SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 27. December, 1968.

Contents

Introduction

The Governing Body have appointed Mr. Hugh Medine, Principal Teacher of Chemistry at St. Michael's Academy, Kilwinning, to the post of Assistant Director.

Mr. W. MacKenzie, formerly of Peterhead Academy, and Mr. R.B. Dunphy, of Allan Glen's School have resigned from the Development Committee. Their places have been filled by Mr. J. Smart, Dundee High School, and Mr. D. Glen, Clydebank High School.

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The Centre will be closed on Christmas Day and New Year's Day.

Trade News

In view of what we wrote in Bulletin 19 on the conflict between the use of Super 8 and Standard 8 formats for the production of cassette loop films, two recent announcements may be of interest to teachers who have still to make the choice of loop projector. The first is that Ealing Scientific have ceased production of Standard 8 format. This means that not only will all new loops be made in Super 8, but that once existing loop stocks of Standard 8 have been sold, they will be replaced by Super 8 loops. So if you have a Standard 8 projector and there are some Ealing loops you would like to have.....

The second is that Sound Services are marketing a Standard 8 loop projector, the THD Model 10, in which provision has been made for conversion to Super 8. This would enable the teacher to have the best of both worlds; Standard 8 until the catalogues of Super 8 have been enlarged, and then to change over to Super 8. The cost of the projector is £87.10s.

The wooden circuit box referred to in the Physics Notes and Workshop sections of this Bulletin is available from Wm. Foster (Rainford) where it is referred to as "1 gang 1 1/8in". Cost of the boxes is 7s. 2d. per dozen, plus postage.

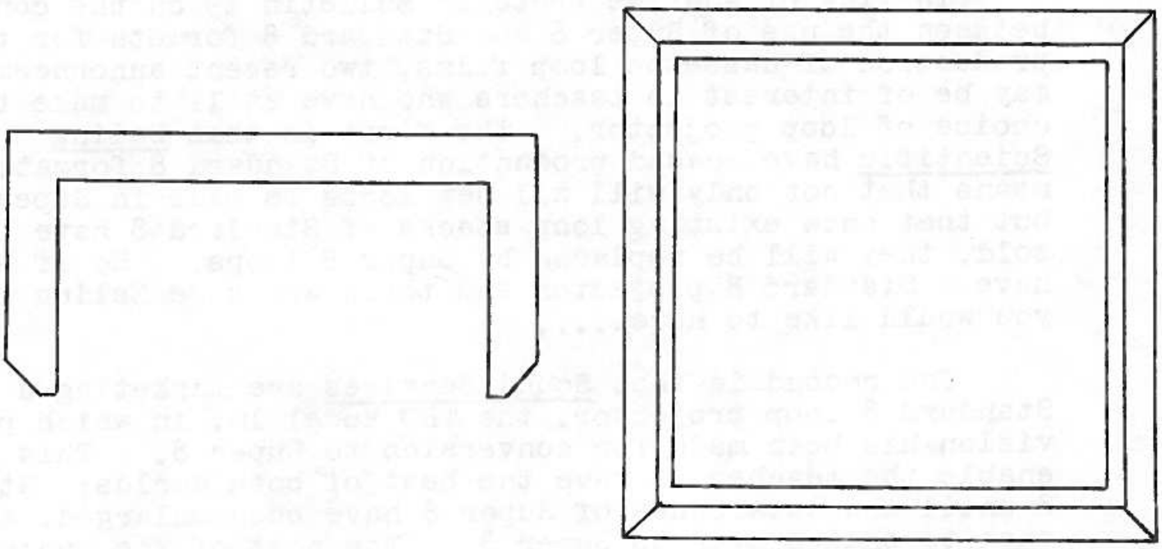
An overhead projector from Rank Audio Visual, called the Rank Aldis projector, is completely portable, and has the ability to be up-ended so that the normal writing surface is vertical, thus allowing the projection of test-tube experiments etc. The projector uses a 650W tungsten-halogen lamp, and costs £98.

Griffin and George have written us stating that the chemicals required for the new Biology Syllabus published in Bulletin 23, viz. Items 54, 55, 57, 60, 85, 93 and 103 have now been added to their stock of chemicals.

Physics Notes

In the previous Bulletin we mentioned the difficulty of securing a supply of wooden circuit boxes, type MK3890, which, since they were brought to our notice by Jordanhill College of Education, have been used here to mount an assortment of small components for connection to 4mm terminals. As readers will see by referring to the Trade News section on page 1, boxes very similar to the MK3890 are still available, but as they have been withdrawn from the official list of electric circuit boxes, which is their original function, there is no guarantee that the supply will continue. If they had to be made specially for schools they would undoubtedly cost more.

It is for these reasons that we rush into print to offer a few of the uses we have found for these boxes. We believe that they are sufficiently versatile for us to suggest that every school should order a gross; larger schools could do with double or treble this amount. Below we reproduce full-scale the design of the box which is hardwood with an open top.



<u>Uses</u>

1. Mounting batten holders for low voltage or mains lamp bulbs; in the latter case the cable is knotted and then passed through a hole in the side of the box, thus avoiding strain on the constructing wires.

2. Mounting wire-ended radio components such as capacitors, resistors, semi-conductor diodes. There are two ways of doing this; firstly to cement the component on the box top with the wire ends passing through the top to 4mm sockets fixed either on the box top or sides. Alternatively, the component may be contained within the box, when the top may be marked in felt pen with the circuit symbol and value, power rating etc. A coat of/

of clear varnish will then preserve the labelling. With either method the boxes are stackable.

3. Mounting the smallest size of Japanese meter, type MR38P. A large hole for the meter, and four fixing holes for the bolts are drilled in the top. It is not necessary, even if it were possible, to screw the meter down as a push fit into five holes is sufficient to hold it in place. If the large hole is drilled centrally on top, the 4mm terminals must come on the side of the box. By off-setting the meter, however, the terminals can also be fixed on the top.

4. Mounting all types of toggle, push-button or tumbler switches. Even a double-pole, double-throw switch can be accommodated with a row of three 4mm terminals along opposite sides of the box.

5. Mounting radio-type potentiometers, and small (transistor) transformers.

6. Mounting transistors. A three-way section of barrier terminal strip is screwed to the box top, and the transistor connections screwed to one side of the strip. This avoids soldering of transistor leads, and facilitates replacement.

7. Mounting U2 cells. Strips of copper sheet are stuck on inside edges of opposite sides and connected to terminals. The box is used upside down as the sides are not deep enough to clear the cell. See the Workshop section of this Bulletin.

8. Mounting selenium photo-emissive cells. These are stuck with impack adhesive to the box top. Four of the <u>Proops Brothers</u> type 1 cell can be fixed on one box to make a battery. See also Bulletin 25 for the design of a light meter, using one of these boxes.

In all cases the 4mm terminals we used were <u>Radiospares</u> type "Insulated Sockets".

Chemistry Notes

One method of demonstrating the existence of polarised molecules in organic compounds is to measure the relative permittivity, or dielectric constant of the compound. If the molecule is polarised, then the application of an electrostatic field causes it to orientate itself in the field direction. Because all the molecules will be orientated similarly, the energy of the system has been increased.

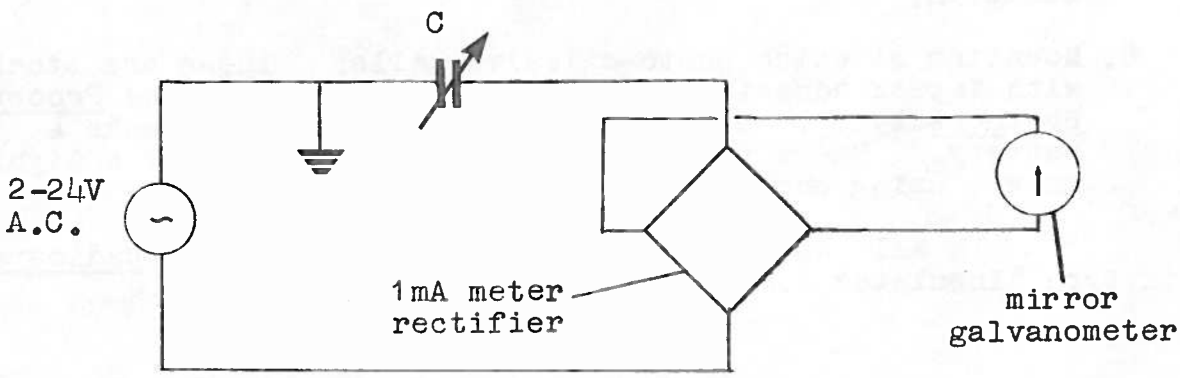
The capacitance of a parallel plate capacitor is given by $C = \frac{\epsilon A}{d}$, where A is the area, d the separation between the plates, and ϵ is the permittivity of the medium between the plates. The dielectric constant of the medium is the ratio of its permittivity to that of free space (or, what amounts in practical terms to the same quantity, air).

Thus/

Thus, relative permittivity = e_r/e_o = k, the dielectric constant. If the air space between the plates of a capacitor is replaced by a medium of dielectric constant k, then the effective capacitance is increased in the ratio e_r/e_o = k. That this increases the energy stored will be seen when it is remembered that energy = $\frac{1}{2}CV^2$.

Measurement of the dielectric constant, which is related to the dipole moment of the molecule, then involves measurement of a capacitance with and without the compound between the plates. What we indicate in this note is a method of doing this using readily available equipment, most of which will already be in the physics, if not the chemistry department. The basic method involves passing alternating current at 50Hz through the capacitor and measuring it. Two methods of measuring the required ratio are possible. One assumes that current is directly proportional to capacitance on a fixed supply, and measures the ratio of currents. This involves the pupils knowing, or accepting, that current is proportional to capacitance, and also assumes that the detecting system is linear. The other more satisfactory method makes no such assumption, but uses a variable area capacitor to produce the same current with and without the medium in the space between the plates. Whatever the failings of the detector system it is then safe to assume that the same current results from the same capacitance, so that $e_o A_1 = e_r A_2$, and the dielectric constant can be deduced from the ratio of the areas interleaved.

The circuit diagram is given below:



The capacitance C is two gangs of a radio tuner condenser - and we use the term knowingly, since the most suitable type was certainly made in the days when it was called a condenser. What is required is a component which is not too small, has a maximum capacity of 500 + 500 pf when both gangs are connected in parallel, and which has its fixed sections insulated from the frame with ceramic rather than plastic insulating material. While some forms of plastic may withstand the organic solvents to be poured round them, others will not, and we played it safe by using ceramic. The capacitor should also have a slow-motion drive, either built-in integrally as is most frequently the case with radio tuners, or by means of external gearing to give a 4:1 gear ratio or thereby. Some form of scale to indicate the position of the vanes is also necessary.

The capacitor is mounted on a metal box lid, the box being also of metal and leak-proof, i.e. if made of tinned sheet it should have soldered joints. The capacitor when in the box requires to be calibrated, and this we can arrange to do for any suitable capacitor sent to us, to within 3-4% which is sufficiently/

sufficiently accurate for this experiment. The determination of relative permittivity then consists in finding the ratio of capacitances, obtained from the calibration graph, with and without the organic substance, which will give the same current reading in the galvanometer. The capacitor is first placed in the empty box, and connected in the circuit shown. The earth connection is to the box itself, and is necessary to eliminate hand capacity effects. Earthing to an adjacent gas tap or mains earth point is sufficient. The capacitor is set at or near maximum, and the input voltage adjusted to give a reasonable reading on some range of the galvanometer. The capacitance C_1 is noted from the calibration graph, the capacitor turned down to minimum capacity and liquid poured in to a sufficient depth to cover the vanes completely (but not to come into contact with, and possibly dissolve, any insulation on 4mm terminals which will have been used to connect the capacitor to the external circuit). The capacitor is then adjusted to give the same current reading as before for the same input voltage. The ratio of the two capacitance values C_1/C_2 is the relative permittivity or dielectric constant of the liquid.

Turning now to the constant capacitance method, it will still be necessary to obtain a radio tuning capacitor, since this is the only readily available form of air-spaced capacitor of sufficiently large capacity. The difference is that it does not require to be calibrated. The galvanometer reading is taken, other things being equal, with and without liquid in the capacitor, and ratio of the readings is assumed to give the relative permittivity. The assumption is invalid because the rectifier system is working under very non-linear conditions, so that although meter reading will increase with A.C. current they are not proportional. It would be possible to calibrate the entire circuit by using high resistances in place of the capacitor, drawing a calibration curve of resistance values against galvanometer reading. The range of resistances required would be from 10 - 500kΩ, and it is doubtful whether the experiment justifies this labour. As it is, the constant capacitance method is probably sufficiently indicative to bring home the main point of the experiment, which is not the accurate measurement of dielectric constant, but to show that the dielectric constants of polar molecules are several times greater than those of non-polar molecules.

The constant capacitance method will give a wide range of values for the dielectric constant, depending on the type of galvanometer and the range on which it is used, and also on the supply voltage. The table we give below will show the type of result to be expected. The galvanometers used were W.P.A. K104 and Pye Scalamp 7904S; the power supply was a Nuffield type low voltage power unit. Chlorobenzene was not measured using the constant capacitance method as the supply of liquid became contaminated before this could be done.

Liquid	Constant Current	Constant Capacity
Carbon Tetrachloride	2.1 - 2.3	2.3 - 4.2
Trichloroethylene	8.7 - 9.5	18 - 30
Benzene	2.1 - 2.2	2.2 - 4.0
Chlorobenzene	22 - 23	---

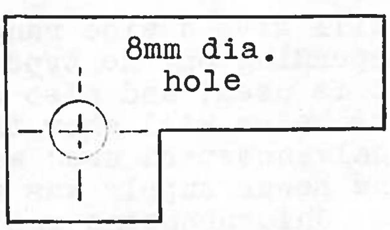
The/

The range of liquids which can be tested with this circuit is limited. Alcohols cannot be used because of water absorption, nor can any liquid which has become water contaminated. What happens when such liquid is used is that the current flowing is more resistive than capacitative, and the galvanometer will deflect off-scale. As a rough and ready test, we rejected any liquid which allowed more than 5μA of current to pass when used in a Griffin and George conical conductivity flask, S75-694/20, with an applied P.D. of 400 volts. This is well below the range of conductivities measured on the standard-type conductivity bridge. For teachers without the Griffin flask, the electrodes were carbon rods spaced 3mm apart and immersed for 25mm of their length.

In The Workshop

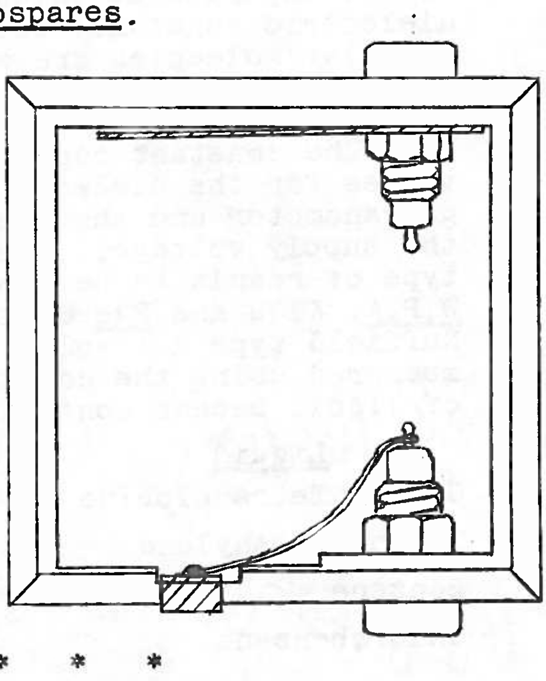
Our method of mounting U2 cells so that they can be used with 4mm plugs uses the wooden circuit box discussed elsewhere in this issue. The inside length of the box is 57mm, which is a mm short of the cell length, so that one has to cut out a slot 35mm wide and 1-2mm deep from one side of the cell. In the centre of this is cut a further 2mm deep slot, 12mm wide to take the raised stud of the centre terminal of the cell.

To make connection to the positive terminal a 10 x 30mm strip of 22 SWG copper sheet, with a wire soldered to one end, is cemented with Evostik into the central slot. The top end of the strip is bent over the lip of the box to give additional strength. For the negative terminal, a section as shown is cut from the same copper sheet and secured to the box by the bolt on the 4mm terminal. If the "flag" position of this is bent slightly forwards it is sufficiently springy to make good contacts at both ends of the cell. The terminals are "Insulated Socket" type from Radiospares.



Strip for -ve terminal connection

Scale full size



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The ether engine published in the School Science Review, No. 167, p.219 is a good example of how a basic energy convertor works, using a temperature difference to produce alternate evaporation and condensation of ether. The volume change displaces mercury, moving the centre of gravity so that the whole apparatus tilts to and fro. We decided to extend the apparatus to make it do work in raising a load, by adding a ratchet and pawl mechanism, and it is for that reason that the design of the apparatus is given here. It is also a very simple heat engine to comprehend, and should find a place in any "Stations" group of energy conversions. Lest it be thought too simple, its construction is a nice sixth-year project. It is a mechanical analogue of the electrical flip-flop or multivibrator circuit, since it has two unstable states and once a change is initiated, it flops rapidly from one extreme to the other. As an open ended project, a search might be made to find a liquid with more suitable latent heat of evaporation, boiling point, temperature coefficient of vapour pressure etc., than ether.

A bulb 15mm diameter is first blown on the end of a 40cm length of soda glass tube, 5mm diameter. If this size is not available, then a smaller rather than larger bore should be chosen to reduce the possibility of ether vapour escaping through the mercury. The tube is then bent as shown in Fig. 1; dimensions are not critical. The tube is clipped to a perspex sheet, measuring 230 x 77 x 7mm, using two Terry clips with two short lengths of rubber tubing wrapped round the glass tube as protection. Perspex was used in preference to hardboard as the ratchet mechanism is then visible. The mercury reservoir is a 10ml disposable plastic syringe, also secured by a Terry clip, and with a 2 BA bolt fixed to the perspex to support the base of the syringe. Without this, the clip is not strong enough to support the reservoir against the shock of stopping the "engine" at the end of each throw, and the syringe jerkily slips down through the clip. Fig. 1 also shows the all-important position of the pivot. This may well have to be determined by trial and error by drilling a small hole first and supporting the apparatus on a wire, bringing beakers of hot and cold water up underneath the bulb to verify whether the apparatus tilts or not.

Filling the tube should be done before attaching it to the syringe, attaching a short-stemmed thistle funnel to it and supporting it in the working position. A little ether is poured in, and by alternate heating and cooling of the bulb, preferably by water baths, the ether, followed at the appropriate moment by mercury, is induced into the bulb. Only a drop or two of ether is required; it should be sufficient to push the mercury half way along the horizontal portion of the glass tube when evaporated. If too much is used and it escapes into the mercury reservoir when the apparatus has been assembled, it will attack the plastic of the syringe. This is a minor disadvantage of using plastic which will only occur at the initial assembly of the model.

Fig. 2 shows the assembly of the combined pulley and spindle, which is made from aluminium rod, and, apart from the 5mm square section which fits the ratchet wheel, is turned and drilled on the lathe. The larger ball-race measures 7/8" O.D., 3/8" I.D., 7/32" thick. It is a push fit inside the face plate, also of aluminium, which secures the outer ring of the race against the wooden support. The inner ring of the race is a push fit on the spindle. The race supports the spindle while allowing it to move relative to the wooden framework. The smaller ballrace is ½" O.D., 3/16" I.D., and 5/32" thick. Its outer ring is a press fit inside the perspex sheet, and the inner ring is sandwiched between two washers which secure it against the outer face of the ratchet wheel. Both races are obtainable from K.R. Whiston, under the heading of 1st Class Races, for 3s.6d. and 2s. respectively.

Our/

Our ratchet wheel was taken from a clock mechanism and has an overall diameter of 25mm, 20 teeth, and a central 5mm square hole to key it on to the spindle. Any other ratchet wheel of similar size will serve, provided the spindle is filed to suit. The pawls are filed to shape from No. 11 SWG (3mm thick) mild steel or brass sheet, starting by drilling and countersinking the fixing hole to give clearance for a 4 BA bolt (No. 27 drill). One pawl is fixed to the faceplate, which has a hole drilled and tapped 4 BA for this purpose. The position of the hole is best found by trial and error, finding an approximate position when the pawl has been roughly filed to shape, drilling the hole and then completing the shaping of the pawl to fit the ratchet wheel. The second pawl is similarly fitted, but is fixed to the rear face of the perspex sheet by a 4 BA countersunk nut and bolt. With both pawls fitted above the ratchet, gravity helps to drop them into place, but we found it necessary to spring-load them, probably because the surfaces get steamed up from the hot water used to operate the engine. Each spring is a length of 26 SWG phosphor bronze wire, wound 6-7 times round a 6 BA bolt. The wire end bearing on the pawl is looped to make it slide freely, the fixed end of the wire is secured to the wooden support or the perspex respectively. One bolt is self tapped into the perspex sheet, the other into the wooden support. Fig. 4 gives details of this part of the construction.

Fig. 5 shows the general shape of the wooden support for the model. The slot has been cut away to allow the load being raised to be seen from the front. The load is a 40mm dia. brass cylinder filled up with molten lead and adjusted when cold by turning on the lathe to have a mass of 750g. We had previously checked that the model would lift a slightly greater weight than this. Two stops A and B, consisting of 2 BA bolts covered with rubber tubing are fixed one on either side of the slot. These arrest the tilting of the model at each end by stopping the perspex sheet, and their position is governed by the need to ensure that the "stroke" of the engine is a whole number of ratchet teeth, in our case 3. A small amount over and above the exact whole number can be allowed as lee-way as the pawls are not close-fitting on their fixing pivots, but anything beyond this will reduce the horse-power - already low enough! - of the engine by allowing it to run back before the pawl arrests it. Both pawls should, of course, drop down on the teeth more or less simultaneously, as shown in Fig. 4. The position of stop B determines the height of platform at the right hand side of the model used to support the heat source, which is a suitably shaped glass or plastic bowl of hot water. A cup hook, secured with thread to the pulley which has a small hole drilled through it for the purpose, and screwed into the lead block, complete the load-raising arrangement.

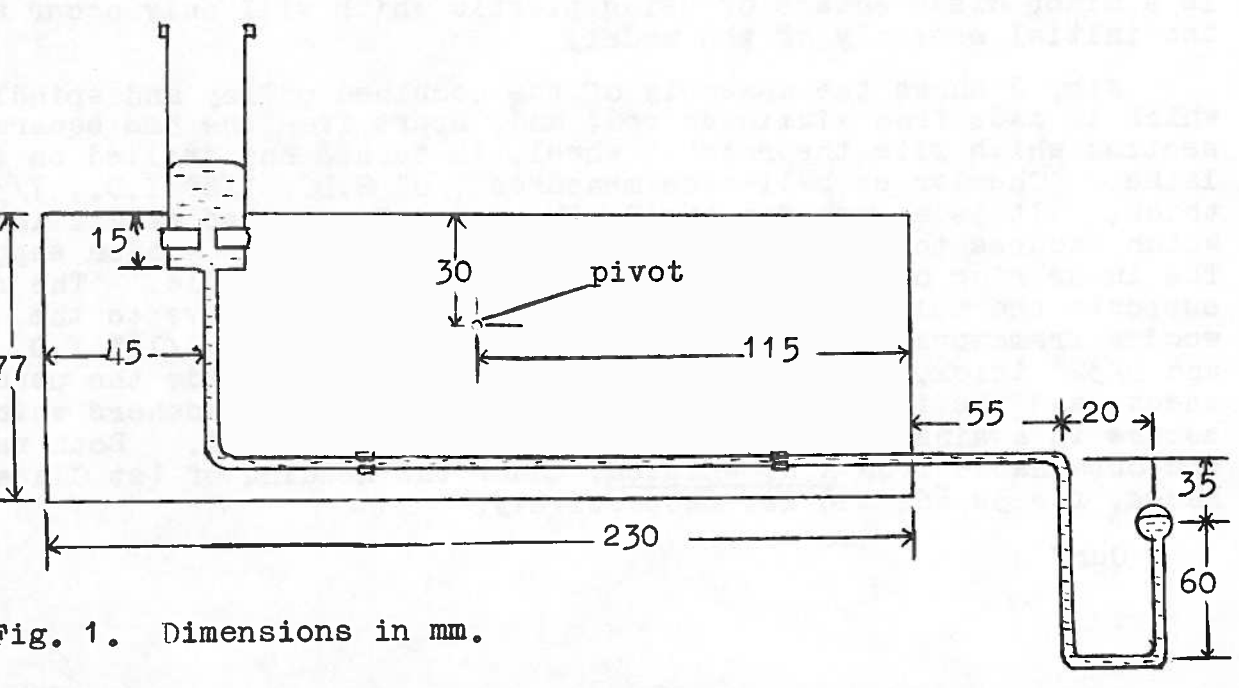

Fig. 1. Dimensions in mm.

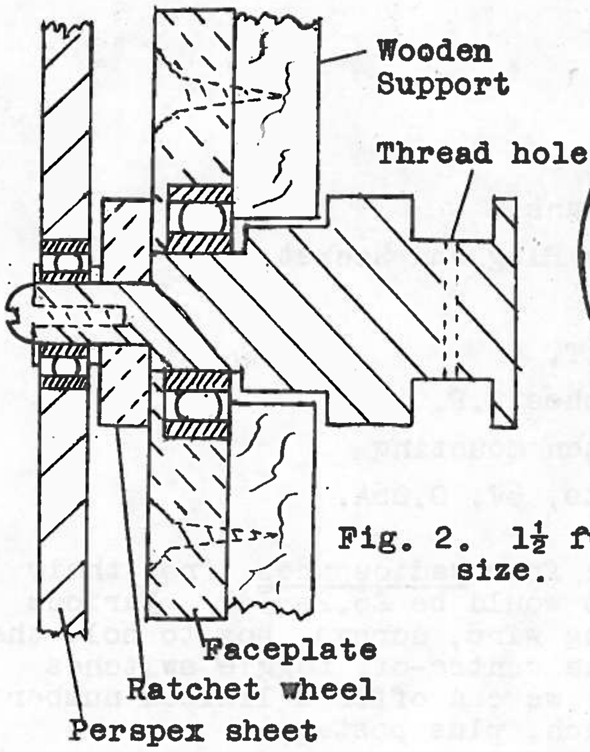

Fig. 2. 1½ full size.

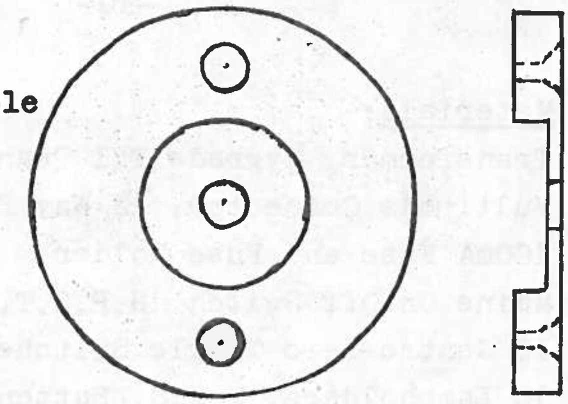

Fig. 3. Faceplate, full size.

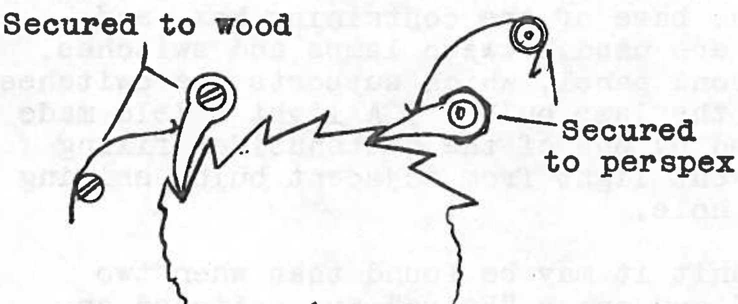

Fig. 4. Ratchet detail

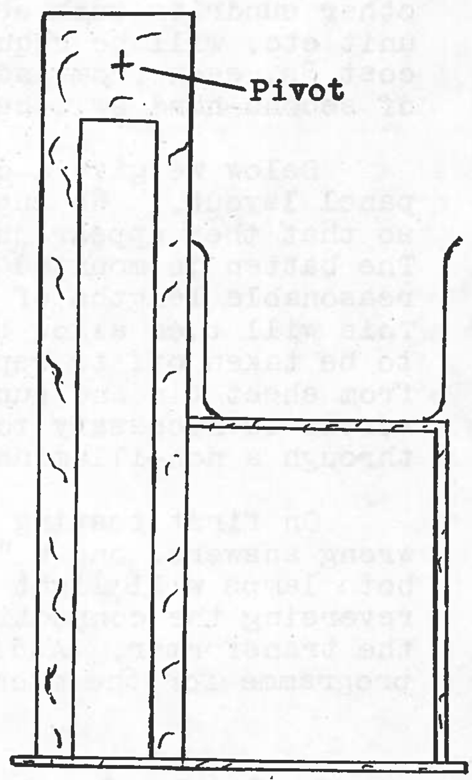

Fig. 5.
Scale: 5:1

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The marking machine described was made up at the request of one of the local authorities for a self testing device which could be "programmed" to cover different topics and which would give a response to ten questions of the straight alternative, i.e. True/False type. A continuity circuit is used, so that the correct response is shown by a lamp lighting up on the front panel of the machine.

The circuit diagram is shown in Fig 1. Two separate power lines, derived from two 6.3V windings on a transformer are used to feed the True and False responses respectively. Three position toggle switches, which have a centre OFF position, are operated by the pupil to select his reply to a printed sheet of the ten questions. "Programming" is done by plugging into the machine a 12-point plug which has been wired internally to correspond to the programme to be used. On the corresponding socket two of the pins are used as links to the power lines and the remainder are wired sequentially to the lamps.

Materials/

Materials:

Transformer, Hygrade Fil Trans.

Multipole Connector, 12 Way Plug and Socket

100mA Fuse and Fuse Holder

Mains On/Off Switch, S.P.S.T.

10 Centre-zero Toggle Switches S.P.D.T.

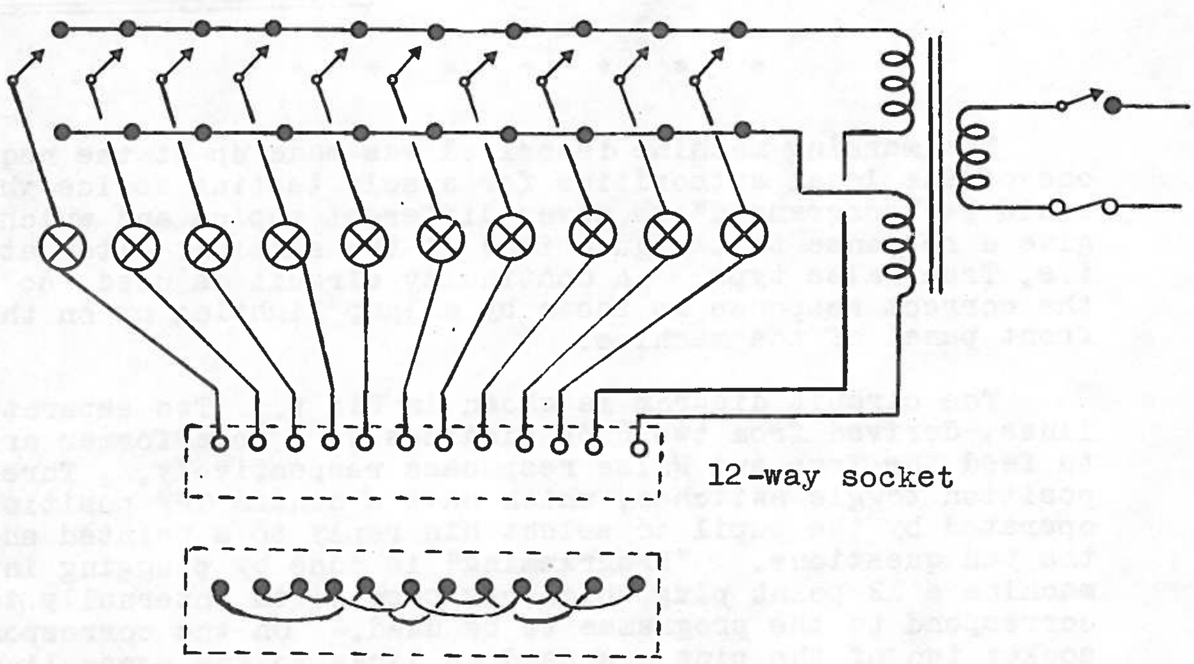
10 Lampholders, M.E.S. Batten mounting

10 Lamp bulbs, M.E.S. pilots, 6V, 0.06A.

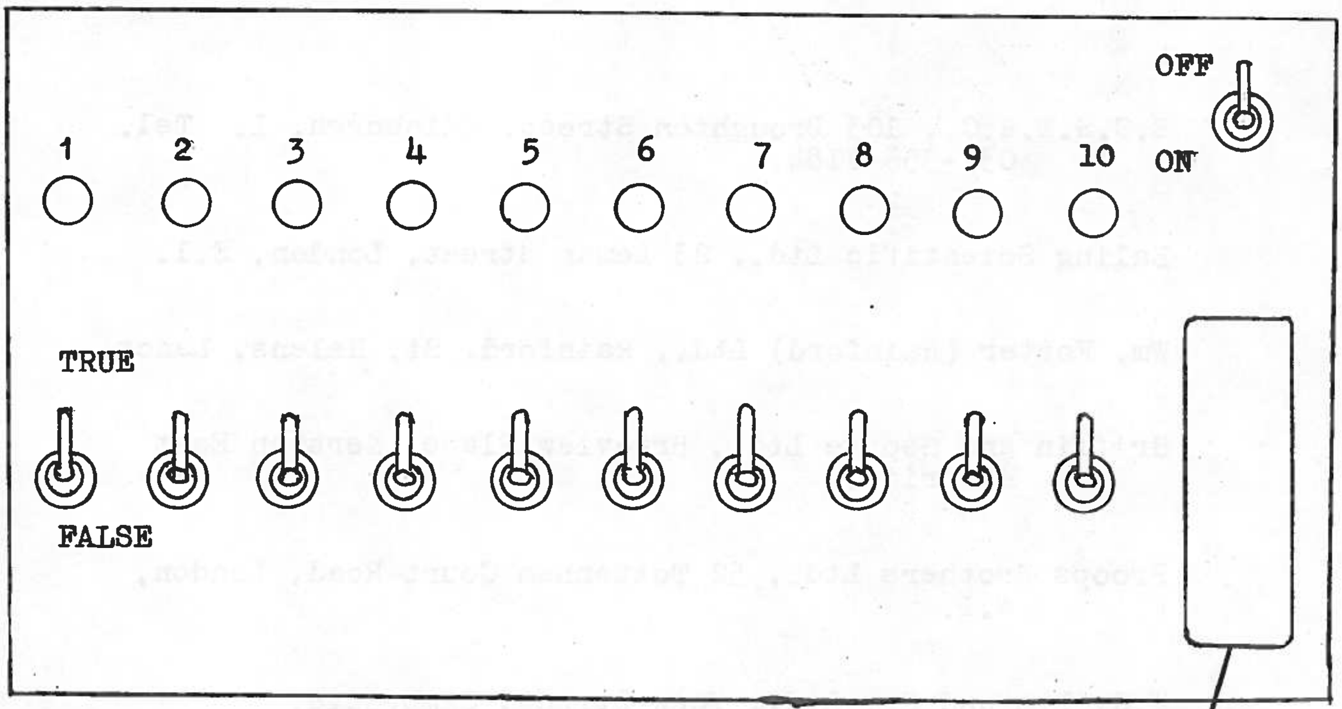
All the above are available from Radiospares; from their current catalogue the total cost would be £6.2s.3d. Various other sundries such as connecting wire, screws, box to hold the unit etc. will be required. The centre-off toggle switches cost 8s. each from Radiospares; we can offer a limited number of second-hand switches at 2s. each, plus postage.

Below we give a circuit diagram, and one possible front-panel layout. We suggest mounting the lamps on a wooden batten so that they appear just beneath the holes in the front panel. The batten is mounted on the base of the containing box, and reasonable lengths of wire are used between lamps and switches. This will then allow the front panel, which supports the switches, to be taken off to replace the lamp bulbs. A light shield made from sheet tin and supported by one of the battenholder fixing screws is necessary to prevent light from adjacent bulbs shining through a non-illuminating hole.

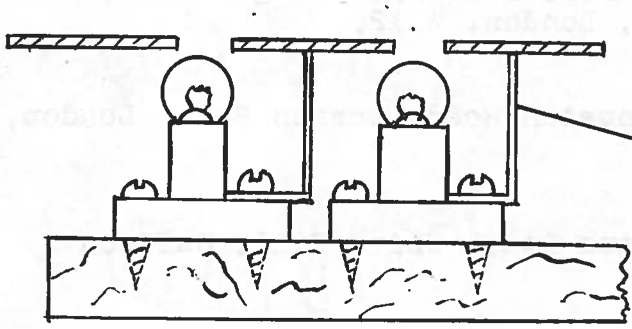
On first testing the unit it may be found that when two wrong answers, one a "True" and one a "False" are switched on, both lamps will light up. This mistake can be corrected by reversing the connections to either one of the 6.3V windings on the transformer. Additional 12-way plugs, to give more than one programme for the machine, will cost 15s. 9d.



12-way plug, wired internally to pins 1 and 2, to correspond to the programme being used.



Suggested top panel lay-out



Mounting of lamps

S.S.S.E.R.C., 103 Broughton Street, Edinburgh, 1. Tel. 031-556 2184.

Ealing Scientific Ltd., 23 Leman Street, London, E.1.

Wm. Foster (Rainford) Ltd., Rainford, St. Helens, Lancs.

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

Proops Brothers Ltd., 52 Tottenham Court Road, London, W.1.

W.G. Pye and Co. Ltd., York Street, Cambridge.

Radiospares Ltd., P.O. Box 268, 4-8 Maple Street, London, W.1.

Rank Audio-Visual Ltd., P.O. Box 613, Woodger Road, Shepherd's Bush, London, W.12.

Sound Services Ltd., Kingston Road, Merton Park, London, S.W.19.

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

K.R. Whiston Ltd., New Mills, Stockport, Lancs.