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ABSTRACT

This bulletin of Scottish Schools Science Equipment Research Centre provides information about new scientific equipment for use in classrooms and laboratories. The sciences covered are biology, chemistry, and physics. The pieces of equipment can either be purchased from manufacturers or constructed in schools. All descriptions include advantages for the use of new equipment over other similar instruments. A detailed outline is included for constructing a hot air engine model in school workshops. (PS)

SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 57 August 1972.

Contents

Introduction

Our Director, Mr. J. R. Stewart, returns from his U.N.E.S.C.O. post in Bangkok in the middle of August. We are sure that he will have much interesting information about his work in designing and developing new equipment there and we in Scotland should benefit from his experience. Dr. V. McKenna, who has been at the Centre as physicist during Mr. Stewart's absence, leaves us at the end of August to take up a temporary appointment with U.N.E.S.C.O. in Bangkok before going home to Australia. We wish to thank Dr. McKenna for his efforts and the advice he has so freely given to teachers and others who had the good fortune to meet him.

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The use of Earth Leakage Protection units to protect against mains shocks with aquarium immersion heaters and the like is discussed in Biology Notes. It seems to us that it would be well worth considering the installation of such devices in all new laboratories and workshops when they are built and to this end we would recommend a C.L.E.A.P.S.E. leaflet which sets out the arguments for and against these units in some detail. The leaflet is available on loan for one month from the Centre, as are all C.L.E.A.P.S.E. reports and information leaflets.

Biology Notes

Supply of Rhabditis We have been told by biological suppliers that several teachers are ordering *Rhabditis* from them, for the embryological work in section IV(7)(a) of the new syllabus. This organism is extremely difficult to culture, and teachers are therefore advised either to obtain their own specimens when required, from earthworms, or to order the Vinegar Eel Worm, *Anguillula aceti*, instead.

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Bile salts We have had several telephone calls from exasperated teachers, who have searched the catalogues in vain for bile salts. We have looked at the catalogues of five suppliers, all of whom supply them, but only one of whom - Gerrard and Haig Ltd. - actually list them as bile salts. In the four other cases they masquerade under the title of sodium tauro-glycocholate - though no doubt the chemists have now dreamt up something even more impressive with their new nomenclature!

* * * * *

Aquarium Heaters and Thermostats From time to time fears are expressed about the safety of mains electrical equipment when used in aquaria. Indeed, we recently received a letter from a teacher who had had a mains shock from an immersion heater. Our sister organisation in the south of England, CLEAPSE, has designed a 'safe' heater/thermostat. This incorporates an earth wire wound on the porcelain former alongside the heating element, and a fuse is present in the live wire of the leads fitted to the heater. As a result, if the glass tube enclosing the heater becomes cracked and water reaches the heater, the leakage current passes mainly to the earth wire rather than to a hand immersed in the water or touching the frame. After a short time the fuse blows and makes the device inoperable. This heater/thermostat is manufactured by L. P. Butler Ltd. and is also supplied by Griffin and George Ltd.

We should point out, however, that while the CLEAPSE heater is an undoubted improvement on conventional types, it does only protect against a broken glass tube. It is also possible though admittedly less likely for the wire leads into the heater tube to become frayed, cut or burned so that contact with the live lead could occur outwith the tube. In this case the body could well receive the major part of the current. The best way to protect against both types of hazard is probably to use an earth leakage protection unit such as the D. W. Blakley 'Lectroguard' or, more simply and cheaply, their 'Pluguard' - preferably with the CLEAPSE heater for double protection. The 'Lectroguard' must be incorporated into the wiring circuit of the laboratory, while the latter simply plugs into a 13 amp mains socket.

We realise that there is an argument against these devices on the grounds that they do not protect against simultaneous contact with live and neutral (nothing practicable can) and that they could engender a false sense of security. However, the earth leakage hazard is so much more common that it is probably worth guarding against on its own, and the 'sense of security' argument could presumably be levelled against most safety devices, e.g. car seat belts. Further, if the presence of such a unit is not mentioned to pupils the danger of them regarding protected sockets as 'safe' should be eliminated.

Further details of both the heater/thermostat and earth leakage protection units are given in Trade News.

* * * * *

Electronic Thermometer Probes For those schools who have made up the Silicon Diode Thermometer, described in Bulletin 55, and find it a useful instrument for detecting small temperature changes, the production of cheap disposable thermistor probes by Medicon U.K. Ltd. will be of interest. While the resistance relationship will not be linear over the full 100°C range, these probes are extremely sensitive, completely encapsulated, have a fast response time, and a low cost - 20p each. Designed for hospital use they are in two colours - white (oral probe 13155PS) and red (rectal probe 13046PRS). They are of particular value in such experiments as the demonstration of heat production by respiring organisms. Their sensitivity is so much greater than that of a diode probe that significant movements are shown on most demonstration meters from the heat output of, e.g. one 4th instar locust! For convenience they can be stuck through a hole in the plastic lid of a specimen tube in much the same way as shown for the screw-top jars in Bulletin 55. They can also be used, of course, to detect small temperature changes in physics and chemistry experiments, and for larger temperature ranges, provided the milliammeter in use is calibrated against them.

Chemistry Notes

A Mechanical Analogue for Modes of Vibration of Molecules in the Infra Red

The details of this very simple and easily constructed model have been sent to us by the Chemistry Department of Eastwood High School, Renfrewshire. What we like about the model is that it uses equipment, all of which is probably in science departments already, apart from the springs which are quoted later. It is possible, with the model, to show quickly a number of features of the vibrations of bonds in a molecule as well as the general principle that a molecule will absorb energy in the infra-red at definite frequencies only.

For a diatomic molecule, e.g. HCl the bond between two atoms in a molecule may be considered as analagous to a spring holding two masses together. Just as the spring has a fundamental frequency of vibration dependent on the elasticity of the spring and the actual value of the masses, so a bond has a fundamental frequency of vibration dependent on the force constant of the bond and the masses of the atoms.

In the case of the diatomic molecule the frequency of vibration is given by a Hooke's Law type of equation:

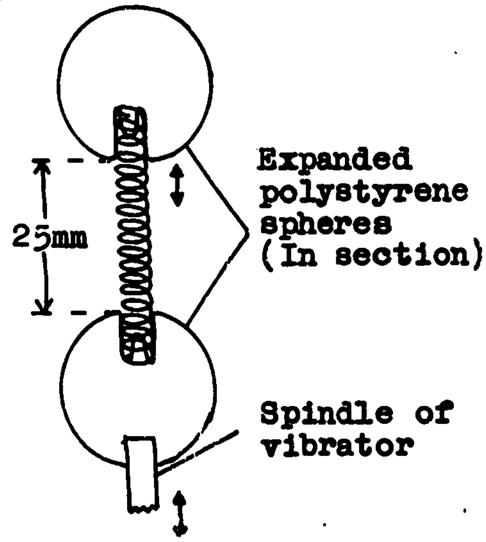
$$\text{Frequency} = \frac{1}{2C}\sqrt{\frac{K}{\frac{M_x M_y}{M_x+M_y}}}$$

where K = stretching force constant (related to strength of bond) and M_x and M_y are masses of the atoms.

For construction of the model, spiral wire used in calendars and small note-books, and 25mm diameter expanded polystyrene spheres are required. The wire spiral used in our models was diameter 7mm. A 50mm length of this is warmed at both ends and each end plunged firmly into a 25mm polystyrene sphere as centrally as possible. The spindle of a vibrator such as the Linstead type, is also warmed and pushed well into one of the spheres opposite the spring so that the molecule stands vertically as shown in Fig. 1. When removing the model from the vibrator it should be done by unscrewing the bottom sphere from the spindle. A plastic sleeve can be inserted in the hole in the sphere if the spindle becomes a loose fit.

A signal generator such as the Linstead LF Signal Generator Type GI is used to operate the vibrator. The output of the signal

Fig. 1



generator must be controlled so that at the critical frequency the excited vibration is clearly visible but is not so violent that the whole molecule oscillates wildly for in the latter case it is difficult to ascertain the exact frequency of vibration. A xenon stroboscope is used to show up the vibrations of the spring and spheres.

With the model we constructed excited vibrations occurred at 44 Hz, 56 Hz and 78 Hz. Other higher frequency vibrations occurred at higher frequencies but these were mainly detected by a sudden "buzz" or "whine" rather than visually.

The effect of altering the mass of one of the spheres can be investigated by pushing drawing pins into the top sphere. The lower sphere is, of course, fixed to the vibrator and altering its mass would have no effect.

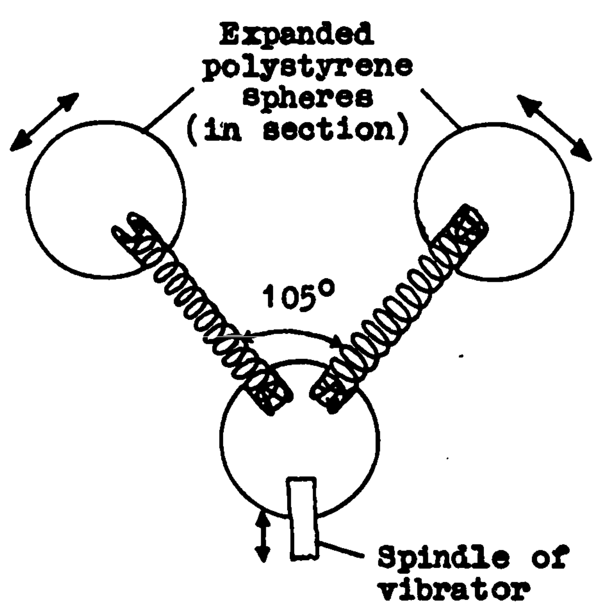
The table below shows the results we obtained.

No. of Drawing Pins inserted	0	1	2	3
Frequency (Hz)	78	66	59	49
Frequency (Hz)	56	53	48	44
Frequency (Hz)	44	43	39	36

By using the same size of spheres and springs of different elasticity the shift in the fundamental frequency can be shown.

An angular water molecule, for demonstration of bending ("wagging") vibration is constructed with 25mm spheres as before and the centre sphere attached to the spindle of the vibrator as shown in Fig. 2.

Fig. 2



Again 50mm lengths of spiral spring are used, the springs being attached as before. The centre sphere is attached to the spindle of the vibrator so that the spheres are held in the position shown in the diagram. Bending vibrations occur at lower frequencies than stretching vibrations, in our case at 20 Hz. The wagging motion can be "slowed down" very effectively using the stroboscope to illuminate the spheres or indeed "stopped" altogether in which case the frequency of the wagging vibration can be obtained from the stroboscope. It can be shown that the stretching vibrations occur at higher frequencies but unless the springs are carefully matched, the bonds will not vibrate at the same frequency.

Equipment and Materials used

LF Signal Generator - Linstead Type GI or Griffin and George L88-720.
Vibrator - Linstead Type VI or Griffin and George L62-248.
Stroboscope - Dawe Instruments Ltd. Type 1214A.
25mm expanded polystyrene spheres - Griffin and George S33-390/015.
Spiral spring from small notebook or calendar - diameter of spring 7mm, thickness of wire approximately 0.63mm.

Physics Notes

Use of Chart Recorders in School Science Teaching

The arrival on the market of chart recorders, costing less than £100, and suitable for school use, has opened up a new era of practical work in school teaching laboratories. It may not be obvious, at first glance, what advantages a pen recorder has to offer as an aid to science teaching. Any experiment from which the output is electrical or is some variable which can be converted to an electrical signal, lends itself to the use of a recorder, usually with a distinct increase in convenience, accuracy and speed of measurement. For example, what is your reaction to the thought of an accurate measurement of periodic time of a pendulum after one swing, or a complete melting point curve done in less than two minutes, or a continuous record of the magnetic flux density along the axis of a solenoid, or the accurate timing of two carts on a linear air track before and after a collision? These are only some of the experiments for which a chart recorder is of immense value.

For those not familiar with the use of a chart recorder in the school situation, the following advantages are listed:

1) It allows an immediate plot to be obtained without the need to first record data in numerical form and then transfer it to graphical form.

2) The curve plotted is continuous, whereas most graphical results are obtained from discrete points connected by a line of best fit.

3) It becomes possible to record rapidly changing data, such as the decaying current into a capacitor, whereas previously the decay rate had to be slowed down by some means, e.g. use of a very large capacitance.

4) A permanent copy of the phenomenon is obtained immediately, whereas for example an oscilloscope screen gives only a transient display.

5) Individual copies of a graphical record may be given to each student for analysis - these are as cheap as paper and as rapidly produced as the occurring phenomenon.

6) Short time intervals may be recorded, e.g. period of a 10cm

pendulum, or photoelectric pulses from a comb on an accelerated air track cart, by using fast paper movement.

7) Long time intervals may be recorded, e.g. diurnal variation of earth's magnetic field or of solar radio signal not to mention seismographical or biological movements, by using very slow paper movement.

8) The recording once made cannot be obliterated or lost by accidentally superimposing new data, as can happen for example when a single scaler/timer is being used to record collisions on an air track.

9) There is no need for strobe lighting, photographic developing, or printing, when photoelectric recording of velocities is being made, as the print-out of the recorder is immediate.

10) As well as signals which vary with time, those which vary with distance can be recorded by synchronising chart paper drive with the distance parameter (X-Y recorder).

Since a chart recorder costs about as much as an oscilloscope, an EHT supply, or a good microscope, there should be no difficulty in budgeting for at least one of these instruments. However, before rushing off to buy one of these valuable teaching aids, first look at the characteristics which make a recorder useful in school experiments. The points to look for are:

1) Pen response time
2) Range of paper speeds
3) Inking system
4) Type of pen movement
5) Paper width
6) Cost

1) Pen response time It is no use trying to record accurately a transient lasting a fifth of a second with a pen which requires several seconds to move. This is not important if only slow changes are to be recorded, but fast pulses of short duration could be lost with a slow pen. The fastest response available is from the moving coil pen of the Russian Recorder, Frequency 5Hz or Period 1/5sec.

2) Range of paper speeds To allow accurate measurements to be taken from a record of fast pulses, e.g. accelerated carts, human pulse, short pendulum swings, the paper speed should be fast enough to give adequate separation between pulses. Too rapid paper speed is wasteful of paper and a maximum speed of up to 5cm per second is adequate for school experiments. For long term measurements, e.g. overnight recordings, speeds of the order of several cm per hour would be necessary.

3) Inking system Some of the recorders available will accept any type of felt tip, ball point or cartridge type pen. This has obvious advantages for replacement or colour changes. However the heavier the pen system the slower the pen response time. If a capillary or syphon system is used it should be sealed from dust and the stylus tube should be able to be cleaned.

4) Type of Pen Movement Three types of movement are available for school recorders:

(a) servo motors (b) stepping motors (c) moving coil

The first two types are powerful enough to drive felt tip pens, and give a straight line X-axis movement for the pen. Both however are inherently slow, typical times being 1 or 2 seconds for full scale movement. The stepping motor has the disadvantage of drawing a stepped trace rather than a continuous line. This can be troublesome in some graphical forms. The moving coil system has the advantage of a faster response time but is restricted in its inking system and gives a curved trace on the X-axis.

5) Paper width While wide paper systems appear an advantage, e.g. 10in paper or graph sheets, it should be remembered that wider paper is more costly and the wider the trace the more time the pen requires to move across it.

6) Cost For school recorders this ranges from £55 to £95. However the cost of necessary accessories, e.g. spare paper, roll attachment, amplifier, can raise this amount considerably.

Chart Recorders for School Use

The Russian Recorder H320-1, from Z and I Aero Services, at £55, with a pen response period of 1/5sec, is a very useful instrument. The fastest paper speed is 5cm/sec, and the slowest is 7.2cm/hour. Minor disadvantages are that the trace is curved and the input required is 8mA. However, used in conjunction with a SSSERC Meter Amplifier (Bulletin 55) costing £3, it is a very economic proposition. The recorder is supplied in a robust wooden case and comes complete with ample supplies of paper and ink, spare pen and capillary cleaning wire, and curved scale graticule. There is a separate pen for an event marker, and a pointer indicates the amount of paper remaining on the roll. Paper as used can be wound onto a drum, or allowed to fall free if desired. Remote drive can be taken off the paper supply spindle, and the paper may be rewound onto the supply drum by means of this same spindle. A three channel version of the same recorder is available at £90.

The WPA Recorder, CQ75, at £95, has a feature that single sheets of graph paper may be inserted in the recorder and it uses any suitable diameter fibre tip or similar pen. However, the pen is driven by a stepped motor and the steps are sometimes obvious on the trace. Response time for full scale deflection is 2 seconds. The instrument has 12 current input ranges from 1μA to 5mA, and 12 P.D. input ranges from 1mV to 5V. The fastest paper speed is 0.2cm/sec, insufficient for many Physics applications. A Chart roll holder is supplied as an accessory, with 2 rolls, at £7.80, and a gas syringe attachment is also available, £4.10. Remote drive is available from the paper drive axle.

Heathkit puts out a ready assembled recorder, IR-18M, at £95. It uses a servo motor to drive a fibre tipped or cartridge type fountain pen. Response time is 1sec F.S.D. The fastest paper speed is ½cm/sec, and it has two input sensitivities - 1mV and 10mV. The recorder uses 25cm wide paper rolls, perforated on both edges.

Jay Jay Instruments also put out a recorder, CR100, listed as costing £99.20, but as it is necessary to purchase an amplifier, CR120 at £20.80 to go with the recorder, the basic cost is £120.

Provided that the recorder is used as an aid to teaching the concepts of science, and not as a replacement for the necessary skills in collecting and plotting data, and provided it enhances student activity rather than replacing it, a chart recorder will be a most valuable piece of equipment in any laboratory.

In future bulletins there will be listed practical details of some of the experiments that can be performed better with a chart recorder, together with a summary of available recorders and their characteristics.

* * * * *

The following items of surplus equipment are now available at the Centre:

Item 15(31)	Relays. Mostly G.P.O. 3000 type with 2000Ω coils and four pairs of light duty c/o contacts, but some other types available. 5p each.
Item 16(31)	Switches. Heavy duty mains, 16A. 250V A.C. 5p each. Wafer, light duty, at least 2P3W. 2½p each. Toggle, centre off, bias one way 3A 250V A.C. 5p each.
Item 333	Exposure meters. Weston Master II and III types. Also one Weston II Cine type. £5 each.
Item 334	Component boards. Contain three "Ferroxcube 25" cores, one 500Ω w/w potentiometer, one CV4052 miniature valve and other useful components. 5p each.

Trade News

The Northern Media Supply Ltd. have a new address from 17th July, 1972. See address list.

Griffin and George supply the CLEAPSE designed aquarium heater/thermostat mentioned in Biology Notes. The catalogue number is L-05-570 and the price is £2.16.

The D. W. Blakley 'Lectoguard' Earth Leakage Protection unit also mentioned in Biology Notes costs £26.25, including a choice of circuit breakers from 10A to 80A. The 'Pluguard' costs £15.75.

Radionic Products Ltd. Their address has been changed. See address list.

The price of the Swift M240 microscope, mentioned in Bulletin 54, has now been increased from £29.50 to £31.50, duty paid.

The London office of the Aluminium Federation has closed. All inquiries for Anodising Kits, which now cost 35p, should be made to their Birmingham address. See address list.

We are advised by Morris Laboratory Instruments Ltd. that they are now the educational suppliers for the Russian Pen Recorder. Any other items in the Z and I Aero Services catalogue can also be supplied by MLI Ltd.

(Please note change of address of the MLI Scottish representative as given in the address list.)

In The Workshop

<u>Hot Air Engine Model</u> This was described in the Swedish Journal 'Elementa' Vol. 54, No. 4, December 1971. It is designed to show the direct conversion of heat into work. The model is very easily constructed from materials which are readily available. It is based on a filter receiver tube and a 10ml glass syringe.

The diagram on page 10 shows the construction. We mounted the whole on a wooden stand but instead the mounting can be done using a retort stand, bossheads and clamps. If the retort stand mounting is used weights can be placed on top of the syringe piston so that the raising of different weights can be studied. A weight carrier is provided in the model mounted on the wooden stand.

The displacer piston can be made from ordinary iron wire gauze but better results are obtained by using brass gauze. The brass gauze used in our model was 24 gauge, length 22cm, width 7cm. If iron gauze is not used a small oblong magnet must be wrapped up inside the gauze, and the ends of the roll of gauze are bent inwards so that there would be no sharp edges to rub against the glass and increase friction. The Eclipse horse shoe magnet may be attached by a bolt and nut to a strip of aluminium bent round the filter tube. This arrangement holds the magnet close to the filter tube so that moving it will cause the displacer piston with the small magnet inside it to move. The displacer piston also acts as a heat regenerator. The small roll of brass gauze next to the stopper is made from a piece of brass gauze 20cm x 2cm. This small roll of wire gauze improves the performance by acting as an additional heat sink.

To ensure uniform heating, ordinary wire gauze from a piece 7cm square is bent round the outside of the left-hand end of the filter tube.

To operate the model:

1) move the external magnet to the right so that the displacer piston is at the stopper end;
2) heat the left-hand end of the filter tube;
3) when the syringe piston has risen about half way in the barrel, move the displacer piston to the left and syringe piston should come down. Movement of the displacer piston backwards and forwards results in up and down movement of the syringe piston, even after the bunsen has been removed.

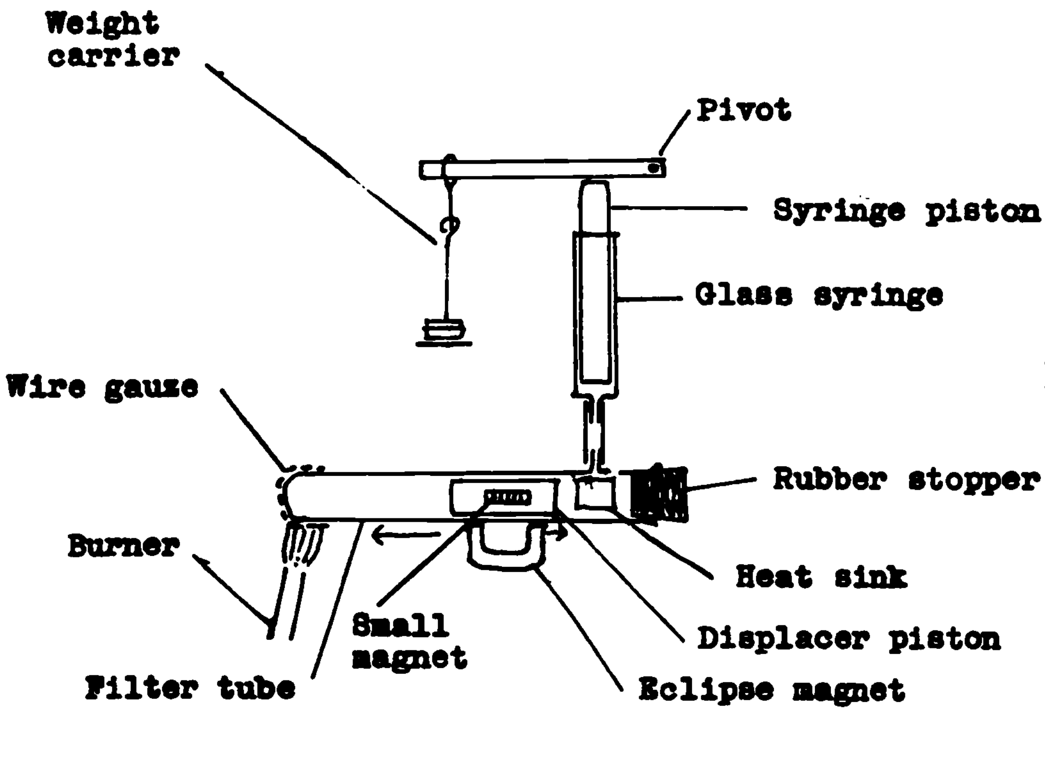
When the displacer piston is moved to the heated end of the tube, hot air is displaced and passes through the displacer to the cool end. This cools the air to produce a contraction which results in the piston of the syringe descending. When the displacer piston is moved to the stopper end, cold air is displaced and passes through the now hot displacer piston to the hot end in doing so becomes heated. This produces the expansion which results in the piston of the syringe rising. The model shows the principle of the hot air engine very clearly.

Materials used

Filter receiver tube 150 x 25mm Griffin and George S.25-722/020 Pack of six	£1.20
10ml glass syringe Gallenkamp SY41Q	.72
Eclipse magnet Philip Harris P6518/25	.73
Oblong Magnet Arnold KN647	.07½

A school may have alternative magnets which will be suitable.

Fig. 1



S.S.S.E.R.C., 103 Broughton Street, Edinburgh EH1 3RZ.
Tele. 031-556 2184

The Aluminium Federation, Broadway House, 60 Calthorpe Road, Fiveways, Birmingham B15 1TN.

E. J. Arnold and Son Ltd., Butterley Street, Leeds 10.

D. W. Blakley Ltd., 149-159 Ivydale Road, London SE15 3DX.

L. P. Butler Ltd., Grafton Street, High Wycombe, Bucks.

Dawe Instruments Ltd., Western Avenue, Acton, London W.3.

Ealing Beck Ltd., Greycaine Road, Watford WD2 4PW.

(Jay-Jay) Educational Measurements Ltd., 1 Brook Avenue, Warsash, Southampton SO3 6HP.

A. Gallenkamp and Co. Ltd., Technico House, Christopher Street, London E.C.2.

Gerrard and Haig Ltd., Gerrard House, Worthing Road, East Preston, Sussex.

Griffin and George Ltd., Braeview Place, Nerston, East Kilbride.

Philip Harris Ltd., 63 Ludgate Hill, Birmingham B3 1DJ.

Heath (Gloucester) Ltd., Gloucester GL2 6EE.

Linstead Electronics Ltd., Roslyn Works, Roslyn Road, near Braemar Road, London N.15.

Medicon U.K. Ltd., 5 Afton Bridgend, New Cumnock, Ayrshire.

Morris Laboratory Instruments Ltd., 96-98 High Street, Putney, London S.W.15.

Scottish Representative: Mr. Edward J. Brown, 23 Quarry Road, Law by Carluke, Lanarkshire. Tele. Carluke 3755

The Northern Media Supply Ltd., Crosslands Lane, Newport Road, North Cave, Brough, Yorks.

W. R. Prior and Co. Ltd., London Road, Bishop's Stortford, Herts.

Radionic Products Ltd., St. Lawrence House, 29/31 Broad Street, Bristol BS1 2SF.

Walden Precision Apparatus, Shire Hill, Saffron Walden, Essex.

Z and I Aero Services Ltd., 44a Westbourne Grove, London W2 5SF.