SCOTTISH SCHOOLS SCIENCE EQUIPMENT RESEARCH CENTRE

Bulletin No. 110. January, 1979.

Contents

Introduction

About the time that this is being read by science teachers, the SSSERC 'Hazardous Chemicals Manual for Schools and Colleges' will make its first appearance in the educational bookshops. Through some fault of ours, the publishers, Oliver and Boyd have been unable to keep it at the promised price of £3.95, and it will now cost £4.25. The main reason is that when the proofs were read by selected persons in England, they suggested a number of chemicals for inclusion, and this increased the entries by about 10%.

It will appear in a comb binding, which makes it possible although not easy to remove and replace pages. We requested this so that independently of the publisher we could supply up-dating sheets for new entries where needed, or for revision of existing entries. This would not happen very often, certainly not more often than yearly, but they would be supplied as part of the SSSERC service free of charge through the usual bulletin channel. In absence of other information we would supply one set of up-dating sheets per school, but where we know that schools possess more than one copy of the manual we would send however many were needed. Hence we ask the principal teacher of chemistry to let us know soon after he has received his copies, how many he has, so that our records may be kept straight. Orders should be sent to Oliver and Boyd, although any that we receive will be passed on but we do not guarantee them special treatment.

Every new product has to have a sales gimmick, a point of uniqueness which makes it superior to every other; we hope ours is truer than most. What we claim for ours is prevention. Most manuals of dangerous chemicals tell the user what the hazards are, and how to cope with them if an accident occurs. We tried to see the situation through the eyes of a junior technician in his/her first year in a large school. We felt sure that insofar as he knew there were risks, he would want to know a safe way through the job which hopefully would not cause an accident. He first meets the chemicals when he opens the crates in which they arrive. How does he handle and store them? If he drops a bottle, what are the risks and how should he deal with the spillage? We want him to know the answers to these questions while he is still reading the list of items on the delivery note, which should be, but almost never is, tacked to the outside of the crate. We hope he will read our manual at this stage, we hope he has been instructed to do so by his superior (it may safeguard the superior if he has) and we hope he will find there specific instructions related to his own school which the principal teacher has already written in. If all this has been done we feel that the technician will have been shown how to handle these substances with the minimum of risk. It would be unrealistic to expect more.

Biology Notes

It is prudent to check occasionally the efficacy of sterilising procedures used to prepare media for microbiology and for disposing of used cultures (see Bulletin 98). Rubber seals on autoclaves can become inefficient. The recommended pressure of 103kN/m^2 may not be

fully maintained and the required 120°C for 15 minutes to ensure sterilisation may not be achieved. Equally ovens may not be reaching the temperatures shown on thermostat settings or calibration charts.

Teachers and technicians who have attended recent SSSERC exhibitions and safety lectures, will have seen our demonstrations of the use of autoclave tape. Autoclave tape is heat-sensitive and when adequately exposed at the right temperature it develops deep brown or black diagonal stripes. Pieces attached to apparatus before it is autoclaved or subjected to dry heat in an oven, provide a simple method of checking that it has spent the requisite amount of time at the correct temperature. Autoclave tape is available from a number of major and local suppliers. Ours was purchased from Mackay and Lynn at £1.09 for the 3/4" width and £1.28/reel for 1" wide.

There is another technique but this is more laborious and involves the use of spore strips of the heat tolerant bacterium Bacillus stearothermophilus. Dry spore-treated strips of paper are placed inside the apparatus and, after sterilisation, the strips are removed and incubated. Nutrient broth is used as the medium with an incubation temperature of 55°C. Sterilisation is held to be effective if there is no growth (indicated by turbidity) after 4 days. Spore strips are available from some supply houses (e.g. agents for Oxoid) and cultures of B. stearothermophilus are sold by Philip Harris Biological. It will not be necessary at school level to include tape or spore strips on every occasion that a heat sterilising system is used. However it would be wise to so test the system whenever it is brought into use, with the first batch of a set of materials, and at intervals if a large number of batches is to be treated.

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In our review of oxygen meters in Bulletin 102 we mentioned that some oxygen electrodes can be bought as separate items and used with school-built circuitry. With recent increases in the price of commercially produced oxygen meters d-i-y circuitry has become an even more worthwhile proposition. Uniprobe sell a galvanic electrode (see Bulletin 102), the DO 100 Cat. No. 15-141 and also provide some circuit details and applicational notes. At the time of writing the DO 100 electrode costs £16.50.

The operation of a galvanic electrode does not require the application of a voltage, there already being a potential difference between the silver cathode and the lead anode. The simplest circuit which can be used therefore is with the electrode connected directly to a moving coil microammeter in order to measure the variation in the current output of the electrode with changing oxygen concentration. We have evaluated this circuit and have made calibration graphs for both gaseous conditions and dissolved oxygen. However we found that maximum current outputs were small, typically less than 20μA, so that only crude measurements were possible.

A more practical circuit is obtained by using the electrode with a voltage divider and a mirror galvanometer, which almost every school possesses, or a sensitive chart recorder. The electrode is first conditioned by immersing its tip in an oxygen-free environment e.g. a 6 per cent (w/v) solution of sodium sulphite, with the terminals shorted. This is in order to remove any oxygen which may have built up in the electrolyte. The electrode is then connected in the circuit. The 1kΩ potentiometer acts as a simple 'span' adjustment and allows the system to be calibrated so that a direct reading of oxygen concen-

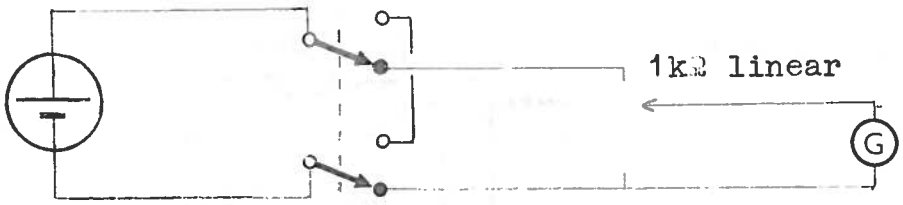

Fig. 1. Circuit for use with mirror galvanometer or chart recorder.

tration can be obtained. For gaseous measurements the reading in air can be used for single point calibration - being assigned a value of 21 per cent oxygen. For dissolved oxygen measurements the reading in a 6 per cent (w/v) solution of sodium sulphite is the zero reference and the reading in an air-saturated sample is assigned a value of 100 per cent saturation. With a mirror galvanometer such as the WPA Edspot or a Scalamp a scale is chosen which will allow, for gaseous measurements, a value of 2.1 (= 21 per cent) to be set for air and for dissolved oxygen measurements a value of 10 (= 100 per cent saturation) for a saturated sample, the oxygen content of other samples at the same temperature being determined by comparison. An alternative method for dissolved oxygen, if all the measurements are to be taken at the same temperature, or temperature corrections are to be made, is to calibrate so that the galvo scale readings correspond to p.p.m. or mg/l oxygen. If a chart recorder is used it is a simple matter to calibrate the system so that divisions on the chart paper correspond to the required units.

Unfortunately the circuit shown in Fig. 1 is useless for measurements in the field since it requires mains-powered ancillary equipment. To make the system battery powered, the electrode signal must be amplified so that it can be conveniently displayed on a moving coil meter. The circuit shown in Fig. 2, which uses an operational amplifier, is based on that given in the Uniprobe literature, but we have made a number of modifications so that only one battery is required and a milliammeter rather than the more expensive micro-ammeter can be used.

The set-zero control is used to offset the small residual current which is produced by the probe even in media of zero oxygen content. The 1kΩ variable resistor is used as before to set the span, allowing calibration of the electrode so that the meter reads full scale in a saturated sample of water, reads 21 per cent oxygen in air or full scale in oxygen. When not in use the probe discharges through the 1kΩ potentiometer, which prevents a build up of oxygen inside the electrode and removes the need for too frequent 'conditioning'.

Polarographic electrodes of the type sold by WPA and Griffin and George can also be used in home-made circuitry. This type of electrode requires an applied polarising voltage of between 0.6 and 0.8V. A suitable circuit for providing such a polarising voltage is shown in Fig. 3. The output from this circuit can be fed directly to a chart recorder such as the WPA CQ75 or the Educational Measurements CR500.

When the output is to be displayed on a mirror galvanometer, it is convenient to be able to arrange the circuit so that it can be set to 2.1 (= 21% oxygen) for air, and to 10 (= 100% saturation) for dissolved oxygen. The size of signal from the probe is very different in air and in water, so that different resistors have to be switched for the two sets of conditions. A further complication occurs because the WPA Edspot is a low resistance type, and the Scalamp is high resistance. Hence we give two separate circuits, Fig. 4.

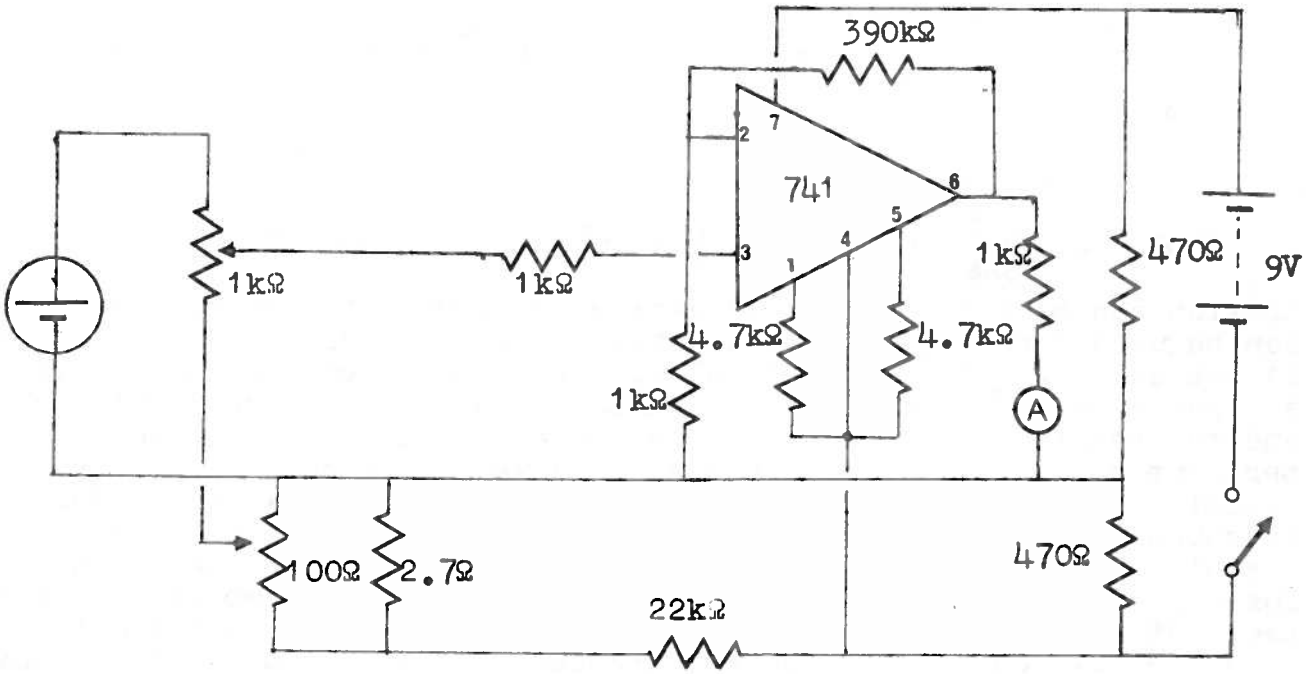

Fig. 2. Amplifier for Uniprobe galvanic electrode.

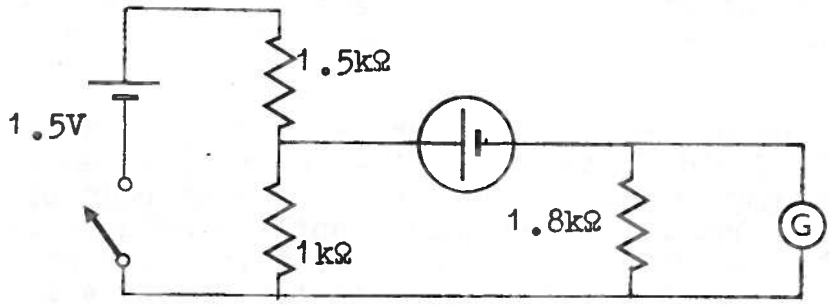

Fig. 3.

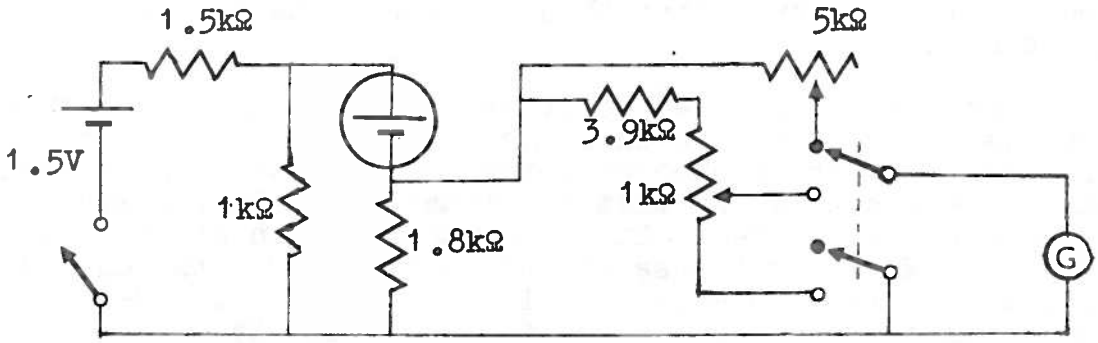

Fig. 4(a). Scalamp circuit.

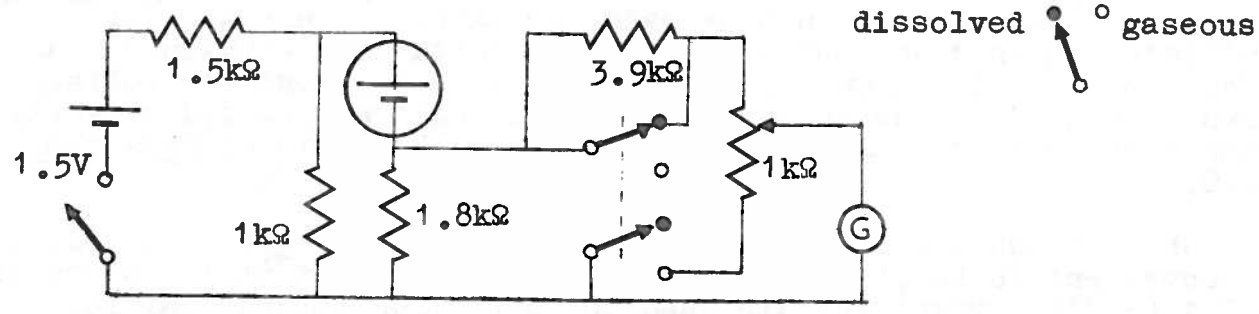

Fig. 4(b). WPA Edspot circuit. In both circuits the potentiometers are wire-wound linear types.

Obviously the Fig. 4 circuits are useless for fieldwork, and for this the output across the 1.8kΩ resistor of Fig. 3 must be amplified using a similar circuit to that of Fig. 2.

Chemistry Notes

Schools which have bought water de-ionisers in the past will have bought a book of vouchers which are exchanged for fresh cartridges as the resin becomes exhausted. Some are now finding that when the book is finished, another one costs more than they may be prepared to pay, e.g. for the Permutit Mark 7 which we have, a book of five vouchers costs £44, and when ordering the book we also have to pay a delivery charge for all five cartridges of £17.50. Hence when a school asked if it were possible to do-it-yourself, we thought it worthwhile to look into the problem.

BDH, in their book, Ion Exchange Resins, describe a method of doing this in one container (see Fig. 1). Water fed in at the bottom of the column separates the two resins, because the exhausted cation exchange resin is more dense. The molar sodium hydroxide flowing down from the top regenerates the anion exchange resin. The problem of how to pass hydrochloric acid down the lower half without its destroying the regenerated upper half is solved as shown in Fig. 1 by using a tube immersed to the division between the two resins. It requires constant attention to see that inflow and outflow are matched. Airlocks can and do form in the column, and no matter how careful one is, it is impossible not to get some back flow of the hydrochloric acid into the upper resin during the second half of the process. Since none of these problems arises if one separates the two resins, and since this proved to be an easy process, this is what we did.

The total contents of the cartridge (approx. 1.1 litres) were emptied into two large graduated cylinders (1.5 - 2 litres) and back-washed (Fig. 2) by a slow stream of water. Within a few minutes the resins had separated. The glass tubing should have an internal bore of at least 4mm if it is not to be blocked by resin particles. The top layer, consisting of most of the anion exchange resin was scooped out with the specially made tool (Fig. 5) and put in a regeneration vessel (Fig. 4). The two lots of residue, consisting of cation exchange resin with some remaining anion resin were combined in one cylinder and again backwashed to separate the remainder of the anion resin. Any fine particles of sediment caught by the resin from the water supply during use will be washed over the top at this stage.

The cation resin is dense, and can be regenerated in a 1 litre beaker as shown in Fig. 3. The anion resin is less dense and is easily fluidised, so that it can easily be lost over the top of the vessel. We used a plastic 1½l Coca-Cola bottle with the base cut away. The flow rate can be adjusted by raising or lowering the feed bottle as well as by the screw clip.

The amount of regenerant needed can be calculated using the exchange capacity of the particular resin which can be found in the suppliers catalogue, or by using the amounts given in the BDH book. The volume of the wet cation exchange resin, called the Bed Volume from the graduated cylinder was 650cm^3 in our case. The ion exchange capacity of Zerolit 225 is given as 2meq/cm^3 moist resin, and it is recommended that four times the theoretical quantity of regenerant be used, so that the amount of molar hydrochloric acid needed is

$0.65 \times 2 \times 4 = 5.2$ litres

= 3.8 litres of 5% hydrochloric acid.

An equivalent quantity of sodium hydroxide must be used for the anion resin.

Using the BDH book, Table V:

Type of ion exchange resin	Regenerant 5% w/v	Volume of regenerant for 100cm^3 moist resin
Strongly acidic cation	hydrochloric acid	555cm^3
	sulphuric acid	745
Strongly basic anion	sodium hydroxide	385

The volume of 5% acid calculated by this method would be

$$\frac{650}{100} \times 555\text{cm}^3 = 3.6 \text{ litres}$$

The recommended flow rate of the regenerants is between a twentieth and a tenth of the Bed Volume per minute which in our case gave a regeneration time between one and two hours. Both resins can be regenerated at the same time, and only occasional attention is needed to refill the reservoirs containing the regenerants. When regeneration is complete, three Bed Volumes of de-ionised water are used to rinse each resin; in many areas tap water would be satisfactory for this. To remix, both resins are transferred to a wide-mouthed vessel such as a 2-litre beaker, the excess water drawn off and the resins stirred. The mixture is then spooned into the cartridge and the system set up for de-mineralisation of water. The whole process took less than five hours and apart from the process of separating the resins, required little attention.

The pudding was proofed by running tap water continuously through the de-ioniser, collecting the effluent in 25 litre containers for each of which we measured the conductivity and occasionally the pH. The results were:

100 litres	35µS/m	
"	52 - 87 "	
"	69 - 104 "	pH 6-7
"	87 - 104 "	
"	104 - 174 "	
"	191 - 696 "	
"	696 - 870 "	pH 6
"	696 -1218 "	pH 5-6

These compare favourably with manufacturers' data, e.g. the Elga B114 is claimed to give 30 - 300 litres of water averaging 50µS/m depending on the local water supply.

The chemicals used for regeneration cost less than £1, and this and the fact that the process is so straightforward should encourage others to try it. Even if a school already has a home-made de-ioniser consisting of two separate columns, they might consider going over to a mixed bed resin. Apart from its compactness, it is more efficient. In the two stage process, as more and more cations are removed on passing down the first column, the effluent becomes increasingly acidic which tends to inhibit the exchange process. A mixed bed exchanger does not have this defect.

Two other cheap alternatives are open to someone without a de-ioniser. A pack of four Elga disposable cartridges (C114) costing £7.50 can be used as described in Bulletin 55. A second alternative is to buy 500g each of a strongly acidic cation exchanger (e.g.

Zerolit 225, BDH Cat. No. 550464X) and a strongly basic anion exchanger (e.g. Zerolit FF(ip), BDH Cat. No. 550514H) for a total cost of £8.04. The two can be mixed and put in a large plastic bottle with any suitable arrangement for a through-flow of water. Suitable proportions for the two resins quoted would be equal dry mass, or if wet volumes are used, that of the Zerolit FF(ip) should be approximately 1.6 times that of the Zerolit 225.

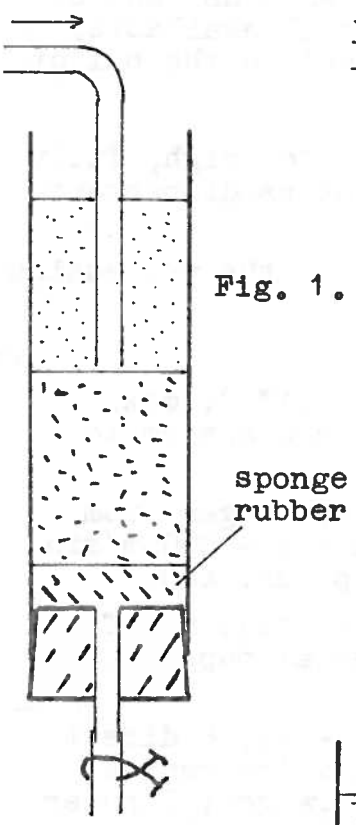

Fig. 1.

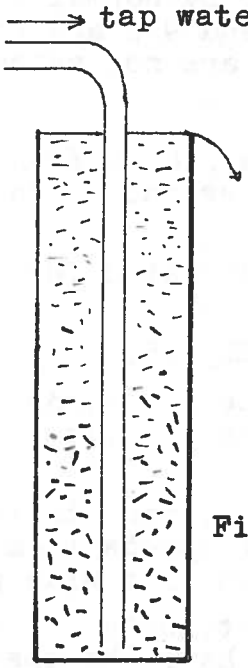

Fig. 2.

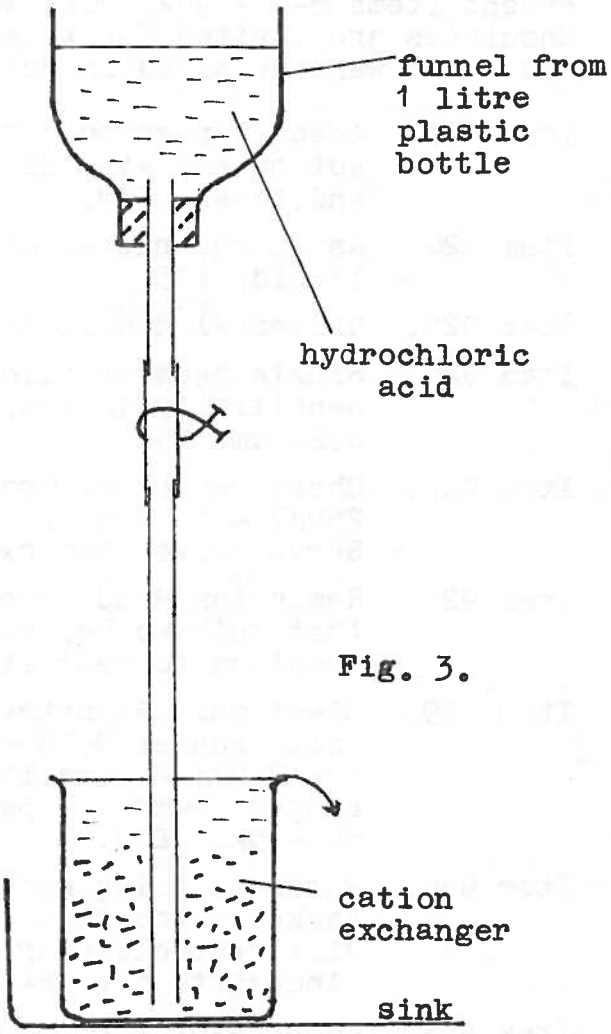

Fig. 3.

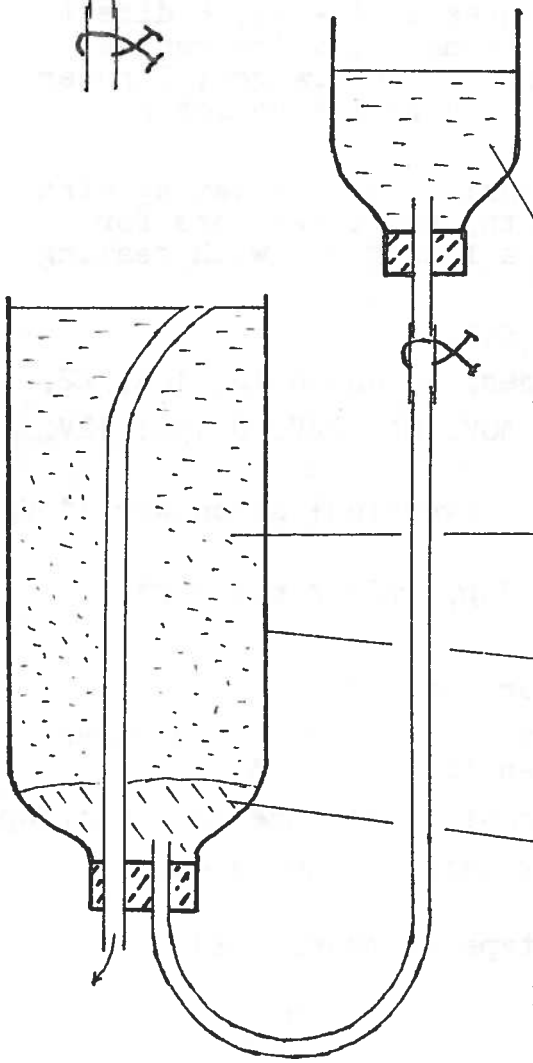

Fig. 4.

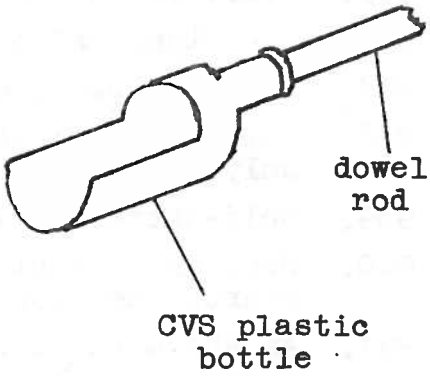

Fig. 5.

Physics Notes

The following items of surplus equipment are offered for sale, and are subject to the ballot procedure described in Bulletin 91. The response to the previous offer was poor by normal standards, and all except Items 898 - 902, 904, 905, 907 and 910 are still available. Enquiries are invited for these, which are not subject to the ballot, and which were detailed in Bulletin 107.

Item 923. Apeco xerographic photocopier, 64 x 78 x 91cm high, fully automated, with 22 rolls paper and 32 bottles dispersant and toner, £20.

Item 924. As above, but without the automated feed of the processing liquid, £15.

Item 925. Universal densitometer by EEL, £5.

Item 926. Single beam oscilloscope type Solartron CD513.2; max. sensitivity 1mV/cm. Calibrated time base 0.2µs/cm to 0.2s/cm, £15.

Item 927. Chart recorder, Graphispot, 12 sensitivity ranges from 250µV - 1V f.s.d. 10 chart speeds from 1.2 - 300mm/min. Servo driven pen recording on 25cm wide paper; £20.

Item 928. Remington Rand type L250 photocopier. We have verified that this works, but do not have the special paper required to test it properly; £3.

Item 929. Electronic Avometer; 10 d.c. ranges 25µA - 1A; 8 direct volts ranges 0.25 - 1000V; 6 alternating volts ranges 1 - 250V; 2 capacitance and 4 resistance ranges; 2 power ranges 500mW and 5W into range of 6 resistive loads 5Ω - 5kΩ; £10.

Item 930. Watch cleaning machine; this consists of a rotating wire basket to contain the watch parts, and three jars for different cleaning fluids, and a fourth jar with heating element to dry the parts; £5.

Item 931. Compressor air pump 50 p.s.i.; £10.

Item 932. Rheostats, heavy duty slide types, 5Ω and 8.4Ω, 10A; £2.

Item 933. Mains transformer, secondaries 30V, 6A; 22V, 0.15A; 12V, 0.06A; £2.

Item 934. Mains transformer for 240/110V conversion; secondary 115V, 2A; £2.50.

Item 935. Electric motor, 115V input, 1/20hp, 1725 r.p.m.; £1.

Item 936. Dial type telephones; £2.

Item 937. As above but rugged for exterior use; £3.

Item 938. Intercom set; uses internal SP11 batteries and requires only two-wire connection between the pair; £3.

Item 939. Self-energised microphone/earphone, impedance ca. 80Ω; 30p.

Item 940. Head and breast set, comprising pair earphones and microphone; 60p.

Item 941. As above but superior earmuff-type earphones; £1.

Item 942. Regulated d.c. power supply; 5V, 3A output, £5.

Item 943. Nichrome wire 25 s.w.g. 25g 40p; 300g £2.

Item 944. Coaxial cable with braided cotton outer covering: looks like 80Ω impedance, 5p/m.

Item 945. Multistrand heavy duty cable with heat resistant (glass fibre) sheath, 5p/m.

Item 946. Typewriter, manual, £3.

Item 947. Electronic calculators, desk type, various makes, £3.

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One Edinburgh school, fed up with the short life of overhead projector mains lamp bulbs, bought two of our hour meters so that the exact lifetime could be logged. These meters, which are still available - Item 660 at £1.50 - are wired across the mains and on the same switch as the equipment being tested and record to the nearest 0.1h the time for which the switch, and therefore the test equipment is on. The results obtained were 30.2, 29.0, 31.5, 17.0, 44.5, 22.7, 16.9, 14.5, and 15.3 hours. Not all the bulbs were of the same make but when we wrote to the makers of Atlas and Thorn bulbs, who are Thorn Lighting, we were informed that the average obtainable under normal operating conditions is 75 hours. From the many complaints we have heard we are sure that few lamps in use reach this average, although unless an hour meter has been fitted it is impossible to be precise.

Fortunately the school had kept the evidence and took up Thorn's offer to examine the failed lamps, and the firm sent us a copy of their report. In our view it exonerates the lamps and places the blame where few teachers might have expected it. We believe that many teachers reading the account below will have cause to feel grateful to the physics teacher who didn't just grumble about what is a common complaint, but took positive action to remedy it.

> "In all cases these failures were induced by an oxide wedge formation on the molybdenum foils which subsequently caused an air leak to occur at the pinch seal area. This oxide formation is produced by excessive over-heating of the lamp pinch, and here the cause is established by observing the condition of the lamp pins. Poor lamp holder contact is clearly in evidence on all of the lamp pins as the pins are badly burned and pitted due to arcing. This condition in turn creates a high resistance and an inevitable temperature increase. Owing to the conditions described, the lamp pinch temperatures were well in excess of the specified 350°C maximum and the lamps unavoidably must fail prematurely. I estimate the lamp pinch temperature evolved in your equipment to be in the order of 500°C. I have enclosed herewith the lamps returned as faulty so you may observe first hand the deterioration of the lamp pins. The remedial action required is to replace all the lamp holders in your equipment and thoroughly check that the air cooling systems are working efficiently. Our own life test results on A1/264 lamps, which incidentally are conducted environmentally using overhead projector machines with controlled volts, are constantly recording a life achievement of virtually double that which we claim, (75 hours)."

S.S.S.E.R.C., 103 Broughton Street, Edinburgh, EH1 3RZ.
Tel. No. 031 556 2184.

B.D.H. Chemicals Ltd., Poole, Dorset, BH12 4NN.

Educational Measurements Ltd., Brook Avenue, Warsash, Southampton, SO3 6HP.

Griffin and George Ltd., Braeview Place, Nerston, East Kilbride, Glasgow G74 3XJ.

Philip Harris Biological Ltd., Oldmixon, Weston-super-Mare, Avon.

Mackay and Lynn Ltd., 30 Marchmont Crescent, Edinburgh.

Oliver and Boyd Ltd., Croythorne House, 23 Ravelston Terrace, Edinburgh, EH4 3TJ.

Thorn Lighting Ltd., Thorn House, Upper St. Martin's Lane, London WC2H 9ED.

Uniprobe Instruments Ltd., Clive Road, Cardiff, CF5 1HG.

Walden Precision Instruments Ltd., Shire Hill, Saffron Walden, Essex, CB11 3BD.

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