.



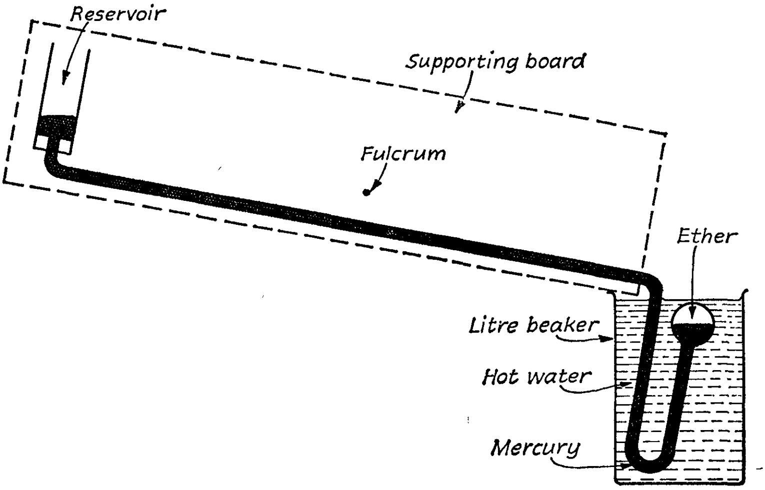
In use, air is first removed from the apparatus by allowing a flow of steam to pass for several minutes. The steam outlet pipe is then closed, as is the steam supply. The steam condenses, the load is raised, more steam is admitted and so on. When the amount of condensed steam has become excessive, opening both valves allows it to drain out. No special cooling is needed as the loss of heat through the thin walls of the cylinder is very large. About six or seven strokes may be made to the minute, with a throw of 5–10 cm. Presumably the engine could be made self-acting, and a separate condenser could be added, together with a lagged cylinder, though this has not been tried. This method of constructing pistons and cylinders could probably be used to improvise a hydraulic jack, and similar apparatus.

A pure heat engine

W. K. MACE

In the introductory teaching of 'forms of energy' the conversion of heat into work is most commonly illustrated with reference to the steam engine. As a clear-cut example of the conversion in question this engine leaves much to be desired. I know that when I was a child, whatever the textbooks might say, a steam engine to me was a thing which took in water and coal and gave out work, steam, smoke and ash; all outputs and imputs were equally prominent. In fact, I doubt if I really understood heat engines properly until many years later, when I acquired a hot-air engine to play with. Suddenly it was clear: you took it out of the cupboard, played a Bunsen burner on it, and work came out!

My own view is that all 'energy conversion kits' should include a hot-air



engine. Unfortunately there does not seem to be a suitable cheap toy one on the market, so one has to be made. If this should be impossible, the ether engine illustrated above is in many ways a fair substitute. All you need to do is take it out of the cupboard and give it a beaker of hot water. It immediately starts doing work.

Heat is absorbed by the ether which evaporates and pushes mercury over into the reservoir. The tube tips, the bulb comes out into the air and cools; the mercury runs back, re-immersing the bulb in the water. The cycle repeats indefinitely.

The tube shape is dictated by the problem of getting the optimum amount of ether. Initially one puts in too much, and excess then finds its way out to the reservoir surface. Stability is a nice problem: in practice the position for the fulcrum has to be found by trial and error.

NOTE

This device will be very reminiscent of the 'Noddy birds' occasionally to be found. The principle of action is somewhat similar in each of the two cases.

Mechanics

Introduction

The subject of mechanics is not a popular one to science teachers. Many of the reasons that make heat unpopular apply here, but again it is a fundamental field whose understanding is essential for any other one. The concepts of force and mass are basic, and the section opens with a brief but succinct account of teaching them at an elementary level—one of the many such contributions in the pages of *SSR*. The rest of the material here is a collection of 'wrinkles' on the various standard subsections—particularly pressure, hydrostatics, and elasticity. The area is such a large one, however, that this selection can be only a superficial one. Considering the lack of excitement caused by mechanics generally, it is remarkable how much material is available for teaching it. Certainly, that is a good thing.

Force, weight and mass

M. F. JAMES

While we were considering recently a change in the syllabus of our (secondary) first forms, it occurred to me that pupils often do not know the newton as a unit of force until they meet Newton's second law. This is rather like the state of affairs, now happily past, when a colleague of mine used to teach magnetostatics to his sixth forms before current electricity, 'so that he could get the e.m.u.' to use in the latter. This particular order, though commemorated in the sequence of topics written into the 'current electricity' section of the JMB A-level physics syllabus, is rarely followed today. We simply do not believe that the definition of the unit is important to the concept. We take a metre rule, use it, and tell our class that scientists have agreed about how long it should be. For less intuitive concepts, such as that of electric current, we might have to assert initially that scientists have agreed about *all* the markings on the scale. This is something which pupils tend to do anyway; it is harder to make them suspect the linear scale on a thermometer than it is to make them believe it. In this way, pupils acquire an operational understanding of concepts—they learn how to measure them in everyday scientific life. At first-form level, measuring and understanding are nearly synonymous.

It came to me, while we were thinking about such an introduction to force and weight, that the humble slotted 'weight' was more guilty than we commonly suppose of confusing young minds on the subject of weight and mass. Not long ago, when I heard a suggestion to print '1 newton' on 100 g slotted weights, I reacted with instinctive but ill-defined horror. The horror now took a more definite character. Suppose we set ourselves, dogmatically, never to use slotted weights to exert a force, in spite of their convenience. What sort of teaching sequence would emerge? It was obviously necessary to introduce our three difficult concepts in the order given in the title to this article, and in each case one needed an appropriate 'meter' to measure them, calibrated in the appropriate units.

The rebuilt syllabus started with a cycle of eight experiments, designed to last for three weeks and give our newcomers some impression of what physics is about. Into one of these, 'Metric Measurement', we slipped without comment a bathroom weighing scales with the scale calibrated in newtons. The accompanying worksheet asked them to record their weight in newtons, which they did with surprisingly little comment. A race of children who had bought their sweets in grams would have had far more to say! After a few weeks, forces came under consideration, following length and time, as things which need to be measured. Some 100 g spring balances were re-calibrated at 1 newton full scale, and were used on the copper spring experiment of the Nuffield O-level Year I. The 10 N spring balances worked nicely on the steel springs. The breaking force of copper wire was found with the large 5 kg spring balance, its scale re-written to 50 N. After a week or two of this, everyone knew that forces were measured in newtons, and had some idea of how 'forceful' a newton was.

One thing which most of our pupils know now, which they did not know ten years ago, is that things weigh one-sixth as much on the moon as they do on earth, and that in space one can be 'weightless'. In the context of this knowledge, it is easy to sell the idea of weight as the force of gravity on an object, and it makes sense to measure this force in newtons. They appreciate that the bathroom scale would give a smaller reading on the moon, and would float away in space. (Of course, we keep quiet about weightlessness in satellites. 'Sufficient unto the day is the evil thereof.')

We can now hang a mass marked 1 kg on the spring balance, and the reading is 10 N. On the moon, it would be 10/6 N. In future, we would not get this far without mention of the kilogram, but now is the time to ask why it is that butter will be bought in grams and sugar in kilograms, and not in newtons. If we take a kilogram of sugar into space, have we no sugar because it is weightless? Surely we could tell if the sugar bag was empty, or full of lead shot, without opening the bag? One could, for instance, punch it as it floated in the spacecraft. Now this is the place where many books and courses have in the past shied off and 'left it until later'. One book of wide circulation even defines density as 'weight over volume', because mass is 'too hard'. We, however, plough onwards. We present a sequence of inertial experiments, without explicit statement of Newton's laws, to suggest what a cook might do in a spacecraft to 'weigh out' a kilogram of sugar. In the future, our students might become blasé about all this space business. At present, it goes down very well.

We start off with the famous tin cans on string, one 'massive' and one not. We ask one of the characters of the class to punch them, but the situation is clear enough even before he tries. Would this still happen in space—would you still get raw knuckles? Next, we take two large Nuffield trolleys and seat pupils of contrasting masses on them. We stand across the gap between them and give them a push apart, before jumping off. We let them use the inertia balance (the wig-wag). Finally, we make a trolley spring away from a stop by itself, then with another trolley on top, then with a 1 kg mass on top. It is not hard to convince pupils that this is a 'mass meter'. It seems a cumbersome device compared with a 'length meter', or a 'force meter', but it *would* give the same reading for a given object in space. So our cook in the spacecraft could still 'weigh out' the ingredients for a cake if he were weightless. No doubt, they would be pre-packed on earth in reality, but he *could* do it with our inertial 'mass meter'.

One reason for the apparent success of this last part is that the experiments themselves are picturesque and appealing. We don't expect the last word on mass to have been pronounced, by any means. We do find, however, that they are clearer about weight and force, that they have a feeling for the size of one newton, and (we hope) that they are aware of a *separate* concept, called mass and measured in kilograms. They feel superior in knowing, unlike the 'man in the street', that your weight should be measured in newtons, or how else could you weigh less on the moon?

Those slotted weights, relegated to their cupboard, may still be used occasionally to provide a force. But round their neck will be hung a prominent notice, an indictment of their inconstancy: 'Gravity pulls me with a force of . . . newtons', on earth, *not* as it is in heaven.

Grateful thanks are due to my colleagues K. Bamford, P. Beaumont, M. Crossland, D. J. Dunn and B. Hargreaves, whose contributions and criticisms helped to form this radical attitude to mass in general, and to slotted weights in particular.

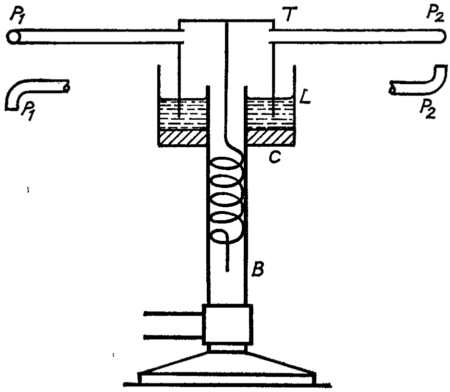
NOTE

Indeed, the question of units and elementary concepts is one that tends to put many teachers off mechanics. In particular, the relationships between force (including the force called 'weight'), mass, and the other quantities involved in dynamics are liable to cause a lot of trouble. The pages of *SSR* seem to be dotted by letters and notes from people trying to put these ideas straight!

'Jet propulsion'

W. E. PEARCE

Two holes (6 mm diameter) are drilled near the closed end of a small tin T (diameter 18 mm, length 3.6 cm) so that they are at the opposite ends of a diameter. A piece of thin copper tubing P_1 (diameter 6 mm, length 7.2 cm) is pushed into one of these holes and then soldered. A similar piece P_2 is fixed through the other hole. 2.5 cm of the outer end of each tube is bent through a right angle in a horizontal plane. A piece of stiff brass wire (No. 18 s.w.g.) is bent into a spiral so that it is a tight fit when pushed into the tube of a Bunsen burner B. The top of the spiral is straight and is filed to a point. A metal cylinder L (diameter 3.6 cm, length 5 cm) is closed at one end by a cork C, through the centre of which a hole is drilled so that the cork is a watertight fit on the Bunsen burner. The tin T, with its projecting tubes, is balanced on the tip of the wire as shown. Enough water is placed in the cylinder L to make a gas-tight joint at the bottom of the tin T.



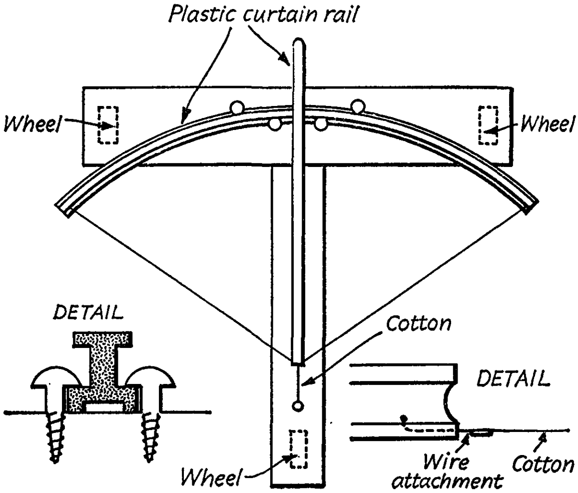
When the gas is turned on, it enters the tin and emerges through the ends of the tubes P_1 and P_2, where it can be lit. The resulting reaction makes the tin revolve fairly rapidly. The change of speed should be noted when

(*a*) the outlets are made smaller by flattening them with a pair of pliers;
(*b*) the air inlet of the burner is opened or closed;
(*c*) the gas issues without being lit.

Simple illustration of Newton's third law

T. J. ERICSON

This demonstration is sketched below and simply consists of a bow on wheels. The cotton connecting the arrow to the frame is burned with a match and the reaction to the force on the arrow accelerates the bow and frame backwards.



The densities of aniline and water

C. G. HANSON

While performing the well-known demonstration of the differing expansion coefficients of water and aniline recently, I thought of a 'new' approach.

Instead of adding the cold aniline from a burette to cold water in a 5 dm^3 beaker, watching it sink and then heating with a Bunsen burner to observe the magic temperature when the densities of the two liquids become the same and the spherules hang 'weightless', I thought out the following variations which do not require the heating of aniline.

Add a drop or two of aniline to a 5 dm^3 beaker, half-filled with water, and then dissolve sufficient sodium chloride to make the aniline float. Now carefully pour cold water on to a floating cork in the beaker, thus establishing a density gradient up the beaker. The aniline spherules of course now hang 'weightless' at the level where their densities are the same as that of the salt water.

Now adjust the burette orifice to the level of the suspended spherules and carefully open the tap. A weightless aniline sphere now grows and more aniline can be added to the burette if required.

Using this method I have grown spherules up to 100 mm in diameter before running out of aniline, which is recovered afterwards using a separating funnel.

On completion of the above, which takes about five minutes, class discussion is almost limitless, covering density, Archimedes' Principle, 'weightlessness' in space, surface tension, the shape of the earth (the 'sphere' is not in fact spherical), the solubility of so-called immiscible liquids, expansion coefficients and Stokes's Law (viscosity).

All the students I have shown this demonstration to have been fascinated and I have even been offered money to buy more aniline and hence produce even larger spheres!

'Blowing up' a girl

ALAN WARD

Breath blown into a plastics bag can raise a teenager of moderate weight. But the bag must be put under a strong wooden board, upon which the person stands. We tried this successfully with a girl student. The idea came during a session on water pressure, when the girl, who was standing upon a metal dish resting on a hot-water bottle, was being lifted slightly by a small quantity of water poured into the bottle down a long 1 cm diameter plastics tube.

We set up our experiment with the plastics bag upon a bench, near an edge—where it was easy to blow into the bag's opening. A second student stood behind, to steady the girl on the board if she overbalanced. Of course we were exploiting Pascal's principle, which explains that pressure is communicated equally to every part of a container. Low 'breath pressure' was transmitted to every square centimetre of contact between bag and board—and provided enough total force to raise the girl dramatically.

Some elementary demonstrations of pressure phenomena

MURIEL WHITTAKER

The commonest type of syringe used nowadays for injection is the ready-sterilized, plastics one. These syringes are relatively cheap to buy from medical suppliers, and they can often be obtained free after use from medical or veterinary sources. They can be put to many uses in the laboratory, including the simple demonstration of a number of aspects of air and fluid pressure, some of which are outlined below.

A 10 cm³ syringe will be found the most convenient size for most purposes. The plunger should be well greased or lubricated with liquid paraffin.

1. AIR PRESSURE AND VOLUME

(*a*) A small volume of air is drawn into the syringe, and the nozzle is closed by pressing the thumb over the end. Alternatively, thin rubber or plastics tubing can be slipped over the nozzle and closed with a clip. The air in the syringe can be expanded by withdrawing the plunger of the syringe, and the effort exerted can be felt to increase as the plunger is drawn out. On releasing the plunger the volume of the air in the syringe returns to approximately the initial value.

(*b*) A larger volume of air in the syringe can be compressed with the plunger, and will return to the initial value when the pressure on the plunger is released. Both these demonstrations can be made roughly quantitative if the syringe is suitably clamped so that a known weight can be applied to the plunger. This provides a simple demonstration of Boyle's law.

2. DEMONSTRATION OF COOLING BY EXPANSION

A few drops of water are introduced into the syringe, and the barrel is then filled with air. The nozzle is closed and the plunger pushed in to raise the air pressure in the barrel as high as possible. The nozzle is then opened, and the plunger immediately pushed home to the end of the barrel, when a jet of condensed water vapour will be seen coming from the nozzle, showing the cooling of the air on expansion. It is best to use the thumb to close the nozzle in this demonstration, as it is then easier to ensure that release of pressure and ejection of the cooled air follow each other very closely. The water vapour is most clearly seen against a dark background.

3. BOILING A LIQUID UNDER REDUCED PRESSURE

About 1 cm³ of water or other liquid is drawn into the syringe, then a very little air. The nozzle is closed and the syringe held nozzle end upwards, so that the water covers the end of the plunger. The plunger is gradually drawn out, and as the pressure falls in the syringe the liquid begins to boil. Liquids of different vapour pressures may be compared, but care must be taken that the liquids are not solvents of the material of the syringe.

4. DEMONSTRATION OF HYDRAULIC PRESSURE

Two syringes are half filled with coloured water, and their nozzles joined by a piece of tubing. Pressure on one plunger will then push out the other.

If syringes of different sizes are used, the apparatus provides a demonstration of the principle of the hydraulic ram, as movement over a short distance of the plunger in the larger syringe causes movement over a greater distance of the plunger of the smaller syringe, the ratios depending on the internal diameters of the syringes.

The above applications of syringes were discovered by free experiment by children of various ages, and there are doubtless many more still to be found.

NOTES

1. In her second sentence, the author of this note mentions that a good source of plastics syringes is the 'second-hand' market. It cannot too strongly be emphasized that the use of such syringes in schools after employment by doctors or by vets is not something to be encouraged. The syringes are not expensive to purchase, and the risk of contamination and infection is far too great.
2. As the author notes in conclusion, the potential of plastics syringes in the teaching of physics is enormous. To some people, in fact, the syringe is coming to rival the test-tube as a basic piece of scientific apparatus; few issues of *SSR* go past without some new application being reported. The next piece in this book discusses another such use.

Low pressure in a 'mini-chamber'

ALAN WARD

Wooden houses caught in the violent low-pressure vortices of tornadoes can explode, when 'normal' pressures inside them blast out windows and walls. An explosion of this sort can be shown by pumping air out of a sealed jar that contains a little corked pill-bottle of air. The climax comes when relatively high pressure inside the bottle blows out the cork like a bullet from a gun.

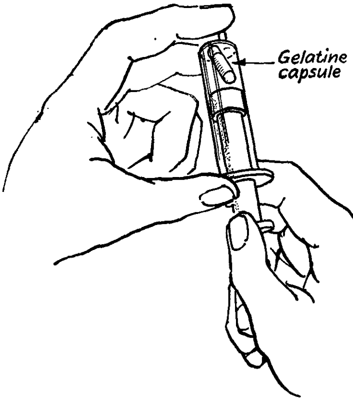
Racking our brains to find a cheap, quick and easy way to show the effect, we thought of a 10 cm^3 plastics hypodermic syringe. Surely here was the means to produce low pressure easily—even if only in a very small space. But where would we find a 'corked bottle' so tiny? The answer was a gelatine pill capsule —obtainable several for a penny, at chemists' (see the diagram).

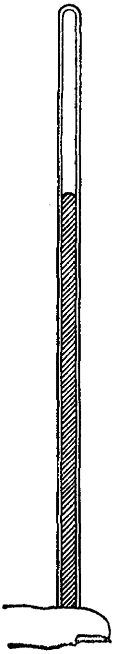
Each hollow transparent capsule is a pair of rounded 'ends' fitting snugly together. Put a capsule inside the barrel of a syringe. Push in the piston. Then, with a left hand over the nozzle (to stop air entering) use the right hand to pull the piston. Immediately pressure in the barrel is reduced—causing air in the capsule to expand forcibly and blow the ends apart.

With practice, the experiment can be done inside the space where the slide carrier should go in an Aldis projector—and so the apparatus can be magnified on a screen as an animated 'transparency'. Obviously the technique can be further adapted . . . Will warm water boil in the syringe when low pressure is achieved? Also, can the syringe be exploited as a *high*-pressure 'mini-chamber'?

NOTE

Using the larger sized plastics syringes, the same effects may be produced on the stage of an overhead projector. This is yet another example of the many scientific applications of this 'visual aid'.





Vacuum at the top

J. C. SIDDONS

Dismantling apparatus is generally rather a dull job but this need not be so with a simple mercury barometer. Put your finger across the end of the tube and lift the tube a little above the mercury in the bowl as shown. Ask the class what will happen when you remove your finger. As a general rule, junior pupils expect the mercury to fall out in an unbroken column.

What actually happens is that a drop of mercury detaches itself from the column and falls out of the tube: the remaining mercury shoots quite fiercely to the top which it hits with a loud clack. This is audible confirmation that there is nothing on top of the mercury.

A ‘squeeze pump’ from plastics bottles

ALAN WARD

With inexpensive materials to hand, this simple ‘squeeze pump’ can be assembled in fifteen minutes. It provides an interesting activity for juniors, and is a valuable starting point for general studies on pumps and valves.

Cut the bottom off a cylindrical plastics detergent bottle that has a hard top and shoulder (try the ‘Sqezy’ or ‘Fairy Liquid’ types). Invert the bottle and put in a marble A, to ‘sit’ over the neck hole (see the diagram). Telescope an identical second bottle, neck first, into the first, going about halfway. Cut away the projecting part of the second bottle.

Use a cork-borer to make a hole through both thicknesses of plastics in the top compartment, into which a short piece of plastics tubing can be inserted, forming a spout. Then put a second marble B in the top compartment, to sit over the second bottle-neck. Finally, bore a hole in the bottom of a plastics yoghurt pot, and wedge the pot, upside-down, over the top of the device, to make a neat ‘cap’ (Fig. 1).

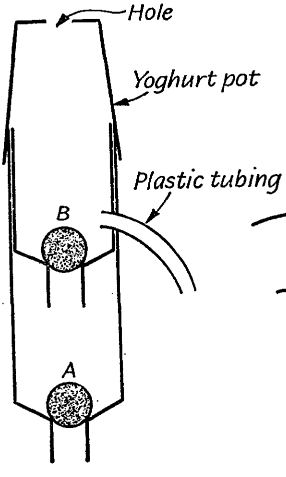


Fig. 1

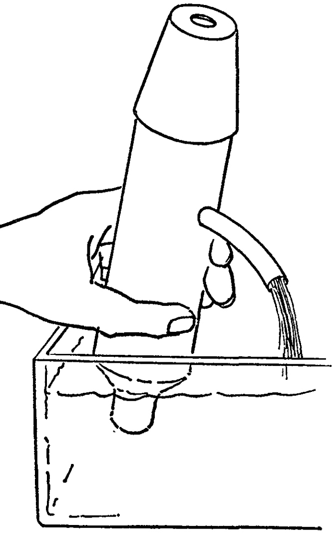


Fig. 2

Pour water down the hole in the cap, to cover marble B—so that its subsequent valve action is more effective. Dip the bottom of the pump under water, and begin squeezing and relaxing the bottom compartment (see Fig. 2). Doing this makes water enter the bottom compartment through marble valve A, and eventually forces some water up through valve B into the top compartment, where it soon reaches the spout and starts pouring out. Maintain a constant flow of water, by ‘pumping’ gently.

It is interesting to compare the squeeze pump with the action of an old-fashioned village pump, or with the two-chamber heart of a fish. There is also scope for several technical improvements. Do ball-bearings make better valves than marbles? Can a see-through model be built with transparent plastics bottles? And, if the spout and bottom of the pump are connected, via rubber tubing, is it possible to circulate water continuously—like blood being pumped around a body by a heart?

Experiments on surface tension

J. HOWARD BROWN

1. Suspend a glass plate horizontally by cotton and wax from a balance arm, and counterpoise. Raise the water in a shallow tray so that the surface touches the plate pushed down to make contact. Add weights to pull away the plate. (For ordinary gas-jar plates, this will require about 30–32 g.) Repeat with other liquids, such as alcohol.

2. Put a needle on blotting-paper or tissue paper and float this on water. The paper sinks and leaves the needle floating on the surface. (Rub the needle between the fingers first.)

3. Make a jumping frame from a broken pipette carrying a horizontal wire frame above the bulb, weighted with mercury so that it floats with the frame 1 cm or so above water. Hold the frame below the water and let go; it will not break through the surface.

4. A paraffined sieve. Lay a piece of wire gauze on a circular block so that 2.5 cm overlaps; turn down the edge and wind wire around to keep it tight. Dip into melted wax and shake the wax out of the holes. The sieve will float on water, and water can be poured into it (on paper to break the fall) without running out.

5. Float two matches on water, placing them parallel and 2.5 cm apart; touch the water between them with wire moistened with alcohol. The matches spring apart.

6. Cover the bottom of a white photographic dish with coloured water and touch the surface with a glass rod dipped in alcohol. The liquid leaves that part, making the bottom of the dish dry. Repeat with ether.

7. Repeat experiment 5, touching the water between the matches with a hot wire. They spring apart, showing the lower surface tension of hot water.

8. Sprinkle sulphur powder on water in a shallow metal dish (such as a large tin lid) and heat the edge with a Bunsen burner. The part of the water above the flame is rapidly swept clean of sulphur.

9. Repeat experiment 2, adding soap solution to the water on which the needle is floating; the needle then sinks.

10. Twist a thin wire into a flat spiral and float it on water. Drop a little soap solution into the centre of the spiral; it then begins to rotate.

11. Rub soap on one end of half a tooth-pick and float on water. It moves about over the water.

12. Fasten a small piece of camphor to the stern of a tiny wooden boat and float this on water. The surface tension of the water in front dragging the boat forward is greater than that of the camphor solution behind, so that the boat moves forward. The boat may be cut from thin aluminium foil, to which a thin circle of cork is gummed, holding a 'mast' of drawn-out glass tubing. A paper 'sail' completes the boat. The experiment is best done in a large photographic developing dish.

13. Weight a tube 3–4 cm long and 5 mm in diameter, with a cork in about the middle, to float with the open end just flush with the water. Put one drop of oil on the water as far away as possible: the model sinks when the oil reaches it. (Given in Latter: *Studies of Living Things*, to illustrate method of clearing ponds, etc., of gnat larvae.)

14. Form a soap film on a wire triangle (about 5 cm side); place a matchstalk or needle across, parallel to the base, and break the film on this side. The match is pulled towards the apex.

15. Tie a loop of fine thread across a wire ring 5 cm in diameter and dip into soap solution to form a film. Thrust a hot wire through the film inside the loop; the thread instantly becomes a circle.

16. Form a soap film across the mouth of a clean 5 cm funnel and hold the stem upright. The tendency of the film to contract lifts it against gravity.

17. Blow a bubble of about 6 cm diameter on the bowl of a pipe; on standing, it shrinks and disappears into the pipe, and also deflects a candle flame held opposite to the mouthpiece.

18. Mix nine volumes of spirits of wine (not methylated spirit, which becomes cloudy) with seven of water in a glass jar with flat sides. Introduce a very little water halfway down by means of a pipette; this makes the liquid below a little heavier. Drop olive oil from a tube into the liquid. If it sinks, add more water to the lower half; if it floats, add more spirit to the upper half. The drop is perfectly round.

19. Half-fill a jar with coloured water and fill up with paraffin to which a little carbon disulphide has been added to make it only slightly lighter than water (11 volumes to 16–17 of paraffin). Dip a wide tube into the water and raise, so that drops fall slowly through the paraffin. Carbon disulphide or zinc sulphate solution may be used in the same way.

20. The lower end—5–10 mm diameter—of a dropping funnel containing aniline dips into water at about 60 °C. (The density of aniline at 64 °C is equal to that of water.) Open the tap slightly; drops of aniline fall slowly through the water, so that their formation can be watched.

21. Clean two glass plates, about 10 cm square, with soap and hot water. Separate them at one edge by a matchstalk and hold in position by a rubber

band. When this is dipped into water, the water rises; as the distance between the plates diminishes, it rises farther, so forming a hyperbola.

22. Draw out capillary tubes with diameters of about 1, 0.7, 0.3 mm and clean carefully with sulphuric acid, followed by distilled water. Fix them vertically in a beaker of liquid. When the rise has finished, raise the tube about 1 cm so that the liquid may flow back on the wetted surface. Read the height by means of dividers and add $\frac{1}{3}r$ to correct for meniscus error; find the bore of the tube by the mercury weighing method; verify Law of Diameters (rise × diameter = constant) and calculate the surface tension of the liquid.

23. Make a rectangular frame of platinum wire, $3 \times 1\frac{1}{2}$ cm. Clean in a flame and hang vertically from a balance so that it dips in water with 3 mm about the surface. Add weights to balance. Now immerse the frame in water; it will have taken up a film of water on rising, and more weights will be required to balance. Difference = pull of film = 0.4 g (approx.); and surface tension = pull ÷ 2 length.

24. Hang a small circular copper wire ring (freed from grease with soapy water) from a balance so that it rests on the surface of water in a dish on a bridge. Add weights to pull the ring away from the surface, when surface tension = pull $\div 2\pi d$.

Note. For these experiments, the water must be perfectly clean: even contact with the fingers seriously reduces the surface tension.

NOTE

With reference to Experiments 18 and 20 above, the piece by Mr Hanson (page 34) will be of interest. The above suggestions, however, present a full summary of traditional ways of putting across the ideas of surface tension.

A direct illustration of Hooke's law

I. G. HOLT

This demonstration is intended to come at the conclusion of a series of elementary class experiments in elasticity, such as the Nuffield Year I sequence. Alternatively it might be used to introduce the topic of elasticity in a more advanced course.

Sixteen identical steel spiral springs are suspended from a common level, spaced at equal distances. A convenient arrangement (Fig. 1) is formed by two metre rulers drilled together at 6 cm intervals; large pins passing through the holes so formed hold the upper end of each spring between the rulers (Fig. 2). The 16 springs are loaded with slotted weights, from 100 g to

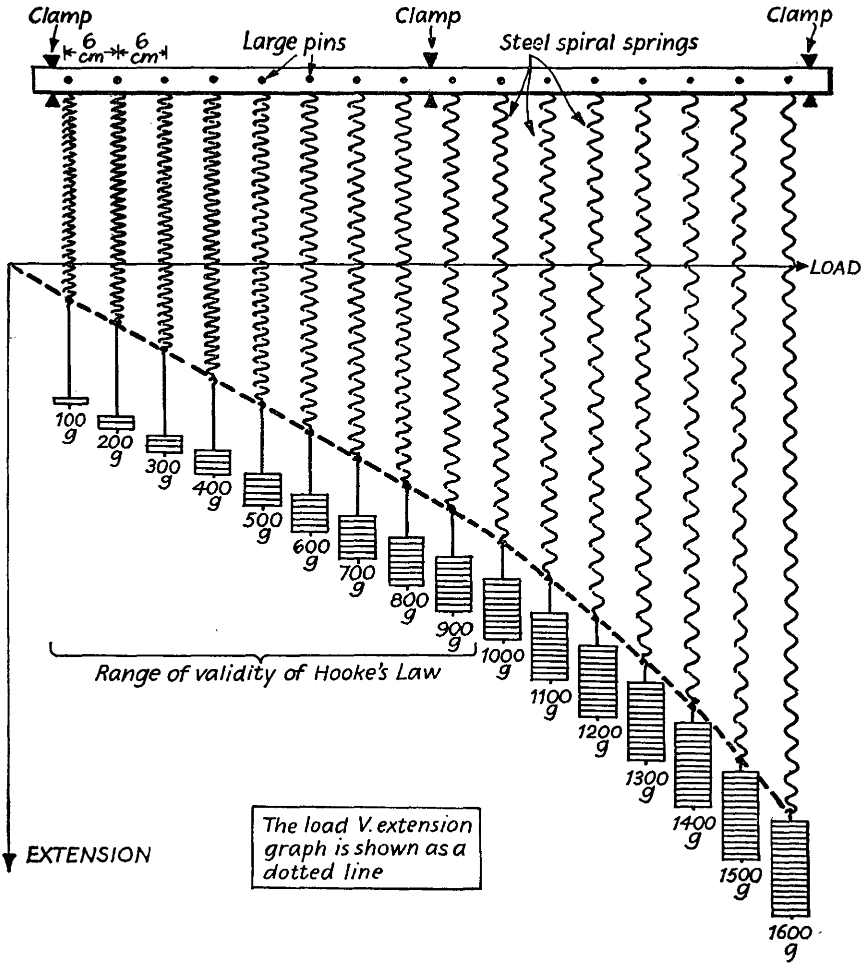


Fig. 1. Demonstration arrangement: the 'elasticity harp'

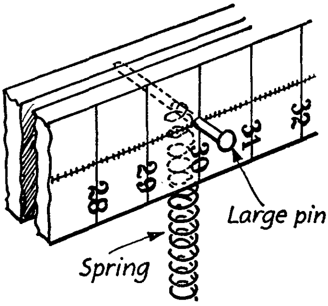


Fig. 2. Method of mounting and suspending the springs

1600 g respectively. Using Nuffield-type slotted weight sets, a wire extension to the hangers is necessary to accommodate loads in excess of 1 kg.

Points at the lower ends of the springs trace out a load *v.* extension graph directly. With springs supplied commercially the limit of proportionality usually occurs at a load of under 1 kg.

Because of the large total load involved firm clamping of the suspension is essential. Three clamps, located at each end and at the centre of the metre ruler, have been found to be satisfactory. The stands supporting them are fixed to the bench top with G-clamps, enabling the 'business end' of the demonstration to hang over the front of the demonstration bench (Fig. 3).

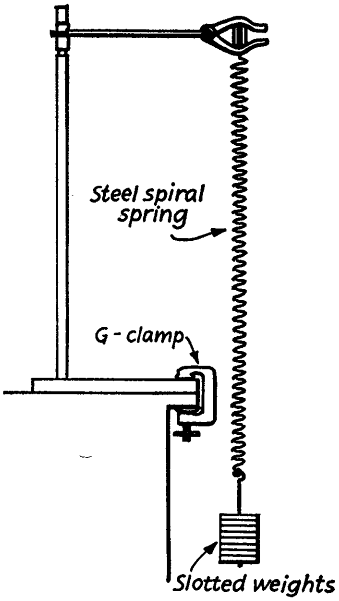


Fig. 3. Method of suspension

Provided that the springs are as nearly identical as possible, Hooke's law and some idea of its limitations emerge quite satisfactorily from this demonstration. The behaviour of the springs loaded beyond their elastic limits is not entirely predictable, partly because creep can become significant at these loadings. As in other experiments of this kind, those springs stretched beyond their elastic limits are of no further use and should be discarded.

We used Griffin and George springs (Cat. No. L24–240). They are approximately 22 cm long, 6 mm in diameter and stretch about 12 cm with a load of 250 g (2.5 N).

NOTE

If you are fortunate enough to have access to an overhead projector which can be used on its side, this experiment is extremely effective shown in this way.

Aeroplane wings: a simple laboratory demonstration

R. W. JOTHAM

The simple system shown in Fig. 1 provides a remarkable and unexpected demonstration of the manner in which an aeroplane wing provides lift. When the compressed air is turned on, the loose filter paper below the funnel does not just blow away. Instead (to the initial amazement and consternation of the writer) the filter paper leaps up to the funnel. Glass and paper are in firm contact around most of the rim of the funnel, and the air escapes in one small arc over the fluttering paper. A bubbler in the incoming air-lead shows incredulous students that it is not suction which is being deceptively applied. The relationship between the suspended filter paper and an aeroplane wing is shown in Fig. 2.

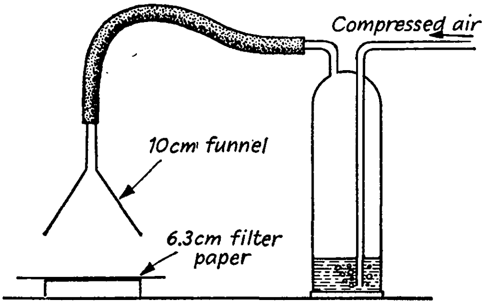


Fig. 1

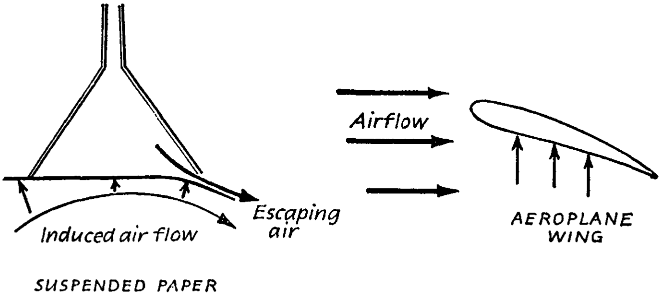


Fig. 2

NOTE

This experiment is one of the very many able to demonstrate the basic idea of Bernoulli's Principle—which states effectively that the pressure in a fluid decreases as its speed increases. Although the concepts involved in this work are not simple, the experiments are (like this one) always intriguing, and the significance is enormous.

Electromagnetics

Introduction

As has long been the case, this particular field is probably the widest in physics, covering as it does concepts ranging from electrostatics through circuitry to electronics, and magnetics through electromagnetism to induction. All of these subfields are represented here with the exception of work on electronics. This does not as yet receive much attention at Middle School level (although doubtless it will continue the steady progress of the last few years down the educational ladder).

The bulk of this bulky section consists of two detailed accounts of introductory teaching schemes, one covering electric charge and the other magnetics. Both, of course, are fields which are essential to the proper development of ideas in this area as a whole; both are also, sadly, ones in which there are many misconceptions in the minds of teachers. Doubtless these accounts are not perfect either, but each should go a long way towards straightening out basic understanding. As usual, there is also a number of notes of more specific bits of work of varying length and complexity. Proper teaching of electromagnetics is of vital importance—and great interest—so it is hoped that this section will be of particular value to the Middle School teacher.

Some simple experiments in electricity

J. C. SIDDONS

ELECTROSTATICS

1. *Moving heavy bodies*

Every child knows that bits of tissue paper can be lifted by electrified rods. Much heavier bodies can, however, be moved electrostatically. Start with a half-metre stick which is a big jump from tissue paper. Rest it on a glass slide which in its turn rests on an upturned watch-glass. Bring a charged ebonite rod alongside the stick (Fig. 1). The stick should begin to turn: once it has started turning its motion can be stopped and then reversed by changing the position of the rod. After succeeding with a half-metre stick, try a metre one.

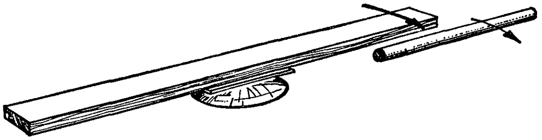


Fig. 1

Then try such an object as a window pole (weighing about 1 kg). In this case cut-out corks or Plasticine will be required to prevent rolling.

After or even before the teacher has shown this experiment he should let a member of the class try it. Generally children do not do this well; they do not hold the ebonite rod parallel to the stick or pole.

2. *Two kinds of electricity*

Cut two strips of polyethylene sheet, about 25 cm by 2 cm. Suspend them from a clamp, using two small pieces of wood to facilitate the hanging. Rub the strips quickly with your fingers. If you have a dry skin the strips will be strongly charged and repel each other (Fig. 2). Charged polyethylene repels charged polyethylene.

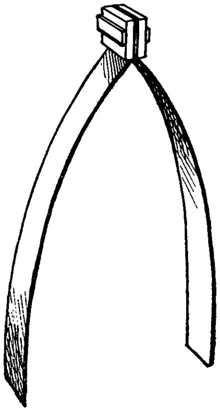


Fig. 2. Charged polyethylene

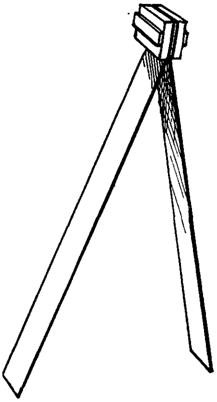


Fig. 3. Charged Ethulon or acetate

Some stationers sell a sheet material called 'Ethulon', used by draughtsmen. Cut two strips of Ethulon of the same size as the polyethylene. (In place of Ethulon, acetate sheet can be used.) Charge the Ethulon with your fingers. The strips repel each other but as the Ethulon is stiffer than the polyethylene there is a slight difference in appearance between repelling polyethylene and Ethulon (Fig. 3). Just as charged polyethylene repels charged polyethylene, charged Ethulon repels charged Ethulon.

The next question to settle is obvious. What does charged polyethylene do to charged Ethulon? Slowly bring the two lots of strips together. As they approach the neighbouring strips will begin to stretch towards each other until suddenly and decisively they catch hold of each other (Fig. 4). Charged Ethulon and polyethylene attract each other so the charges on the two substances must be different.

Separate the two pairs of strips. Bring to each pair in turn as many charged substances as you can think of. Those which repel Ethulon will attract

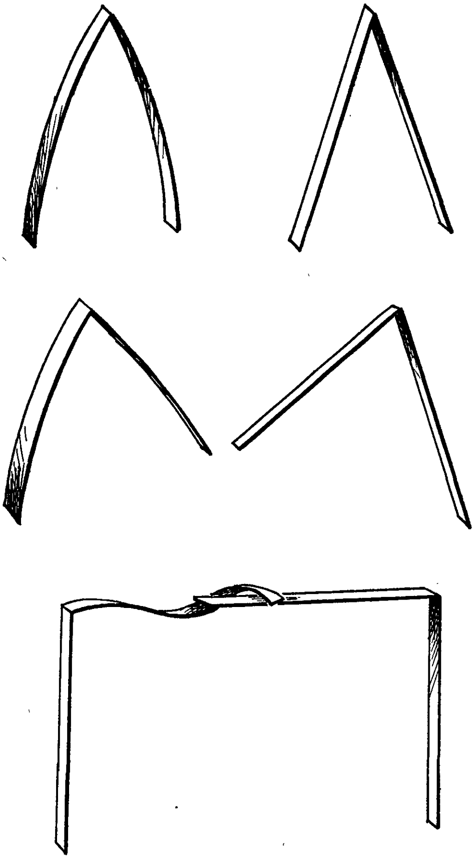


Fig. 4

polyethylene and those which attract Ethulon will repel polyethylene. Thus, we can divide charged bodies into two classes. Bodies in the polyethylene class (like polyethylene) will repel polyethylene and similarly for the other class. (There are plenty of members for the first class, which is the 'negative' class, but not so many convenient members for the second.) So far the experiment has shown that there are two kinds of electrical charge, but it has not suggested any connection between them. Repeat the experiment with the two lots of strips. When the two inner strips catch hold of each other notice what happens to the two outer strips—they no longer stick out to the side, but hang down limply (Fig. 4). The two outer strips are no longer repelled and so the charge on the inner Ethulon cancels out the effect of the charge on the inner polyethylene. But positive quantities cancel out negative quantities, if taken in equal amounts. The experiment, therefore, suggests that the two kinds of charge are to each other as positive is to negative.

3. *Flames and electricity*

Charge two polyethylene strips so that they repel each other. Bring a burning match near them. They collapse like a pricked balloon. The flame has made the air no longer a good insulator. The charges on the strips have leaked away. A simple explanation can be offered. In the flame the particles of the gases are moving very quickly, so quickly that in their mutual collisions the outermost electrons are knocked off. These electrons are for a short time free and render the air conductive.

4. *Discharging polyethylene*

As we have seen, if two strips of polyethylene are rubbed quickly they become charged and repel. Slowly rub charged strips with your fingers—the strips lose their charges and no longer repel. Mr G. Lodge of the Irish Science Teachers Association pointed this out to me and put me this conundrum: if rubbing briskly charges uncharged polyethylene and if rubbing slowly discharges charged polyethylene, what will happen if the rubbing takes place at an intermediate speed?

5. *The electrophorus*

Traditionally the electrophorus uses a brass plate and an ebonite disc but there is some advantage in having an aluminium plate and a disc of foam polystyrene. I obtained an aluminium plate 30 cm in diameter and of 16-gauge thickness. At its centre on one side I stuck a cork using 'Bostik' and into this cork pushed an ebonite rod. (A small electrophorus can be made simply from a tin lid on to one side of which is fastened an ebonite rod by Plasticine.)

(*a*) *Gold-leaf in space.* Charge the electrophorus and hold it face upwards. Drop on to it a piece of gold-leaf or Dutch metal. The leaf will immediately spring off like a cat falling on to hot bricks. It hovers in the air above the plate. By skilful manœuvring it can be kept in the air for a long time or piloted along any desired course. This particular space-traveller can be brought back to earth (i.e. the electrophorus plate) at any moment by touching and so discharging the plate.

(*b*) *Lighting a Bunsen burner.* A large electrophorus plate is required here; the experiment should work every time with a 30 cm plate and most times with a 20 cm plate, but I have never succeeded with smaller ones. Charge the polystyrene or ebonite disc briskly and then the electrophorus plate. Bring the latter near the top of the burner as shown (Fig. 5) turning the gas on at the same time, with the air hole fully open. The spark between the electrophorus and burner tube will ignite the gas, showing that there is heat in the spark. An explanation can now be made of the noise of the spark.

(*c*) *A detectable current.* The charge on a 30 cm plate is of the order of $\frac{1}{2}$ microcoulomb. This is sufficiently large to show up on a sensitive ballistic galvanometer (e.g. the Scalamp galvanometer 7901/S). The galvanometer, of course, is an electromagnetic device and so from the charge on the electrophorus we have obtained electromagnetic effects. This experiment is a useful bridge between electrostatics, current electricity and electromagnetism.

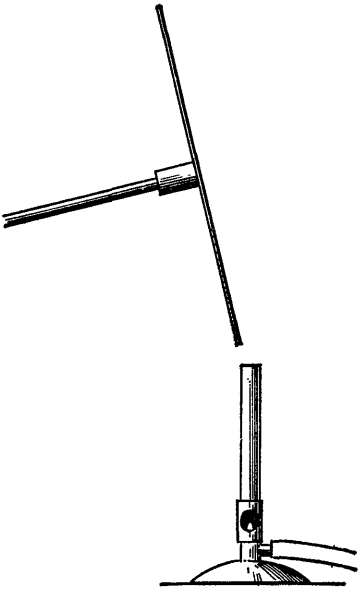


Fig. 5

(*d*) *Lines of force.* Hole the ebonite rod in a suitable clamp so that the electrophorus faces upwards. Fasten at its centre a 15 cm length of cotton. Charge the plate with the expanded polystyrene—it is more convenient to do this by moving the polystyrene and keeping the plate fixed. When the polystyrene is removed the cotton will stand up as shown (Fig. 6) along the line of force. Bring your finger near the top of the cotton. It will seek out for your finger in a pleasing fashion. Fastened near the edge, the thread droops down (Fig. 7). If five lengths of cotton are used and the charged polystyrene is held above, the cottons will—eventually—all point upwards, showing the lines of force between the two parallel plates (Fig. 8). The behaviour of the threads is quite amusing—three or four of them will do what is expected of them straight away, but the last one or two can be very obstinate and do many things except stand up. It reminds one of the lion tamer in the circus who can get four of his lions on to their perches, but not the fifth.

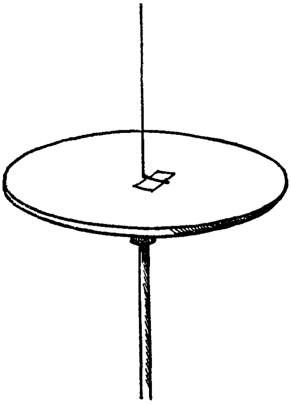


Fig. 6

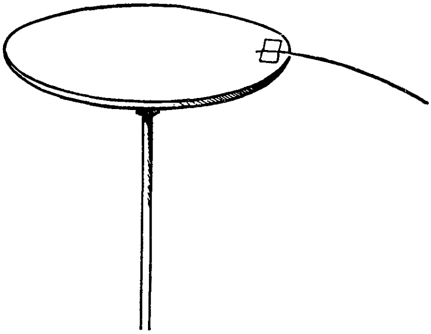


Fig. 7

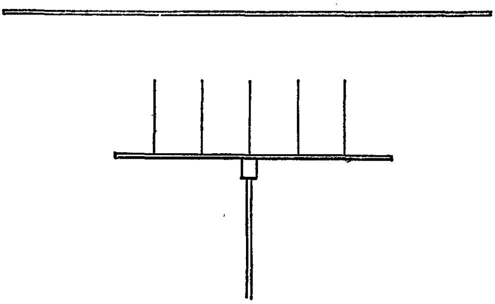


Fig. 8

(*e*) *Charging by flicking.* It is not only ebonite rods that become charged by friction—metals flicked with such things as nylon also become charged. Normally the charge flows straight away to earth but if the metal is held by an insulating rod (as the electrophorus plate is) it can be given by quick flicks a charge which stays. The size of this charge can be measured with the ballistic galvanometer; it is only about one-fifth of the charge it gets from the usual electrophorus procedure.

Uses for the overhead projector in the teaching of electrostatics

P.C.F. PORTER

The overhead projector can be extremely valuable in the teaching of electrostatics and especially in the lower school for showing separation of charges within conductors.

MATERIALS

1.5 mm thick card (black one side and white on the other if available).
18 s.w.g. copper enamel wire.
A small piece of red colour filter.

CONSTRUCTION

The outline of a conductor may be formed by bending the wire as shown in Fig. 1. A piece of card cut into a 'T' shape is taped to this to provide an 'insulated' base. This is placed directly on to the overhead projector, and when projected it gives a section through a conductor as required. Also an electroscope (Fig. 2) can be constructed in wire, the leaf hooked on to the bottom as shown so that it may be moved up and down. The leaf must be wide enough to take the 'charges'.

The 'charges' are made using a 1.25 cm diameter cork-borer to cut out discs

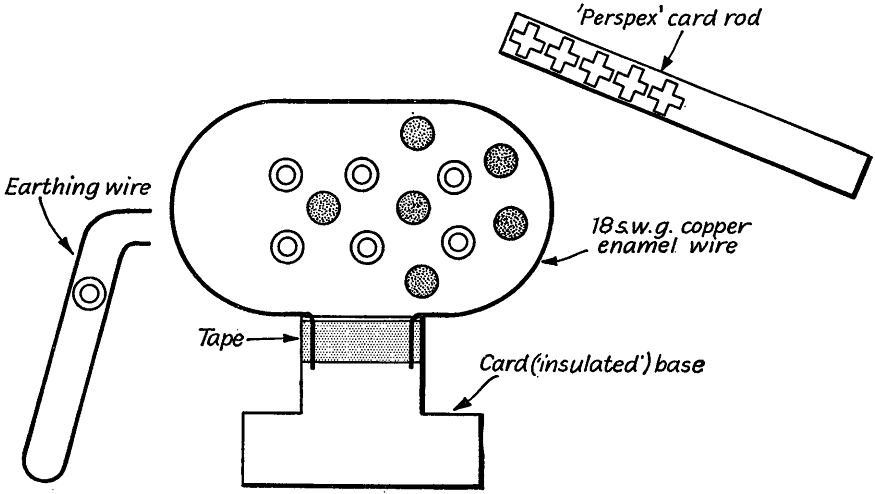


Fig. 1

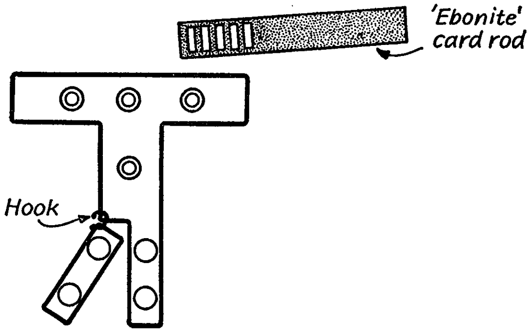


Fig. 2

of card. Negative 'charges' are represented by a solid disc, which shows up black on the screen. Positive 'charges' are made by first marking a circle with the 1.25 cm cork-borer on the card; then a 6 mm diameter cork-borer is used to make a hole in the centre. Finally the ring of card is cut out with the larger borer. To make these positive 'charges' show up as red spots on the screen they are covered with a disc of red plastics (Fig. 3). Filter discs can be cut quite easily with a cork-borer, and cemented to the card ring with plastics cement.

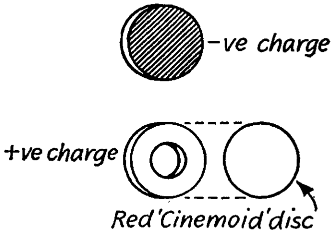


Fig. 3

The diagrams show charged 'Perspex' or ebonite rods, which are made by cutting out plus and minus signs in a strip of card.

SUGGESTED USE

We start by having equal numbers of positive and negative charges within the conductor. If we bring up a charged rod three things can happen: (1) the positive charges move, (2) the negative charges move, (3) both move. 'Johnny, come out and show us what will happen—the remainder of the class tell me if he is right . . .'—and so on.

For charging by induction an earthing wire may be used, as shown in Fig. 1, down which charges can slide out of sight.

COMMENTS

1. Conductors could be made by drawing on an acetate sheet, but a wire boundary prevents the charges from moving through the sides of the conductor.
2. Many other conductors can be made; circuits can even be devised to demonstrate the flow of current.

NOTE

Already in this book we have seen a number of examples of situations in which the overhead projector can be used as a sort of demonstration table for experimental work. This piece illustrates its use for animated translucent models. There is a great deal of scope for work of this nature in the teaching of the sciences; such applications really make the overhead projector invaluable.

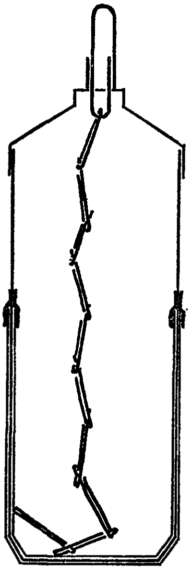
A simple Leyden jar

ALAN WARD

A serviceable Leyden jar can be made in about 15 minutes for a cost of a few pence.

Cut the top off a plastics detergent bottle, from which the little cap has been removed and discarded; then, thoroughly wash and dry it.

Line the bottle's lower half and bottom with kitchen aluminium foil; also use foil to line the lower half and bottom of the bottle's outside; fix the foil in position with 'Sellotape'. Replace the cut-off part to form a lid and, finally, dangle a long chain of small paper clips down inside the bottle, to touch the foil on the interior bottom. Attach the top of the chain to a large paper clip, which must be fastened to the rim of the bottle-neck.



Stand the completed jar on the floor and charge it with 'static' electricity. A Wimshurst machine may not be necessary, as remarkably big charges can be generated using a coarse woollen scarf to rub a plastics document tube (in which rolled pictures are sent through the post). The tube acquires a strong negative charge.

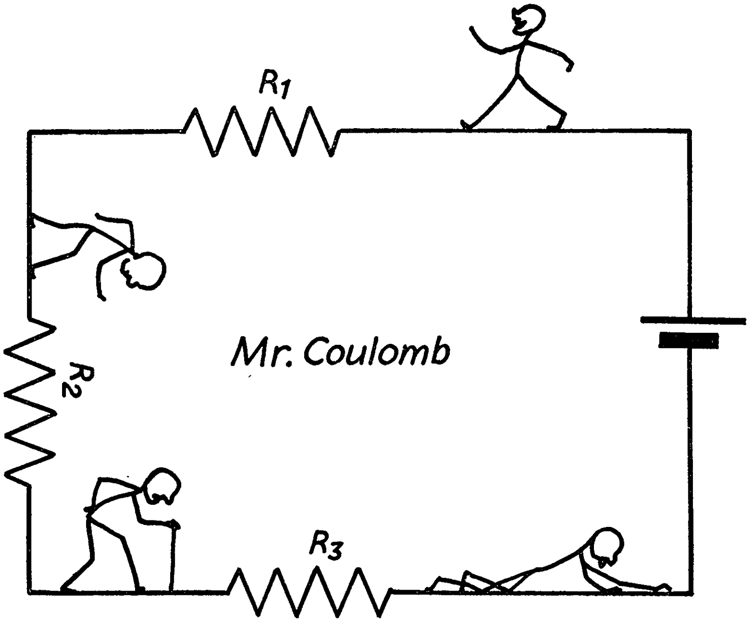
Keep rubbing and then discharging the tube by holding it just above the clip on top of the jar.

A dozen repetitions should be enough to give a sufficiently painful electric shock, when the jar is held by its outside foil lining in one hand, while a finger of the other hand barely touches the metal clip. Several people linking hands will all receive a shock together. The apparatus can be used for many more enlightening experiments.

Mr Coulomb

W. C. HALL

Young children often experience difficulty in understanding that 'electricity' (electric charge) is not used up in an electrical circuit. This diagram helps them, in an amusing way, to understand what really does take place.



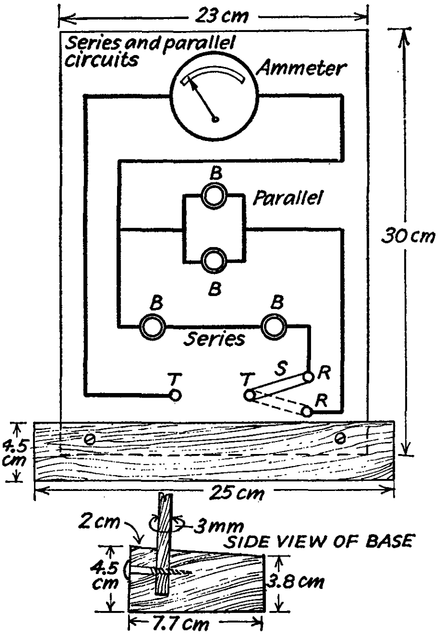
Resistances in series and parallel

G.I. JONES and J. POWELL

The apparatus consists of a sheet of 'Perspex' wired as shown and screwed to a wooden block.

By means of a movable brass strip S connected to one of the terminals T, series or parallel connections to the pea-bulbs in bulb-holders B can be made. Changes in current and lighting can clearly be seen when a bulb or bulbs are removed, illustrating say Christmas-tree 'fairy' lights (series circuit) and household lighting (parallel circuit).

In the actual model all the wiring was at the front and was anchored into position by thin wire tied round it through pairs of holes at intervals. The brass strip S made contact on two roundhead screws R.



A simple voltameter for class use

M. J. LONG

For some time, I have felt a need for a simple, robust voltameter which would enable pupils to perform some simple introductory experiments on electrolysis for themselves.

The present design is for a free-standing and compact voltameter costing only a few pence. The electrical connections to the electrodes, which are always a potential source of trouble, are completely enclosed and so are much less likely to come adrift; at the same time, they are clearly visible. Using three 'Nife' cells in series, it was found that a number of experiments could be carried out reasonably quickly.

CONSTRUCTION

The main vessel (Fig. 1) is a cheap, transparent but fairly strong plastics beaker of about 200 cm^3 capacity. The electrodes are carbon rods from old dry cells and were supplied by pupils. Where these carbon rods still had their brass caps, we soldered the connecting wires directly on to these. In other cases, the rods were drilled with holes into which were screwed copper screws to which the soldered connections were made. One of each type is shown in the diagram. Each type was found to be equally effective. Ordinary nuts and bolts were used as terminals; proper terminals could be fitted at extra cost. After fitting, the ends of the bolts were cut off with pliers and held to a grindstone for a few moments. By thus destroying the thread at the end of the bolt, the terminal nuts were rendered 'captive'. Sixteen of these voltameters were easily constructed by half a dozen upper fifth boys in the course of an afternoon.

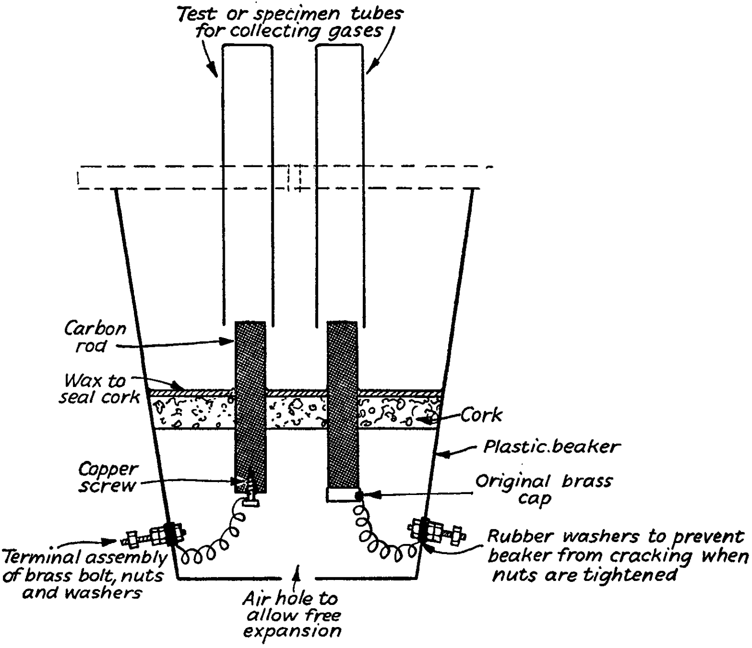


Fig. 1. Voltameter

USE

The use of the apparatus for studying electrolysis of aqueous solutions using inert electrodes is obvious. The only experiment which I do at this stage and which does not fall into this category is the electrolysis of cupric sulphate solution using copper electrodes. This was done by first 'electrolysing' the cupric sulphate solution with carbon electrodes. Then the electrical connections to the battery were reversed, thus making the copper-plated electrode the anode. The removal of copper from this was obvious and striking.

Initially, it was found that oxygen and chlorine did not evolve from the

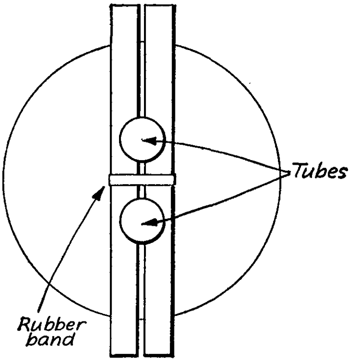


Fig. 2. Plan view of simple wooden tube holder

carbon anode in the correct proportions. After a little use, however, this effect wore off—no doubt as the adsorbing surface of the carbon became saturated.

Gases are collected in small test- or specimen tubes either held in the hand or supported by a simple wooden device such as that illustrated in Fig. 2.

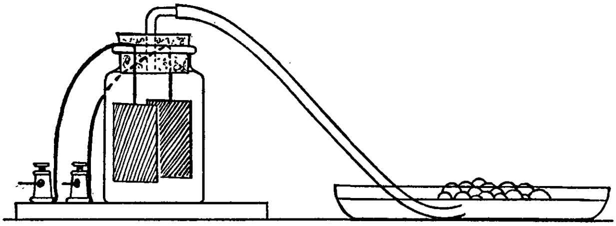
NOTE

Here is a situation in which the use of the ubiquitous yoghurt carton is invaluable—one of many such cases.

Electrolysis

J. C. SIDDONS

If a froth is blown, not with air but with the electrolytic mixture of hydrogen and oxygen, then when a flame is applied it makes a bang which is much larger than what one would expect from mere froth. A weighing bottle of capacity 18 cm^3 makes a suitable voltameter. A bigger voltameter is quite unnecessary. The two electrodes are of platinum, 2 × 1$\frac{1}{2}$ cm, and are held by platinum wire. The electrolyte is bench sulphuric acid. As a safety



precaution, the bottle should be filled up to the bung with liquid so that there is no room for gas to accumulate. Care must be taken to ensure that the two electrodes are not free to move—the rubber bung must hold them firmly. A d.c. voltage of 6 is sufficient—with a higher value the platinum wire will get too hot. The electrolytic gas is taken along the rubber tube into an evaporating basin containing water with a drop of detergent. When sufficient froth has been blown, the current is stopped, the basin taken well away from the voltameter and then a match is applied.

A pleasing variation of this experiment—mentioned to me by Rev. Dr M. T. Casey of Maynooth—is to dispense with the evaporating basin, and use the palm of your hand instead. Sufficient water can be held to get a good froth —it takes a little courage to apply the match for the first time. A great bang is heard, but nothing is felt. A bang in the hand is worth two in the basin.

First lessons in magnetism

L. J. ROWSE

Nature's method of teaching is divided between imitation and individual experience. The former might be regarded as making use of the experience of others and the latter as making discovery first-hand. It is by this second method of learning that human progress has been made over the centuries, but attempts to use it as a major teaching method in schools have generally proved too slow and time-consuming. Nevertheless there are occasions on which the heuristic method can usefully and economically be applied in school and it is the purpose of these notes to show that one of these is in the introductory lessons to magnetism.

The pupil first conducts a series of simple experiments in order, thus providing a personal experience on which the lesson and discussion which follows is based. Experience shows that if the teacher has made adequate preparation of apparatus and of typed sheets of instructions, a fair class will complete and make brief record of the results of such a practical lesson as the following in a double period of 80 minutes. The demonstration experiments are best set up in working condition for the single-period lesson and discussion which follows within a few days of the pupils' practical work.

THE TEACHER'S PREPARATION

Prepare sufficient 10 cm lengths of 26 s.w.g. 'dead hard' steel piano wire to supply four or five to each pupil. These are made by running along a stretched length of wire with a Bunsen burner to straighten it by making it just red-hot; when cold it is cut into 10 cm lengths.

Close one end of a 15 cm length of steel conduit with an iron plug. It is convenient if a handle made of 6 mm iron wire 45 cm long is welded near the open end of the conduit (Fig. 1).

Loosely pack the conduit tube with the 10 cm lengths of wire and raise them to a bright red heat. Pour the red-hot wires from the conduit tube directly into a bucket of cold water; the dried wires are then ready for use. It has been found better to prepare fresh wires each year as stored wires tend to pick up some magnetism. Some may find it sufficiently effective to wipe away any stray magnetism in stored wires by slowly withdrawing them from an a.c. coil.

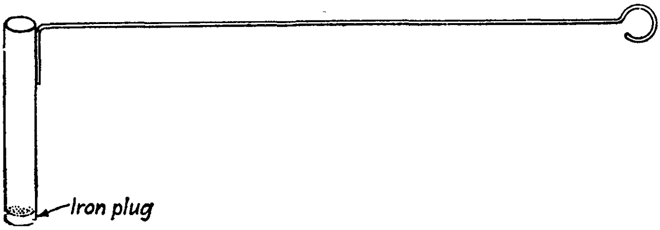


Fig. 1

Each pupil will require

1. four 10 cm lengths of 'dead hard' steel wire;
2. three 10 cm lengths of florists' soft iron wire;
3. about six cork discs from 'pop' bottle caps;
4. a pinch of iron filings on a sheet of paper;
5. a corked 5 cm test-tube of iron filings;
6. a large watch-glass to hold water for the floating compass;
7. a beaker for the 'ships' experiment (Expt 16);
8. a small pivoted compass needle (as used for mapping fields);
9. a straight unmarked Alnico (or similar) magnet, to be given out *after* the second experiment has been completed;
10. a typed sheet of instructions on the following lines.

MAGNETS

A. *Practical Lesson 1*

These experiments should be performed in the order given.

Make brief notes of results under numbers corresponding to those of the experiments.

Note: The hard steel wire supplied is very brittle and easily broken but the soft iron wire is very easily bent—keep it straight.

Testing for magnetism

Expt 1. Test a soft iron wire and a hard steel wire for magnetism separately by seeing if either will pick up any of the iron filings.

Expt 2. Test each of the two wires in turn to see if either affects the plotting-compass needle.

Magnetic induction and residual magnetism

Expt 3. Stick one end of a soft iron wire across one end of the steel magnet with which you have just been provided. While still held together by magnetic attraction, test the other end of the wire for magnetism by dipping it into the iron filings.

Expt 4. Carefully detach the magnet from the wire to see whether the wire remains fully magnetized. Using finger and thumb, wipe the filings from the wire and then drop the wire on to the floor from a height of about a metre. After picking it up again test it for magnetism with filings. Is it still as strongly magnetized?

Expt 5. Repeat Experiment 3 using one of the hard steel wires.

Expt 6. Repeat Experiment 4 using the steel wire from Experiment 5.

Magnetic poles

Expt 7. Break a 2.5 cm length from an unused steel wire and draw one end of the steel magnet along it once only and in one direction from end to end. Test the wire for magnetism with filings. Are filings attracted equally along its whole length? The areas of strongest attraction are called the poles.

The magnetic compass

Expt 8. Place the wire magnet prepared in Experiment 7 along the diameter of a cork disc floating on water in a watch-glass so that it can freely rotate. After removing all magnets and iron to some distance away, try turning the floating wire magnet and see if it will remain pointing in any other direction. Fix a tiny paper arrow-head (with gum or shellac) to the end of the wire magnet which tends to point North. This is called the 'North-seeking pole' of the magnet (or the N-pole for short). Roughly to find the direction of North consider the movements of the Sun. The other pole of the magnet is called the 'South-seeking pole' (or S-pole for short).

The law of magnetic attraction and repulsion

Expt 9. Prepare a second arrow-headed wire magnet, as in Experiment 8, and, holding it in the hand, bring one of its poles near one of the poles of the floating magnet to discover whether similar poles attract or repel one another. Write down a simple rule about this.

The law of magnetization

Expt 10. Using the rule discovered in Experiment 9, stick a paper arrow-head on the N-pole of the original steel magnet. Take a piece of unused hard steel wire and chalk one end of it. Starting with the chalked end of the wire in contact with the N-pole of the magnet draw the wire once only across the pole of the magnet. Test the polarity of the wire magnet just made. Is the chalked end a N-pole or a S-pole? Using the same wire try to remagnetize by drawing it across the S-pole of the magnet starting again at the chalked end. Can you write down a simple rule summarizing your results?

Breaking magnets

Expt 11. Take a piece of magnetized steel wire with a paper arrow-head on its N-pole. Break the wire in half and see if you can get an isolated pole. Test both ends of each portion and make notes of the results, particularly of the sort of magnetism found on each side of the break.

Expt 12. Break 3 mm or less from a piece of the wire magnet used in Experiment 11 and test it with iron filings if it is too short to test with the floating compass. What result might be expected if you could test a single grain of a powdered magnet?

Expt 13. Try magnetizing the tube of steel filings by stroking it once from end to end with a pole of the bar magnet. Taking care not to shake it, test the tube of filings for magnetism (*a*) with filings, (*b*) by presenting one end of the tube first to the N-pole and then to the S-pole of the floating magnet, and (*c*) by floating it on a cork shive.

Expt 14. Shake the magnetized tube of filings used in Experiment 13 and test for magnetism again. Look again at the result of dropping the wire magnet on the floor in Experiment 4. Can you combine this with the results of Experiments 9 and 12 and suggest what may have happened?

These fourteen should be regarded as the basic experiments. The following ones might usefully be added.

Expt 15. Hang three 10 cm lengths of florists' wire by their tips from one pole of the bar magnet and explain the manner in which they hang. Note how filings arrange themselves when clinging to the pole of a magnet.

Expt 16. Using discs of cork as ships with 2.5 cm lengths of magnetized steel wire as masts (not all magnetized in the same direction) float half a dozen such vessels together. The problem is to separate them into two groups each containing similar vessels.

Expt 17. Will magnetism act through water? Try Experiment 16 after inverting each vessel.

Expt 18. Will magnetism act through wood, glass, brass, iron, aluminium or other material? Place a small iron panel pin on a sheet of the material to be tested and see if the pin will follow the movement of a strong magnet on the other side of the sheet.

Note: An experiment to discover whether magnetism will act through a vacuum is not easy at this stage but a very satisfactory one is given in the fourth practical lesson.

Expt 19. Bring the N-pole of the bar magnet very near to the N-pole of a piece of magnetized steel wire and they are attracted. Consider the results of Experiment 5 and see if you can explain what has happened.

Consequent poles

Expt 20. Take a fresh length of hard steel wire and see if it is possible to produce a N-pole at the centre of the wire and a S-pole at each end by stroking with the pole of the bar magnet from the centre of the wire to each end in turn according to the rule discovered in Experiment 10. Test for polarity with the floating compass and for pole positions with iron filings.

The effect of heat on magnets

Expt 21. Take a piece of magnetized steel wire, heat it to redness and when cold, test it for magnetism.

B. *Lesson 1. Theory and discussion*

This single-period lesson is taken a day or so after the foregoing double-period practical work. On the teacher's bench there are set up the three following demonstration experiments.

A magnetic motor

Dem. 1. A disc of iron wire gauze, about 10 cm in diameter, is mounted so that it is free to rotate on a steel point by pushing a laundry metal collar-stud through the centre. A Bunsen burner and a strong magnet are arranged as shown in Fig. 2.

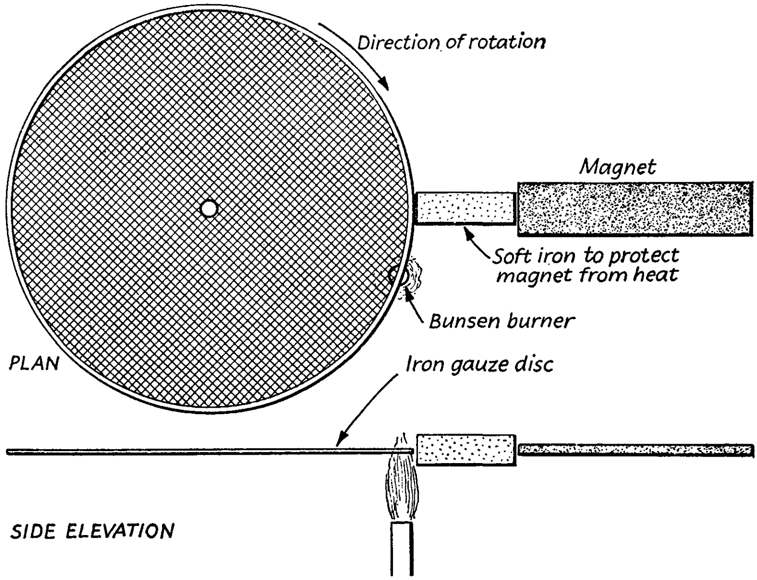


Fig. 2. A magnetic motor

A magnetic pendulum

Dem. 2. Tins are made of thin mild steel sheet covered with a thin coating of tin. A disc of 'tin', about the size of a 10p piece and having a long thin nose, acts as the bob of a pendulum about 45 cm long, Fig. 3. The pendulum is drawn to one side by the head of a 10 cm nail the other end of which is magnetically attached to a strong magnet as shown. A lighted Bunsen burner is arranged so that the nose of the bob is quickly raised to a red heat and thus rendered non-magnetic so that the bob falls away from the magnetized nail. By the time it again approaches the nail on its return swing the nose of the bob has cooled enough to be attracted again and will again attach itself to the magnetized nail head. Careful adjustment will make the action continuous.

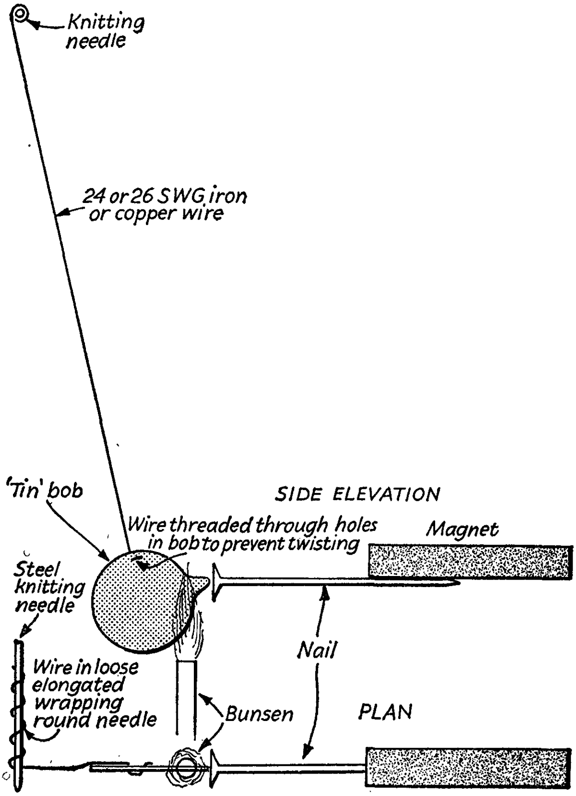


Fig. 3. A magnetic pendulum

Dem. 3. Thread a steel washer tightly on to a wooden rod which is held in the chuck of a hand-drill so that the washer can be rotated. Rotate the washer while one side of the hole only is in contact with a pole of the bar magnet. Gradually remove the magnet right away from the still rotating washer. It is possible that the washer will now exhibit no magnetism until it is cut through from the outside to the central hole.

At the appropriate point in the lesson the members of the class are invited to explain these demonstrations and to answer such questions as: (*a*) How could the speed of the magnetic motor be increased?, and (*b*) What is the purpose of the nail in the magnetic pendulum?

THE SUBSTANCE OF THE LESSON ON MAGNETS

Magnetic iron ore is found in many parts of the world as a heavy, hard and dark mineral. This stone excited wonder in early times because, when freely suspended, a sample always points in one direction like a compass needle. For this reason it was named lodestone (meaning leading stone). Lodestone was found by the Greeks in the province of Magnesia in Asia Minor, and from this the word 'magnet' is derived. Lodestones attract objects of iron as magnets do.

The Chinese claim that they used lodestones to guide travellers across the desert of Tartary over 2000 years ago, but it was not until the days of Queen Elizabeth I that the first scientific account of magnetism was written. Dr William Gilbert (1540–1603) was born at Colchester. After many years of patient experiment he published his famous book *De Magnete* in 1600, and in it he described in detail his experimental work on magnetism. In later years this work earned him the title 'the father of magnetism'.

Our experiments and observation have taught us the following important facts about magnets.

1. Magnetic poles are of two kinds, North-seeking poles and South-seeking poles.
2. Like poles repel each other; unlike poles attract.
3. The poles of a magnet are of equal strength or our floating compass would have sailed off towards the North or the South.
4. It is not possible to isolate a pole; breaking a magnet makes two complete magnets.
5. When making a magnet by stroking, the polarity of the new magnet where the stroking begins will be the same as that of the pole stroking it.
6. Soft iron is easily magnetized and equally easily demagnetized.
7. Hard steel is more difficult to magnetize but it tends to retain its magnetism.
8. Heating or rough treatment tends to destroy magnetism.
9. At about 800 °C iron ceases to be a magnetic substance until it cools.
10. Only substances capable of being magnetized are attracted by magnets.
11. Common magnetic substances are—iron and steel, black iron oxide (Fe_3O_4), nickel, cobalt.

HOW CAN MAGNETISM BE EXPLAINED?

A theory which agrees well with the known facts was put forward by a German scientist, Weber (1795–1878).[1] If we break a magnet new poles appear at the break so that we have two complete magnets. Weber imagined this process to be carried on until the whole magnet had been reduced to single molecules of iron and he supposed that each molecule was, by its very nature, a magnet. In ordinary iron the N-pole of a molecule would attract and stick to the S-pole of a neighbouring molecule so that groups of molecules would form rings and leave no unattached poles. The iron would then exhibit no magnetism.

The act of magnetizing the iron consists of breaking these rings so that the molecules are arranged head-to-tail in lines, thus leaving free and unattached poles at either end of the lines. These unattached molecular poles collectively form the pole of the magnet and exhibit the magnetic properties. If the combing-out action is incomplete a weaker magnet results because there are fewer free molecular poles. If all the molecules are straightened out into lines the magnet would be as strong as it is possible to make it. This conclusion agrees with the known facts; beyond a certain limit it is impossible to increase the strength of a magnet and the material is said to be magnetically saturated.

In soft iron the molecules turn easily but equally easily turn back to re-form rings, i.e. soft iron is easily magnetized and easily demagnetized. In hard steel the molecules are not easily turned; it is difficult to magnetize but tends to retain its magnetism. Soft iron under the influence of a magnetizing force tends to become magnetized only so long as the magnetizing force persists; when the force is removed the rings re-form and the magnetism is lost. Magnetization produced by a magnetizing force is said to be *induced* magnetism. When a piece of unmagnetized iron is brought near to a magnet the iron becomes a magnet by induction and the iron will be attracted to the magnet because the unlike induced pole will be nearer to the inducing pole than the like induced pole. We might say that induction precedes attraction. This explains why iron is attracted by either pole of a magnet and why substances not capable of being magnetized are not attracted. It is now clear why Experiment 2 is not a sound test for magnetism.

Magnetism firmly retained after the removal of the magnetizing influence, e.g. by steel in particular, is called permanent magnetism. If the N-pole of a strong permanent magnet approaches the N-pole of a weak permanent magnet the two repel each other, but if the two are brought very near to each

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[1] *Author's note.* It is appreciated that, in fact, magnetism has little to do with molecules as such; modern theories are more concerned with atoms, electrons, ions and groups of particles called domains. In these elementary notes Weber's molecular theory is conveniently used as a parallel, a parallel which fails to account for the profound differences between the ferro- and paramagnetic substances met with in advanced studies.

other the stronger magnet will induce magnetism in the weaker which is stronger than its permanent magnetism and they will therefore be mutually attracted.

Normally a magnet is always trying to demagnetize itself, particularly at the poles. To avoid this demagnetizing action when magnets are not in use they are stored in pairs so that opposite poles are magnetically connected by soft iron *keepers* which, by completing the magnetic circuit, avoid unsatisfied free poles. It is possible so to magnetize a steel washer that the magnetic circuit is complete and no magnetism will be apparent until the circuit is broken by cutting the washer through from the outside to the central hole.

Today alloys are made which have far greater retentivity than the hardest steel. One such alloy contains aluminium, nickel and cobalt and is therefore known as 'Alnico'. Whenever powerful permanent magnets are required today, such alloys are always used.

Practical Lesson 2. Lines of force and magnetic fields

Patterns obtained in the following experiments may be preserved by using paper soaked in paraffin wax. To fix a pattern melt the wax by passing a Bunsen flame rapidly over the sheet.

Each pupil will require

1. a pepper pot of iron filings;
2. two straight bar magnets each about 7.5 cm long;
3. two soft iron keepers with the magnets;
4. a strip of tinned iron about 2 cm wide and 15 or 20 cm long;
5. three 10 cm lengths of magnetized steel wire;
6. a thin cork disc float;
7. a small plotting compass;
8. a wooden burette stand and wooden stool with hand-hole;
9. a foolscap sheet of plain paper;
10. a glass or plastics tank of water (e.g. plastics lunch box) about 5 cm deep and having a side about 15 cm long.

After the manner of those described in Practical Lesson 1, the teacher will prepare a series of simple experiments designed to bring out the main facts about magnetic fields.

The pupils will first make and study iron-filing magnetic patterns due to a single straight magnet lying on the bench. Combining such a pattern with the end-on pattern, obtained by holding a magnet vertically so that one pole peeps through the hand-hole of a laboratory stool, the student may gain a mental picture of the whole field, in the solid, which exists around a simple bar magnet.

This simple picture might then be complicated by the patterns obtained when two magnets are placed in various positions near each other.

There should be an experiment or two on the distorting effect of a piece

A carbon filament lamp always has the filament in an evacuated space and the filament will stand a surprising amount of flexing without breaking. To conduct the demonstration light the lamp on an a.c. supply and cautiously approach the bulb with the pole of a permanent magnet. If the lamp is greatly valued, care and moderation are necessary.

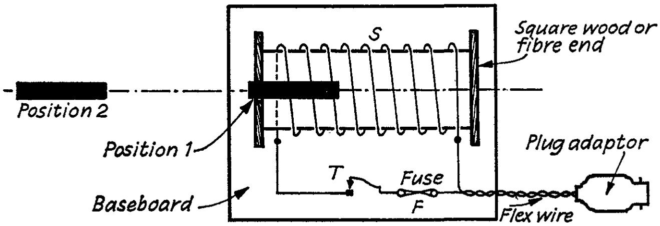
NOTES

1. Magnetism is one of those subjects which many teachers feel to be a 'gift' for teaching at this level. This is indeed true—but as well as being interesting and reasonably straightforward, magnetism does involve some rather difficult concepts, so that it is not always taught as well as it should be. Therefore we give up a lot of the space in this book for the above detailed review of introductory work in this area, so that teachers can see not just what can be done and how, but also why.
2. For magnetization and demagnetization, readers are referred to the apparatus described by Fred Meier below. At the beginning of Practical Lesson 2, the author notes one method for 'fixing' magnetic field patterns, using waxed paper. Lacquer may also be used in a similar fashion, by spraying it gently on to the sheet of filings to trap them. Excess dust may then be shaken off. It is worth noting here that a similar technique may be used for the overhead projector. If a magnetic field pattern is produced on a transparency with iron filings (either on the overhead projector or elsewhere), it may be fixed with lacquer in exactly the same way for future use.

Combined magnetizer and demagnetizer for use on alternating current light mains

F. A. MEIER

It is possible to use a solenoid with *alternating* current, not only for *de*-magnetizing bar magnets, but also for *re*magnetizing them. The apparatus needs but little description. It consists of a solenoid, 40–50 cm long, having about 6 layers of No. 22 insulated copper wire for 110 V supply, wound on a metal tube. Square wooden or fibre ends serve to keep the wire in place. A tapping key and fuse are put in the circuit and a plug adaptor to fit the electric light, as shown opposite. The resistance of the solenoid should be so high that a maximum current of 4–5 A is not exceeded. A continuous current of 5 A would, of course, heat the solenoid too much, but not if the current is used only intermittently, as would actually be the case. For a 220 V supply, a resistor in series with the solenoid will be required. The whole apparatus is mounted on a base-board which can be fixed near the electric-light switch, so that it is always ready for use in the laboratory.



(I) *To 'demagnetize' a bar magnet.* Place the magnet in the solenoid in position 1 (see figure) and, keeping the tapping key depressed, withdraw the magnet along the axis to position 2. Then do the same, inserting the other end of the magnet. It should be completely demagnetized.

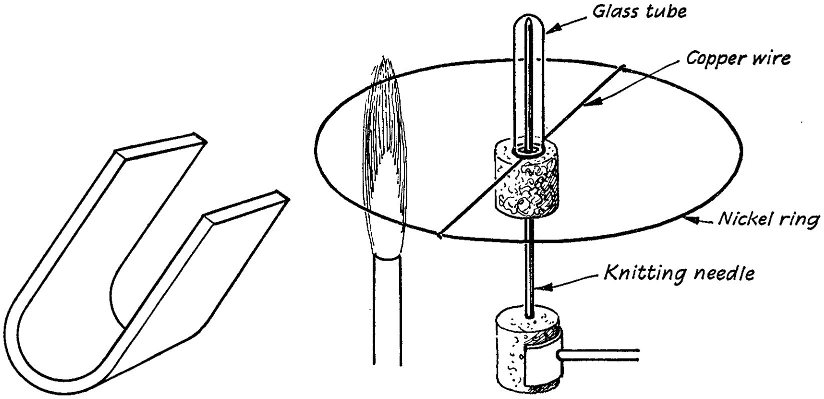
(II) *To 'remagnetize' a bar of steel.* Place the bar right inside the solenoid and *momentarily* depress the tapping key. The bar will be found to be magnetized.

The arrangement just described is a great convenience in the laboratory. It should be permanently set up so that any pupil can magnetize or demagnetize a magnet or piece of steel that he is going to use, instead of having to rely on its being in a suitable magnetic condition. There is a fuse in series with the solenoid for safety. A small compass needle is let into the baseboard on which the coil is mounted, so that the polarity of the magnets after magnetization can be tested. It is a good thing for a child to realize that it is quite possible for the end of a magnet marked N to be a South pole, and that the only safe way is to test it at the start.

The disappearance of magnetism

T. E. NICHOLSON

The experiment to show the disappearance of magnetism on heating a ring of iron wire works much better using nickel.



A 15 cm diameter ring of 24-gauge nickel wire supported as shown will revolve faster than 100 rev/min indefinitely, as the magnet need never become unduly hot.

It is self-starting as soon as the Bunsen burner is put in position not quite opposite the magnet—revolving, of course, because the heated part is no longer attracted. A small movement of the burner to the other side of the magnet causes a reversal in the direction of rotation.

Demonstration of a magnetic field pattern in three dimensions

G. AUTY

This has been achieved using an 'Eclipse Major' horseshoe magnet, with 500 g of iron filings sprinkled on to a glass sheet (the front from a balance case) placed just above it.

When very few iron filings are sprinkled on to the glass, they settle along the smooth curves of lines of force, tracing the directions from north to south, along the glass sheet. Straight lines are evident between the poles; the filings directly above the poles stand up vertically.

As more filings are sprinkled on, they form into a heap above the magnet, and show the curves tracing lines of force above the glass in addition to those along it. A very large field pattern in three dimensions can be built in this way.

Fig. 1. Oblique view of field pattern in three dimensions

Some lines are complete curves, but many are not complete, extending only to the limit of the iron, and finish in mid-air. All two-dimensional field patterns in textbooks show such incomplete lines. By very carefully adding more filings to the centre of the pile, it is possible to show that lines can be completed which were previously incomplete.

When incomplete lines reach the end of the iron available, they pass into the air, and join the iron again near the south pole. The air is of course not noticeably affected by the magnetic field passing through it.

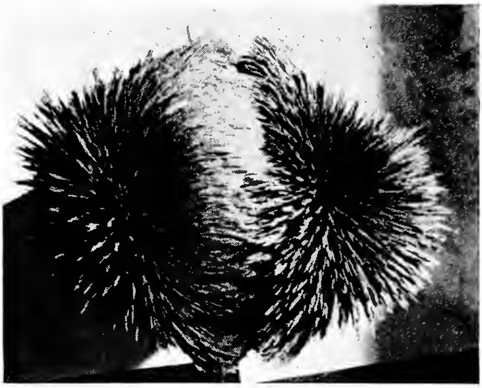


Fig. 2. Plan view showing the lines of force in all directions, particularly those standing up near the poles

If the magnet is turned through 90 degrees, the bulk of the iron filings does not turn with it. The filings in view reorientate themselves to form the pattern in its new position. This illustrates that the magnetic field can be moved through the iron without moving the iron bodily.

Fig. 3. The glass sheet is sandwiched vertically between the magnet and the filings; the demonstrator is holding the magnet only

One can lay further emphasis on the strength of this effect, and on the fact that the position of the field depends on that of the magnet, by holding the magnet only. It can be turned so that the glass sheet is vertical and the iron filings occupy the same position relative to the magnet as they did when the sheet was horizontal.

NOTE

This is one of the Editor's all-time favourite experiments. Not only is it remarkably effective in breaking down one of the serious misconceptions about magnetic fields, but it is also extremely satisfying aesthetically.

Three-dimensional magnetic fields

M. J. HANSON

Magnetic fields in three dimensions may very easily be demonstrated and preserved by the simple technique of suspending iron filings in a clear jelly and then applying a magnetic field.

The jelly we use is made by stirring agar or gelatine into very hot water. This is left to cool, and on the point of solidification iron filings are added and the mixture is well stirred to ensure even distribution. The magnetic field is then applied: the magnets are clamped and the jelly is left to set. When the jelly is cold the magnets can be removed and if the jelly is sufficiently rigid, the filings will stay in place aligned along the lines of force.

For a permanent display care must be exercised to eliminate rusting caused by diffusion of oxygen. We found that this can be prevented by using well boiled distilled water and a stopper for the vessel. Some of the heavier filings tend to sink and spoil the effect. Use, therefore, only the finest filings. These can be separated from the rest by a fine sieve. Before addition to the jelly, demagnetize them and add a few at a time, stirring well between each addition. (Do not shake as air bubbles will form.)

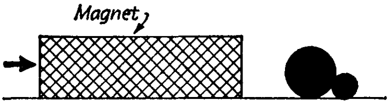
A sufficiently rigid jelly is obtained with a 0.25 per cent solution of agar. The size of the field obtainable depends on the strength of the magnets. We have obtained good fields in jam jars using Alnico magnets. With weaker magnets a boiling tube served as a suitable vessel.

The magnetic 'gun'

ERIC DEESON

This interesting little trick was brought to my attention by one of my students (Michael Silvani). Although simple in operation, its analysis caused a great deal of discussion and it is yet possible that our interpretation is incorrect.

Required are a good bar magnet and two ball-bearings of different sizes (with diameters such as 10 mm and 4 mm). These are laid on a smooth



surface as shown and the magnet is brought gently up to the bearings. At a certain distance the two balls jump to the nearby pole and the smaller is immediately 'fired' away at high speed. The larger bearing remains attached to the magnet.

A large number of variations on this theme were used to investigate the phenomenon. Our conclusion is that the explanation is based on the impulse received by the bearings over the time of impact.

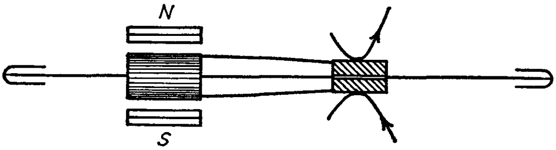
NOTE

No explanation other than the above for this effect has been received; the question remains open therefore.

A model motor

H. G. F. MICKLEWRIGHT

The armature consists of about 4 m of No. 30 D.C.C. copper wire, wound longitudinally on a large cork. The commutator is made by bending two pieces of thin copper foil round a small cork, the end of the foil being bent into slits cut in the cork. The bared ends of the armature wire are pushed



under the foil. The corks are then mounted on a knitting needle, the ends of which rest against the closed ends of two short pieces of glass tubing. The brushes consist of two pieces of thin copper wire, which are attached to a 4 V battery, held lightly against the commutator. The field is provided by bar magnets supported above and below the armature; four to six magnets are usually sufficient.

Miscellaneous

Introduction

The final section of this book comprises only three pieces, all of interest in their different ways. The paper by Mr Robinson on work with balloons is intended to show how much can be done with simple equipment to approach useful consideration of basic ideas in a number of fields. Mr Clark's natty little exposition of animating graphs is far more than a neat but meaningless trick. Pupils so often find it hard to see the realities behind graphs in science work; the technique here considered will allow them to make that essential little jump to bridge the chasm that has ended so many journeys to scientific understanding. Finally there is a long description of some physical field work which opens up all manner of ideas, but should best be left to speak for itself.

Experiments with balloons

C. J. ROBINSON

1. BALLOON ENGINE

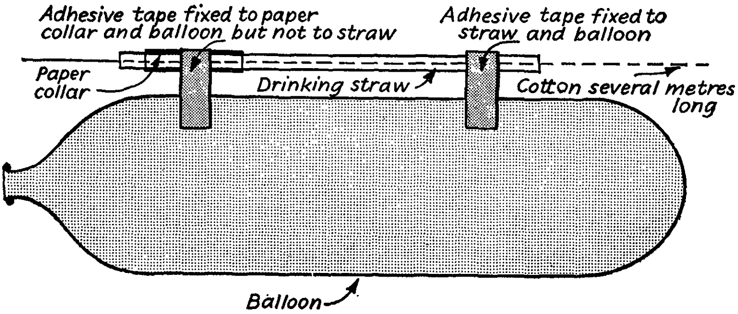


Fig. 1

Various shapes and sizes of jet can be cut from expanded polystyrene or balsa wood.

2. MEASURING THE LIFTING POWER OF THE BALLOON

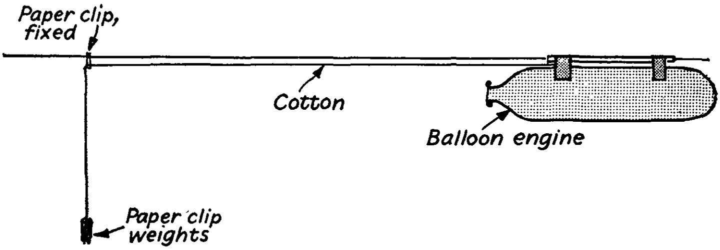


Fig. 2

3. HILL-CLIMBING

Try this also with the thread vertical.

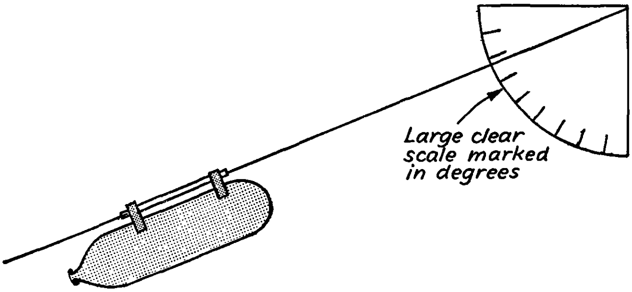


Fig. 3

4. MEASURING VELOCITY

The thread must be horizontal. Compare the velocities of a cigar-shaped and a spherical balloon.

5. FLYING TEST-BED

Fit the balloon engine with 'wings' and a 'tailplane' to demonstrate aeroplane control surfaces and airfoil shapes.

6. HOVERCRAFT

Mark I

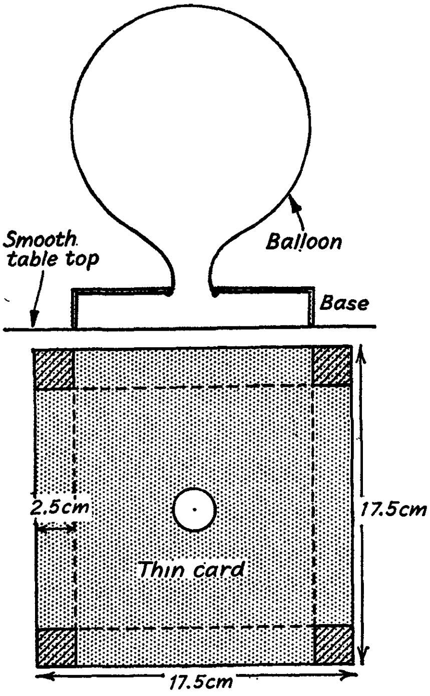


Fig. 4

Mark II

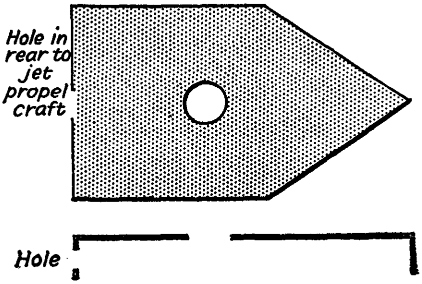


Fig. 5

Mark III

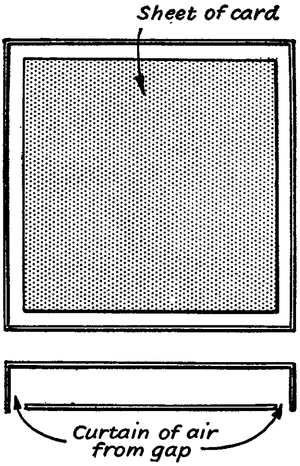


Fig. 6

7. JET-PROPELLED BOAT

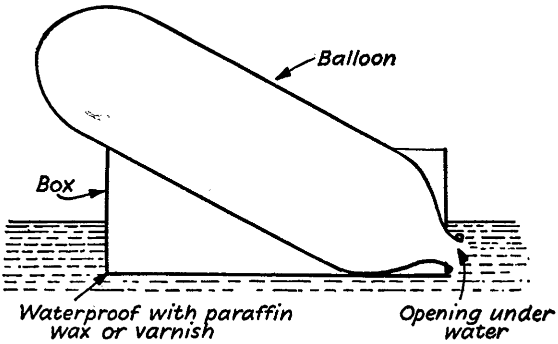


Fig. 7

Fit rollers or wheels to make a jet-propelled car.

8. REACTION TURBINE

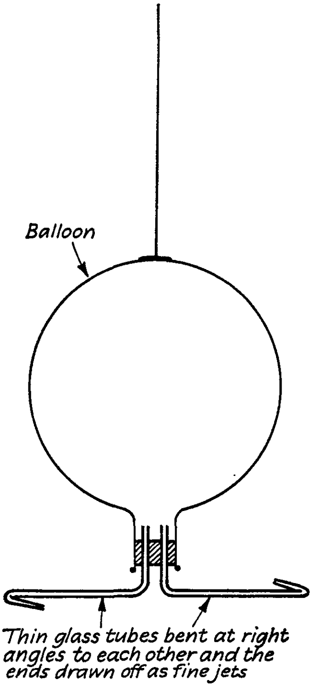


Fig. 8

NOTE

The jet-propelled boat described in Section 7 does not, of course, need to have the opening under water. In fact, this may possibly lead to dangerous ideas.

Activated graphs

J. A. CLARK

If a Perspex rod is placed at an angle to a line on a piece of paper, it is found that the part of the line seen through the rod appears at right angles to the axis of the rod. This effect continues until the angle between the line and the rod is quite small. Fig. 1 shows a teaching aid based upon this effect.

When a graph of distance against time for uniformly accelerated motion is moved laterally beneath a rod, at a steady rate, the line seen in the rod appears to accelerate along the rod. The illusion of movement along the rod is

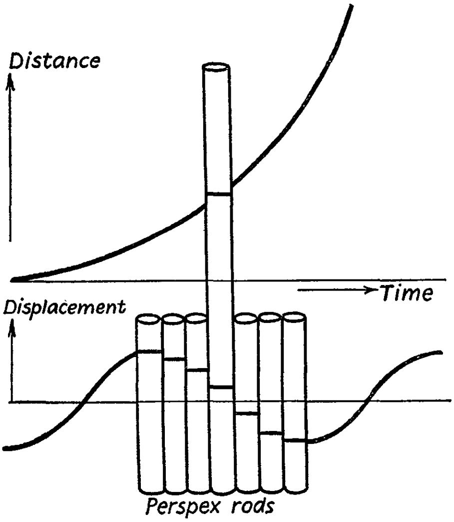


Fig. 1

surprisingly strong. It is possible to demonstrate exactly what an acceleration of 'one centimetre per second per second' looks like.

If a sine curve is moved past an array of rods, it is found that a transverse wave pattern is set up—with each line moving up and down with simple harmonic motion.

A set of notes for use by students is being prepared. Topics already written up include distance–time and velocity–time graphs, simple harmonic motion, the gas laws, resonance phenomena for both longitudinal and transverse waves, the slope of a graph, and the area under a curve. Two applications are shown in Figs. 2 and 3.

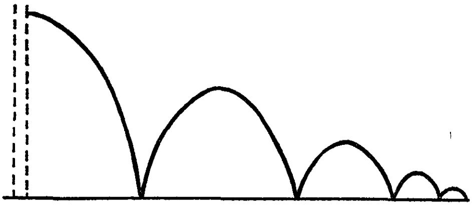


Fig. 2

The bouncing ball: Place the long plastic rod in the position indicated by the dotted lines below. Hold the rods steady and slide the page to the left, at a steady rate. Watch the line in the rod.

The line seen in the rod appears to bounce up and down in the rod, 'writing its own graph' as it does so.

Can you devise a graph which will cause a line seen in the rod to move along the rod at a steady rate and then flash back to its starting place?

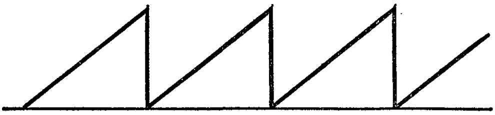


Fig. 3

A 'saw tooth' pattern gives the desired effect.

Middle School field work: the physical science of a stream

T. WARD

The purpose of this article is twofold: (*a*) to give an account of some field work carried out on the physical science of a stream, and (*b*) to make some general observations and comments about the suitability of this type of approach for children of the Middle School age range.

The stream chosen for the survey is shown on the Ordnance Survey 1: 25 000 provisional edition, sheet NZ 05, as the Mereburn and has a tributary stream known as the Yecklish burn. These streams, both of which appear to have as their source general drainage from fields and the surrounding countryside rather than a specific source such as a spring, form part of the overall drainage system of the Derwent valley, which in turn forms for a large part of its course the county boundary between Northumberland and Durham.

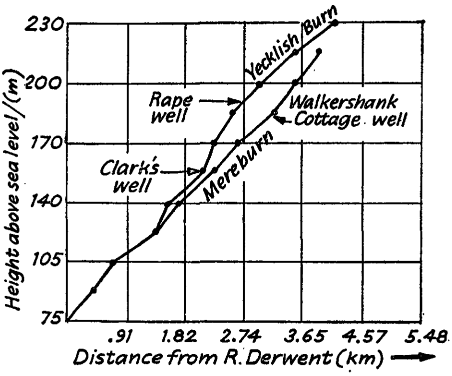


Fig. 1. Profile of Mereburn

To obtain a profile of the stream, 50 foot (15 m) contour intervals were taken and the distance of these contours from the junction with the river

Derwent were measured. This profile is rather interesting in that at no stage does it exhibit a typical stage of 'old age'. This is very apparent when walking alongside the stream. If anything, the situation is the reverse of the normal type of situation. The lowest reaches of the stream exhibit phenomena associated with youthfulness, namely fast flow, waterfalls and steep-side gorges, whereas it is the upper reaches of the stream, particularly the upper reaches of the Yecklish burn, which are more stately in their progress, a sign usually associated with the mature stage of a river or stream. The meanders associated with the lower part of the stream may not be true meanders in the accepted sense of the word (see later text). They may in fact have been present as a result of the underlying rock formation causing the stream to divert from its natural course. (See graph of Fig. 1 for a profile.)

WORK CARRIED OUT ON THE STREAM

The speed of the stream was measured in a number of places. The method of doing this was quite simple: a small piece of wood was put into the stream and the time taken to travel a known distance was measured. The velocity of the stream was then calculated from these figures. The velocity of the stream depends initially upon the gradient of the stream at the particular place where the measurements are carried out. The speed is also governed to a certain extent by the width and depth of the stream. For a given gradient and depth of water, in general the wider the stream bed the slower will the stream be flowing. The velocity of flow was measured under different conditions of the stream on different occasions (see later text).

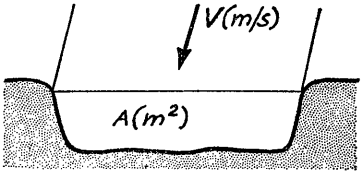


Fig. 2

As already stated, the velocity depends to a large extent upon the gradient; thus one would not expect to find any sort of relationship between the velocity of the stream at any particular point and its distance at that point from the source of the stream or any relationship with its height above sea level. What one could perhaps reasonably expect would be some sort of relationship between the volume of water flowing per second (i.e. rate of flow) and its distance from the source of the stream.

To calculate the rate of flow necessitates measuring the volume of water passing a particular place in a certain length of time. In the absence of a sophisticated measuring device of some type or other, how can the rate of flow be measured? One possible approach to this problem is afforded by a consideration of the following line of argument.

If one considers the cross-sectional area of the stream, then in one second a column of water, equivalent in length to the velocity of the stream, will pass through this cross-section. Thus from Fig. 2, multiplying the cross-sectional area A (m^2) by the velocity v (m/s), one will arrive at the volume (m^3) of water passing a particular section of the stream in one second. This was what was attempted in the investigation. The cross-sectional area of the stream was found by the following method.

A tape measure was placed across the stream. The depth of the stream was then plotted at 15 cm intervals across the entire width. These figures were then drawn to scale on graph paper. By doing this a graphical representation of the cross-section was obtained. The area of this cross-section was then calculated from the graph. The main source of error and inaccuracy of this method lies in the spacing of the intervals at which the depth of the stream was measured. The closer the spacing the more accurate will the cross-sectional area become. All that remains to be done to calculate the volume of flow is simply to measure the velocity of the stream at that particular point. For this purpose one must assume that the velocity at the position of the cross-section is the same as the average velocity, which in point of fact is what is measured.

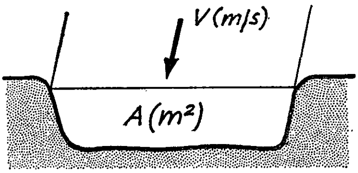


Fig. 3a

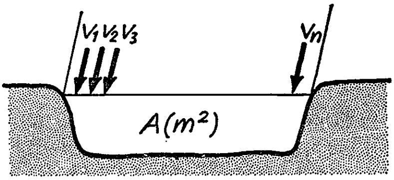


Fig. 3b

This procedure was carried out at a number of places on the stream and the rate of flow was measured. However, the stream itself offered a perfect situation to test the validity of the assumptions underlying this method. At position 080547 the Mereburn and Yecklish burns merge to become *the* Mereburn. Theoretically the volume (V_1) after this junction should be the sum of the volume of the Mereburn (V_2) before the junction and the volume of the Yecklish burn (V_3), i.e. $V_1 = V_2 + V_3$. On measuring the volumes concerned it was found that $V_2 + V_3$ was nowhere near V_1, even allowing for errors in the measurement of the cross-sectional areas and the velocities at the respective positions. This would indicate something radically wrong in the approach to the problem.

On reflection the following reasoning is offered as some sort of account for the discrepancy. Theoretically, the volume of flow should result from the measurement of the velocity of the stream and its cross-sectional area at that particular point. The discrepancy occurs in the practical measurement of the volume. The assumption is that the velocity of the stream is constant across the whole width of the cross-section (Fig. 3*a*).

In actual fact the situation is more likely to be represented by Fig. 3*b*; i.e. the velocity cannot in practice be assumed to be a constant value across the whole of the cross-section. That this is the case can be seen in extreme circumstances by the existence of 'eddies' at the sides of the cross-sections under consideration. Thus, the attempt to relate the volume of flow of the stream at a particular point to the point's distance from the source did not prove to be a viable proposition.

Following from this attempt to measure the velocity of the stream and the volume of flow of water, a comparison was made of the velocity of flow of the stream at a number of places. The velocity was measured in the same way as above. The velocities were again measured when the conditions of the stream were somewhat different. On the occasion of the second comparison the stream was in partial flood owing to melting water from a snowfall.

The following results were obtained.

	Position 1 *Velocity* (m/s)	*Position 2* *Velocity* (m/s)	*Position 3* *Velocity* (m/s)
Stream 'normal'	0.65	0.30	0.12
Stream in spate	1.2	0.80	0.38

If we compare the ratio $\frac{\text{Stream in spate}}{\text{Stream in normal}}$ for these three positions it might be expected that we would obtain a constant ratio since the stream would be in the same condition at all three positions. In fact when this comparison was worked out the following ratios were obtained:

$$\text{Position 1} \quad \frac{\text{Velocity in spate}}{\text{Normal velocity}} = 1.8$$

$$\text{Position 2} \quad \frac{\text{Velocity in spate}}{\text{Normal velocity}} = 2.7$$

$$\text{Position 3} \quad \frac{\text{Velocity in spate}}{\text{Normal velocity}} = 3.1$$

Examining these results it can be seen that the ratios for positions 2 and 3 approximate to each other whilst that for position 1 does not approximate to either position 2 or 3.

To provide some sort of check on the accuracy of these ratios I then compared the following ratios.

$$(a) \quad \frac{\text{Velocity in position 1}}{\text{Velocity in position 2}}$$

$$(b) \quad \frac{\text{Velocity in position 2}}{\text{Velocity in position 3}}$$

$$(c) \quad \frac{\text{Velocity in position 1}}{\text{Velocity in position 3}}$$

The comparison was made under both conditions of the stream. The following results were obtained.

Normal conditions	(*a*) 2.2 : 1	(*b*) 2.5 : 1	(*c*) 5.5 : 1
Flood conditions	(*a*) 1.5 : 1	(*b*) 2.2 : 1	(*c*) 3.2 : 1

It can be seen that when comparisons involving position 1 are not involved the ratios are in closer agreement.

Assuming that this idea of comparing ratios is a valid one then there appear to be two possible explanations for the discrepancies arising. The first explanation is the simpler of the two. This discrepancy could be explained by assuming some inaccuracies in the velocities arising out of the method of measurement. However, one would expect these inaccuracies to be present at all times and they should therefore be apparent, irrespective of the position where the measurements were taken.

The second explanation concerns the cross-section of the stream where the measurements were taken. The cross-sections in positions 2 and 3 were comparable in so far as they were of fairly even depth. They were of the type shown in Fig. 4.

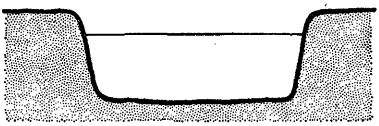


Fig. 4

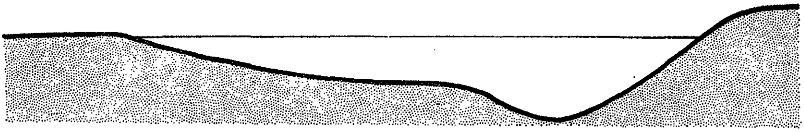


Fig. 5

The cross-section at position 1 was very uneven, being of the type shown in Fig. 5.

The velocity was measured at the deepest point. Hence the average velocities measured for positions 2 and 3 were more representative than that measured for position 1. This appears to be a more plausible explanation for the discrepancies. This idea also offers an explanation for the variations in the ratios for positions 2 and 3. Under conditions of flooding the cross-sections of the stream in the various positions will change. This will depend upon the configuration of the stream's bankside. This in turn will exert an influence upon the velocity of flow past the particular point. Thus an exact constancy in the ratio of velocities for any positions on the stream could not be expected. If this reasoning is correct then the figures obtained for positions 2 and 3 may be considered to be reasonably accurate.

STUDY OF MEANDERS

As mentioned above, the lower section of the stream exhibits what appears to be meanders. However, a cross-section taken on one of the bends of the stream did not exhibit what could be called a 'classical' form. This led to the following piece of work which was carried out on a different stream. This stream also exhibits a stage where what appear to be meanders are formed. An attempt was made to measure the direction of flow of the stream at various positions across its surface.

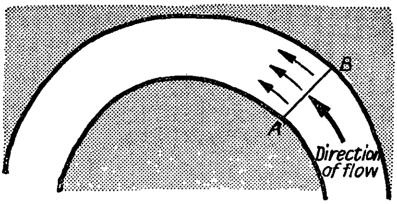


Fig. 6

Two posts were set up in positions A, B (Fig. 6) across the stream and these posts were joined by a line. A small piece of wood was then released at 15 cm intervals across this line. The general angle of drift (measured with an anglemeter) with respect to this line (as shown in Fig. 3*b*) was then determined.

The following data were collected.

Position	*Angle* (°)	*Distance travelled* (m)	*Time taken* (s)	*Velocity* (m/s)
1	82	3.2	15	0.21
2	87	4.1	15	0.27
3	77	3.9	16.5	0.24
4	70	3.1	15	0.21
5	72	4.2	21	0.20
6	90	3.9	33	0.12
7	95	5.3	43	0.12
8	110	—	—	Eddy current

These data were then represented diagrammatically in Fig. 7. The diagram shows the general direction of drift from the point of release. The velocity of the stream in this particular direction is written on to the diagram. Superimposed upon this is a cross-section of the stream taken at a distance of 3.3 m from the point of release. This cross-section corresponds fairly closely to the 'typical' cross-section of a meander. It can be seen from the diagram that not only the greatest velocities occur at the greatest depth but also the directions of flow tend to converge towards this point. The greatest deposition occurs with the lowest velocities. The eddy current initially had the direction of flow indicated but after a short distance this initial direction of drift became dissipated.

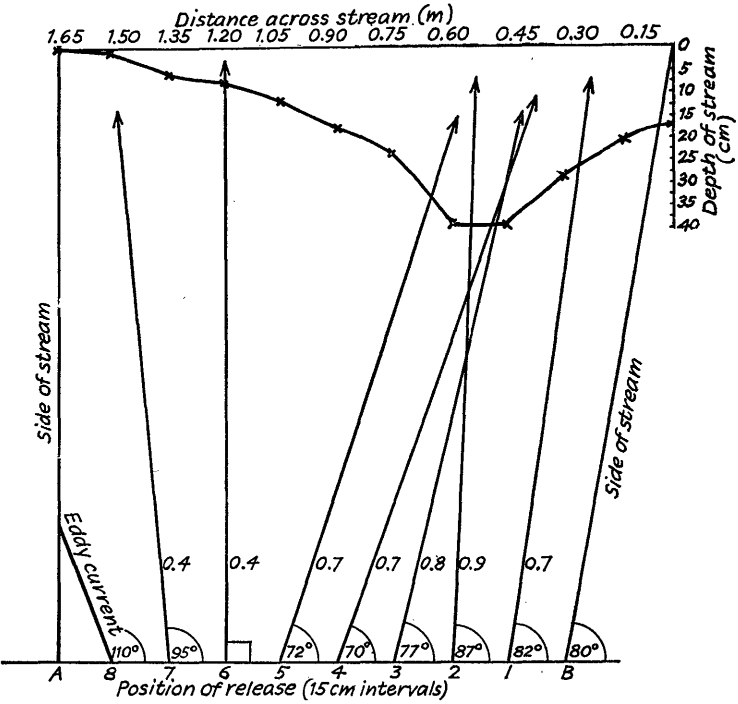


Fig. 7. Study of a meander: chart showing general direction of flow of surface currents. Cross-section of the stream at a distance of approximately 3½ m from point of release, superimposed upon the direction of flow

EROSION

As remarked upon in the initial description of the stream, in its lower reaches there are some excellent examples of erosion channels formed in the sandstone bedrock. This prompted the following investigation.

A piece of sandstone was broken away from the parent rock. It had not previously been immersed in water and was very rough to the touch; it was also fairly soft. This was dried in an oven for several hours and weighed. It was then placed in a 'network bag' made from string, which was then anchored to the stream bed. Originally it was intended that the rock be recovered after a period of a week. However, this proved to be impossible due to bad weather conditions, so that in practice the rock was in the stream for a period of three weeks. During that time there was a period of flooding in the stream due to the melting of snow. The piece of sandstone was eventually recovered, dried in an oven and reweighed. The following results were obtained.

Mass before immersion	686 g
Mass after immersion	540 g
Loss in mass	146 g

This represents a loss of 21 per cent of its original mass.

In addition to this the sandstone, after immersion, was very smooth to the touch. Its loss in mass seems to be fairly large, which raises two relevant questions. The first of these is the question of a continuous survey of erosion. This could be carried out over an extended period of time to see if there is any sort of seasonal pattern to the erosion. Although the loss in mass was very large it would appear to me that erosion on this scale would occur only on a handful of occasions throughout the year. The second question which arises is this: would subsequent erosion of the sandstone occur as quickly as in the first instance?

WELLS

As can be seen from the profile for the Yecklish burn there are two wells present near the stream. These are called Clark's Well (075548) and the Rape Well (070549). Clark's Well lies on the 500 foot (150 m) contour and Rape Well lies on the 625 foot (190 m) contour. On the Mereburn at position (066544) near Walkershank cottages there lies a third well. This well is also on the 625 contour. A search was made for these wells and they were eventually traced. All three wells were of the same type. They issued horizontally from the hillside from holes of approximately 0.6 m by 0.6 m. At Rape Well and Clark's Well there was evidence of their having been built around with dry stone walling. The well at Walkershank was in a better state of repair than the other two. It appears that until fairly recently a cottage stood in a position adjacent to this well. The nearest building to Rape Well was almost a kilometre away whilst the nearest building to Clark's Well was even further. The floors of the wells were identical in all cases, consisting of a smooth horizontal slab of sandstone. An interesting point in connection with these wells was that on the days on which they were visited the stream itself was discoloured with flood water. The water issuing from the wells was crystal clear.

Following these visits a closer examination of the map revealed a large number of wells in the area covered by the map (approximately 90 square kilometres). An attempt was made to assess the distribution of the wells with respect to the height above sea level. When the wells were grouped in 25 foot (7.5 m) contour intervals no particular pattern of distribution occurs. However, when they are grouped in 100 foot (30 m) intervals the graph of Fig. 8 is obtained.

The probable explanation for this particular distribution is that there is likely to be more land between, say, the 500 and 800 foot contours (150 and 240 m) in the area under consideration. There may possibly be some connection with the underlying geology of the area, although this explanation is not quite so probable as the first.

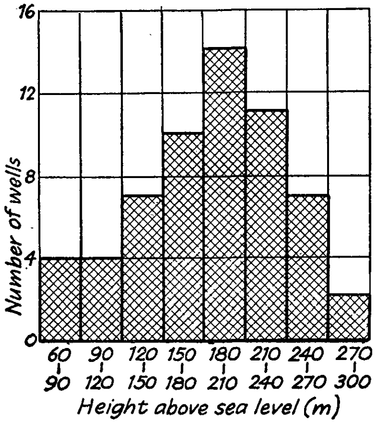


Fig. 8. Distribution of wells (sheet N2 05) by 30 m intervals

GENERAL COMMENTS

The greater proportion of the mathematics employed in this study involved direct measurement of one sort or another. These measurements as such would be well within the capabilities of children of the Middle School age range. However, there are other more complicated mathematical ideas involved in this study. The most obvious of these are ideas involving the concepts of velocity, area and volume. Whilst all of these ideas are within the scope of understanding of older children, the work involving area and volume presupposes a fairly extensive knowledge and familiarity with these concepts. The work involving cross-sectional areas could not be undertaken at all unless the children were familiar with the following fields of mathematics, area, scale and graphical representation. The idea of a cross-sectional area, particularly for a moving entity such as a stream, would constitute a difficult and sophisticated idea for children. This, however, is considering the idea of a cross-section purely in terms of area. From the point of view of representing depths across the stream the idea may not present quite so many difficulties since the children would be able to measure the various depths for themselves and, if necessary, initially represent the cross-section in a direct, concrete fashion rather than in an abstract graphical manner. The step from this representation to the use of the cross-section for purposes of area determination necessitates, in my view, a good understanding of the principles involved.

A similar situation exists with the idea of rate of flow (volume). This is a very difficult concept since it involves the ideas of volume and velocity, i.e. it is a combination of two different concepts. Additionally the ideas involved in this determination demand the finding of the cross-sectional area.

The concept of velocity is perhaps the simplest of these three concepts to handle. Its measurement is more direct and because of this, in all probability it will prove more immediately satisfying. Differences in velocity are more readily observed than differences in area or volume. Of these three concepts, velocity is perhaps the only one which could be directly introduced to children during the course of the survey. It requires the least previous experience and understanding (under these circumstances) and can be visibly seen, i.e. it is a concrete rather than an abstract phenomenon.

These three concepts are by no means the only ideas which could arise from a survey of this type. A vast amount of work involving some of the following ideas could be arrived at in a fairly natural way without deliberately attempting to contrive or manipulate the situations. Ideas concerning the use of maps such as scale, bearings (the use of a compass), angles, etc., are a necessity rather than a contrived situation. Simple survey work to make a simple large-scale map is also possible and within the bounds of the capabilities of Middle School children. Heights of trees, the width of streams, are also situations which occur quite naturally. Opportunities for experience of graphical representation are numerous, ranging from sophisticated ideas such as land utilization (perhaps leading to percentages, etc.) to simple block graphs, such as the graph for the distribution of wells or even simpler counts of various types. Examples of naturally occurring symmetrical objects should also not be too difficult to discover from a survey of this type.

The technical difficulties involved in any of these ideas are well within the scope of these children. A minimum of apparatus is required and this is of the type that is generally available in schools. There are certain questions arising out of work of this type which deserve some consideration. Amongst these questions could be included the following.

How much of this work would arise directly from the children?

What would be the purpose of the study, scientific or mathematical?

How much other school work could be incorporated into this survey?

The first of these questions concerning how much of the work would arise naturally from the children is virtually impossible to answer. It so obviously depends upon the individual children, their intelligence, interest and possibly most important, their previous experience. This should not be underestimated. What do arise from a consideration of this question are two related questions. The first of these is fundamental, namely, what is the overall purpose for the investigation? The second question is this: bearing in mind the overall objective of the study and the amount of work coming directly from the children, how much guidance and prompting should the teacher give?

The overall objective of a study such as this could perhaps be stated in very broad and general terms as enabling the children to become familiar with a part of their environment. However, this is such a broad statement that it is capable of almost any interpretation. One could consider the objectives under two headings such as scientific or mathematical, understanding of course that all of the basic aims in teaching these two branches of knowledge were implicit in the division. If this division is taken one can perhaps consider for which purpose a study of this type is best suited.

If we consider a study of this type to be primarily scientific in nature, what then follows from this? The major implication would be that whatever is investigated would be investigated from the scientific viewpoint rather than any other. This immediately raises the question of teacher direction and interference. The amount of such direction is obviously impossible to predict. The direction and type of interference depends to a large extent upon the teacher's main objective. This is arguing in circles but the two questions seem to me to be closely connected. The direction which teacher interference would tend to take would probably depend upon which branch of science he was particularly interested in. The sciences involved in the study of a stream, or arising from such a study, could be legion, for example physics, botany, zoology, geology, ecology, etc. Thus if any teacher direction became necessary it would seem most likely to follow the particular branch in which he personally was most interested. This is probably a good thing, provided it does not interfere with the child's own ideas concerning the survey, since a teacher's enthusiasm can make a great difference to any classroom project. If the survey is considered primarily in scientific terms it relegates mathematics to what some would consider (rightly or wrongly) to be its proper position, namely as a tool subject, as an aid to scientific (or other) understanding.

This leads to the second way of looking at a survey of this type, that is, to consider it primarily in mathematical terms. If we do this, two points come immediately to mind. The first of these is how much mathematics would arise naturally and, secondly, how would one use the mathematics which does occur? Again it is virtually impossible to answer the first of these questions since the variations in children and schools are enormous. Some general observations may, however, be relevant. In the first instance, any mathematical work arising may well not be recognized as such by the children. This is not necessarily a bad thing but it is worth bearing in mind in connection with the second of the above questions. Secondly, whatever may be said by mathematicians and other interested parties, children—particularly girls—do not express as much interest in mathematics as they do in science. This is perhaps a cultural factor rather than a factor inherent in mathematics itself, but nevertheless it exists and as such may have an inhibiting effect upon the quantity of work which would occur naturally from the children. Thirdly, the mathematics arising out of a survey of this type are perhaps not nearly as obvious as the scientific aspects. This could lead very easily to some distortion and artificiality in the investigation. This question in itself has very wide implications, raising the question of one's basic ideas concerning education in its very widest terms, namely how 'natural' or otherwise does one consider education should be?

The second of the questions raised when one considers a survey such as this in primarily mathematical terms is the question of how one would use the mathematics which occurred. This can be looked at from two standpoints. Firstly we can use the mathematics occurring to introduce directly various concepts and secondly we can use the situations involved to give practical experience and practice in the use of the various concepts. Which of these, if either, should receive precedence? To answer this question it is worth asking which ideas or concepts arise naturally in a simple enough form to serve as a direct introduction.

The ideas involved in pure number work would not arise naturally, thus operations involving number would be used purely as an end to the evaluation of some other quantity. As mentioned above, the concepts of area, volume and velocity are all involved in any physical measurements carried out directly upon a stream. Of these probably only velocity occurs in a simple and direct enough form to be introduced directly. Some ideas concerning symmetry could perhaps be introduced directly, but would these ideas occur without some prompting from the teacher? When one considers the various other mathematical ideas mentioned above it becomes fairly obvious, at least for the age range of the children under consideration, that the majority of ideas involved would be best considered as the application of various concepts previously encountered, to practical and, above all, real situations involving these particular ideas.

Perhaps it is rather artificial to consider a survey such as this in terms of 'either–or'. The scientific and mathematical approaches are so closely interwoven that perhaps both may be catered for. A final general point to bear in mind is the one of other school material which could be entered into as a consequence of a study of this nature. The place of topics such as local history and geography is fairly obvious but there could also conceivably be a place for such topics as art, craft and language. Opposing this, however, it appears that a survey of this type could be so vast as to necessitate some sort of limitation, in which case the above considerations may be of some validity.

NOTE

This article is a suitable one to end this book as in a way it embodies many of the principles involved in modern Middle School science teaching. It is effectively an environmental studies project, which like any true environmental studies project leads from simple geography into numerous other areas. One could take the work quite a lot further, of course, by delving into archaeology and history, as well as the obvious nature-study interests.

Index

Absorption, 14, 19
Aircraft, 45
ASE, ix
Astronomy, 2ff, 35

Balloons, 4, 76ff
Bernoulli, 45

Calorimetry, 24
Camera work, 13, 16
Circuit work, 5, 55ff
Conduction, 24
Constellations, 2
Current, electric, 50, 55

Density, 34

Earth Sciences, 1, 9
Eclipse, 3
Elasticity, 31, 42
Electrolysis, 56ff
Electromagnetics, 46ff
Electrostatics, 24, 46ff
Engines and motors, 27ff, 63, 71, 75, 76ff
Expansion, 20ff, 23ff, 35, 36
Eye, 13ff

Fieldwork, 82ff
Force, 30
Fossils, 10

Graphs, 80

Heat, 18ff

Kinetic Theory, 20

Lapidary, 11
Laser, 15
Latitude, 3
Light, 13ff

Magnetism, 50, 59ff
Mass, 30
Mechanics, 30ff, 76ff, 80ff, 82ff
Mirrors, 16
Moon, 3
Motors—*see* Engines

Newton's Laws, 30, 33, 34, 75, 76ff
Nuffield, ix

Pendulum, 8, 64
Physics, xi
Pressure, 27, 35ff
Projector, overhead, 23, 38, 44, 51
Pump, 39

Rocks, 9

School, First, ix
School, Middle, ix, x, 1, 5, 46
Science, History of, 2, 65, 66, 69
Scientific Method, 2
Smoke Box, 14
SSR, ix, xi, 1, 32
Stars, 2, 3, 4, 5
Stream, 82ff
Sundial, 7
Surface Tension, 35, 40ff
Syringe, Plastics, 35ff

Time, 7

Weather, 11, 18, 19
Weight, 30, 35

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