SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 39. June, 1970.

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Introduction

Mr. J.C. Weatherley, at present Head of the Biology Department, Manor Park Comprehensive School, Newcastle-on-Tyne, has been appointed Assistant Director of the Centre, and will take up his duties early in August. Mr. Weatherley taught in Bathgate and Malvern College before going to his present post, and has several commercially produced items of apparatus, among them the Malvern environmental chamber, to his credit. This appointment means that for the first time since its inception, the Centre has professionally qualified staff in all three branches of science.

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The following programme of exhibitions has been arranged for the summer term.

Exhibition	Date	Place
S.Y. Studies Chemistry	19th June	St. Andrews
Integrated Science	23rd June	Kirkwall
Integrated Science	25th June	Inverness

In conjunction with the latter two exhibitions we shall also give a lecture/demonstration on new equipment in science.

Physics Notes

The following items of surplus equipment are still available, and from Item 50 onwards we give details of new lines not previously listed. The number in brackets after each item indicates the bulletin in which the item was first advertised, and in which a full description will be found.

Item 1 (31) Large Scale Ammeters, 10s.
Item 2 (31) Aneroid Barometers, 10s.
Item 3 (31) Mercury Barometers, £10.
Item 15 (31) Relays, 1s.
Item 16 (31) Switches, 6d.
Item 17 (31) Potentiometers, 6d.
Item 18 (31) Block Paper Capacitors, 6d.
Item 22 (32) Wire-Wound Resistors, 5s.
Item 23 (32) Fahrenheit Thermometers (both types), 5s.
Item 24 (32) Transformers and Chokes, 2s.
Item 25 (32) Electronic Valves, 6d.
Item 26 (35) Heavy Duty Rectifier, 5s.
Item 43 (35) Power Rheostats, 5s.
Item 48 (36) Sine/Cosine Potentiometer, 10s.

Item/

Item 49 (36) D.C. Voltmeter Relay, 5s.

Item 50. Ratemeter. These are unused, and were originally made as food contamination meters for Civil Defence. They are battery operated but are sold without batteries or battery holder. Old batteries (ca 1964) can be purchased from Henry's Radio for £2.15s. who currently describe the ratemeter as a portable Geiger counter in advertisements in Wireless World. We supply with each instrument a circuit diagram showing how a mains power unit and single transistor amplifier can be built into the existing battery box, and a converted ratemeter can be examined in the Centre. The cost of components for this conversion is approximately £4.5s., all components except the transistor and rectifiers being obtainable from Radiospares. The instrument carries a socket for earphone connection so that the G.M. tube discharges can be heard; the transistor amplifier which we recommend converts this output to operate a 3in dia. loudspeaker. The ratemeter is calibrated to 10 mR/h, and is supplied with a CV2247 G.M. tube which is equivalent to a 20th Century G5H. With this tube the background count is approximately one per second, and full-scale meter deflections will be obtained with 5µCi beta and gamma sources. Price £1.10s.

Item 51. Rotary Transformer. 24V D.C. input, +350V and -60V D.C. output. This can also be used as a variable speed D.C. motor, ranging from 2400 rev/min at 3V input to 8300 rev/min at 30V under no-load conditions. Included on one end of the motor shaft is a 480:1 (approx.) reduction gear controlled by a solenoid operated clutch. Price 7s.

Item 52. Rotary Transformer. Similar to Item 51 but without the reduction gear. Speed off load ranges from 2600 rev/min at 6V input to 7100 rev/min at 26.5V. H.T. outputs for 26.5V input are 150V, 5mA and 300V, 175mA. Price 5s.

Note: Both these items weigh 2.5 - 3kg when packed so that personal collection is advisable; otherwise the cost of postage may exceed that of the item itself.

Item 53. Double reduction gear train giving ratios of 2.5:1 and 12:1, i.e. 30:1 overall. One of these is a worm gear. A metal disc acting as a 3 slit strobe, with slit width 1.5mm is fitted on the intermediate shaft while the slowest carries an adjustable cam. This is a precision engineering job with all shafts mounted in ballraces. Price 10s.

Item 54. A.C. Motor for 230-250V mains, 1/10 H.P. speed 2850 rev/min. Supplied with starter and mains switch. Price £2.

Item 55. Wire Recorder. Although incomplete, this has an A.C. mains motor, worm gears and some electronic circuitry. Price £1.

Item 56. Height Capsule. Purpose unknown, but obviously intended to convert variations in atmospheric pressure to some form of electrical signal. The apparatus has a barometer capsule which controls a plunger inside a solenoid. Price 2s.

Item 57. Gear Train, 30:1 ratio. Contains 7 gear wheels, three on ball races. Price 10s.

Item 58. Perspex Sheet, 5mm thick. There are several types of this material, some of it curved. The smallest type is a plane sheet with metal reinforcing on three sides, measuring 41 x 28cm. We reserve the right to mix the types in fulfilling an order. Price per sheet 2s.

Item 59. D.C. Preamplifier, Model 1430 by Cossor. Frequency response D.C. to 30kHz, switched gain of x5, x15 and x50. Maximum output 3V. Power requirements 120V, 8mA and 6± 0.1V, 1.75A. Instruction booklet included. Supplied without batteries, price £1.

Item 60. Resistance Element. This has 10 4Ω resistance mats, each measuring 20 x 16cm. In conjunction with a low voltage transformer these could be used as heating elements in biology e.g. for incubators, locust cages etc.

Item 61. S.B.C. Bulbs. Type (a) 12V, 24W; type (b) 24V, 36W. Price 3d. either type.

Item 62. Silica Gel Desiccant, in cotton bags. Price 6d. per lb.

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Following the publication in our previous Bulletin of the Coulomb inverse square law experiment, we have a note from Jordanhill College of Education wherein the technique originated. They point out that it is not necessary to build a platform to support the hanging ball; theirs was supported on a horizontal rod clamped in a tall retort stand. Our own feeling on this was that the fewer pieces of apparatus which may be dislodged relative to each other during an experiment the better, since one is involved in measuring quite small distances. Thus we tried initially to put the whole thing on a platform, but in the end had to compromise with a separate retort stand for the fixed ball. Certainly this attempt was responsible for our drilling the balls centrally on the lathe; otherwise as the College points out, they may just as well be pierced with a darning needle. Similarly they used proprietary coated spheres from a Malvern electrostatics kit, to which our only answer can be that we did not have any at the time. This overcomes the difficulty we had of coating the spheres, although another teacher has pointed out that Aquadag, which is water based, would probably serve equally well.

Finally the College did not measure the optical magnification as we did, but used a cm scale scratched on a piece of Perspex, taking measurements off its projected image. Our objection to this was that if the scale were placed under the balls, the two were not simultaneously in focus on the image. With the scale in focus the edges of the balls were ill-defined, and with these in focus the scale could not be seen at all. If the scale were supported on the same level as the balls in order to get simultaneous focus, static charges on the perspex deflected the hanging ball unless the scale were placed so far away from the balls that it became difficult on the projected image to line up the centre of the ball with the scale. Teachers trying the experiment may wish to try both techniques, since much may depend on the individual projector used.

Chemistry Notes

Following complaints by several teachers that sixth form projects on gas-liquid chromatography using a katharometer detector gave very poor, if any, results, we investigated the techniques/

techniques involved. Our starting point was the School Science Review No. 167 in which two methods for gas chromatography are described, one using a flame ionisation detector (p.125) and one using a katharometer (p.180). The apparatus we describe below is the result of combining both techniques so that the same column and oven may be used with either detector, although here we are limiting the description to the katharometer technique. The principles involved in the method are first described.

A carrier gas (town gas) is passed through a coiled tube situated in an oven and containing Tide detergent which acts as a separating medium. Before entering the tube the gas passes over a heated filament; there is a similar - in theory identical - filament at the outlet end of the tube. These filaments are in a balanced Wheatstone bridge circuit, and as long as the gas passing over each filament is the same, the bridge remains balanced and no deflection is shown on the detecting galvanometer. If, however, a sample to be analysed is injected into the carrier gas, the sample being either gas or volatile liquid which will vapourise at the temperature of the oven, at the start of the coiled tube but after the carrier gas has passed over the first filament, the two filaments will experience different conditions, and heat will be conducted away from the second filament at a different rate than from the first depending on the thermal conductivities of carrier gas and sample. The second filament will therefore be at a different temperature from the first, and this will cause it to have a different resistance thus unbalancing the bridge and causing current to flow in the galvanometer. If, in addition, the sample is a mixture of gases or vapours, these may become separated in their passage through the separating medium and arriving at the second filament at different times, will register their presence on the galvanometer separately. If the apparatus is consistent, the time taken for a substance to pass through the separating medium is characteristic of the substance and the components of a mixture may be identified by comparison with the times for pure substances.

The two filaments forming the katharometer are taken from two 200W mains electric bulbs, bought at the same time, and one hopes from the same batch. In our case measurement of their resistances when cold gave 20.00 and 19.97Ω. The bulb is cracked by nicking the glass with a file near the base, heating the base cap in the bunsen flame and then plunging the cap into cold water; any other method of cracking the glass is perfectly adequate. The filaments are removed together with as much of their end support wires as can be salvaged, and each is then sealed with Araldite into a straight 11cm length of glass tube, 5mm bore as shown in Fig. 1. In this position the end support wires are stiff enough to keep the filament centred along the length of the tube. The stretched filament length is about 9cm. The Araldite is built up round the outside at each end of the tube to form a tubulure for the attachment of rubber tubing.

Both filaments are then fixed into a wooden lidless box, Fig. 2, made from hardboard and plywood of internal dimensions 70 x 65 x 40mm. Slots cut in the hardboard ends locate the glass tubes so that they can be surrounded with glass wool insulation, since we found it very necessary that the katharometer be allowed to reach and sustain an even temperature. Three 4mm sockets are fixed in the box ends and the ends of the filament support wires are soldered to these using short extension pieces/

pieces of wiring if necessary. Two of the ends go to one terminal since the filaments are in series in the bridge circuit. 6BA bolts were then used to secure the box to the top of the biscuit tin oven, described below.

A metal biscuit tin, measuring 230 x 215 x 120mm deep is used resting on one of its 230 x 120 sides, as an oven. A batten mounting mains lamp holder is secured to the base as close to one side of the tin as possible, the mains cable being led through a grommeted hole in the side next to the lamp. A sheet of 3mm asbestos mat, measuring 12 x 15cm is fixed using a light metal bracket either to the base or back of the tin so that it just touches the largest size of lamp bulb to be used in the oven - in our case 150W. The position, see Fig. 3, should be such as to allow free convection of air at top and bottom of the sheet. A similar sheet is secured against the other side of the tin with a metal bracket soldered to the side.

Two holes 6cm apart are drilled in the top of the tin. Brass collars are soldered into these holes, see Fig. 4. These collars are turned and drilled on the lathe from short lengths of $\frac{3}{4}$in brass rod to give a 10mm inside dia. tube. Brass or steel tube of appropriate size would do, with a washer soldered to one end, but a 3/8in tube would require drilling out, as it is necessary that the 3/8in copper tube which forms the separating column be a loose fit into these collars. The rubber tube connections to the separating column then serve to support the column in place.

The tube used for the separating column is a 140cm length of 3/8in dia. copper tube. This can be bought from heating and ventilation engineers as it is a size used in small bore central heating. An alternative source is <u>K.R. Whiston</u>, who will supply a 6ft length of the tube for 19s, plus 5s. packing charge. It is washed with hot water + detergent, then rinsed out with water and dried by passing hot air through it. Tide which has been retained in a 40 mesh seive is used as the separating medium. A lightly packed plug of glass wool is inserted to 5cm from one end of the tube, and the Tide added at the other end, tapping the tube to assist settling and packing. When full to about 5cm from the top, another glass wool plug is inserted. The tube is then wound three times round any suitable cylindrical object, e.g. a paint tin to give a coil of diameter about 13cm. At each end a 5cm length is straightened out and shaped to fit the collars mentioned above. A small hole is drilled above the lamp bulb to take a thermometer, and the base of the biscuit tin is fixed to a 20mm thick wooden baseboard to give stability; this completes the oven.

A cut-down glass T-piece, Fig. 5, is used with short lengths of rubber tubing to connect one end of the katharometer to the separating column; the free arm of the T is sealed with a subaseal rubber cap, through which the sample is injected. The cap, a No. 13, is fitted over the tubing instead of into it as is the normal fashion in stoppering a bottle. A right-angled glass elbow connects the other end of the column to the katharometer. The carrier gas passing into the system must firstly be dried by passing it through a 20cm length of silica gel desiccant, packed in a 20mm diameter glass tube, e.g. a combustion tube, with a plug of glass wool at each end in addition to the stoppers.

It is advantageous, although not absolutely necessary, to meter the flow rate of the carrier gas by passing it through a flow meter after it emerges from the katharometer. This is mainly/

mainly to check the constancy of flow during a sample run. Because of wide fluctuations in town gas pressure from 11.30 - 1.30 p.m. and again after 4 p.m. we found it impossible to run samples at those times. A suitable flowmeter is the MeTeRaTe Type DR1B with glass float, calibrated from 5 to 190 ml/min for air at £2, from the Glass Precision Engineering Co. This is in the form of a glass tube 18cm x 8mm dia., and can be clipped in a vertical position to one side of the biscuit tin using two Terry clips on the tin. At the end of the flowmeter we attached a short length of glass tube with a twist of copper wire at the outlet end where the gas is burned. The green coloration imparted to the flame when halogenated hydrocarbons are being tested is a very convenient indication that the apparatus is functioning correctly. On its own, the flame height is an indication of the flow rate for those who do not want the additional expense of a flow meter. For example, burning at a 5mm bore tube, a flame height of 2mm corresponded to a flow of 20 ml/min, one of 6mm to 45 ml/min. But as the degree of separation of the components of a mixture depends on the flow rate as well as other factors, this is one aspect on which a Sixth Form Studies Project might be based, and for this a flowmeter would be desirable. If adjusting flow rate from flame size, allowance must be made for the time lag in the alteration of the flame.

The electrical circuit shown in Fig. 6 is a standard Wheatstone bridge network. R and S are the filaments which form the katharometer. All other components of the bridge except the power supply were built into a control box. B, C and D; E, F; L, M are all 4mm sockets planted at convenient points on the box. C requires to be colour coded to distinguish it as the common katharometer connection. E and F are colour coded as the power supply terminals. Points L and M were brought out to form a connection to a pen recorder, although this is not essential in conducting the experiments. Ammeter A, which measures bridge current (most of which flows through the filaments) is a Japanese Type MR38P, 500mA obtainable from G.W. Smith at £1.7s.6d. The centre zero galvanometer G is 100-0-100μA and can also be an MR38P at £1.15s. although we prefer the larger, and consequently more accurately read MR65 type at £2.2s. Any odd meters which the school may have in these ranges will serve equally well. The fixed resistors are ½W carbon types, the rheostat, which is the zero balance control is a 3W wirewound type, all from Radiospares. Any low voltage D.C. supply will do, it does not require to be smoothed.

It is worthwhile arranging the circuit so that clockwise rotation of the balance control gives right hand deflection of the galvanometer. If this is not so, connecting the other end of the potentiometer will give the desired result. It is also convenient that the galvanometer should deflect right-handedly when a sample is being detected, and again if this does not occur when first wired up the connections to the outer ends (not the common terminal) of the katharometer should be reversed. When both these conditions have been met, the +ve terminal of the galvanometer should be connected to the red socket of the L, M pair, where these have been fitted, for connection to the recorder.

The sensitivity of the katharometer and therefore of the whole apparatus depends very much on the temperature of the filaments and hence on the bridge current. The table on page 7 shows the galvanometer deflections obtained, after the bridge has been balanced, when 0.5ml of air was injected.

Bridge Current, mA	100	150	200	250
Galvanometer Deflection, μA	10	35	75	195
Power Supply, V	6	9	12	20

These results were obtained for a flow rate of 75 ml/min and with the separating column at room temperature. Above 200mA bridge current the apparatus becomes too sensitive to be of much use since small fluctuations in mains voltage affecting the power supply give spurious galvanometer readings. The injection of air used above is excellent for adjusting purposes since with Tide there is no retention and a quick response is obtained which is related to the flow rate of the carrier gas.

No temperature control of the oven was attempted, except that achieved by plugging in different ratings of electric light bulb. The table below shows the steady temperatures achieved for different bulbs. The time taken to reach the final temperature varied between 20 and 40 min so that if required the oven should best be switched on about an hour before use.

Lamp Rating, W.	15	25	40	60	100	150
Oven Temperature, °C.	38	41	69	87	112	147

A 2ml glass syringe is used for gases and vapours and a 50μl syringe with 5cm needle for injection of liquids. In the latter case the needle is pushed fully home through a subaseal cap so that the liquid is injected into a heated part of the column and vapourises immediately. After 20-30 injections the cap becomes so perforated as to be no longer gas tight, and this will show up as flicker on the galvanometer needle when the cap is prodded. It must then be changed.

Samples pass through the column in 2-6 min., so that it is a simple matter to record galvanometer current every 5s and plot the resulting graph. If a pen recorder is used, e.g. the Heathkit EU-20VE on which we obtained the graphs shown, its sensitivity range must be selected to suit the galvanometer being used. Our galvanometer has a coil resistance of 300Ω, so that at full scale the P.D. across it was 30mV. Hence the 0-50mV range on the recorder is satisfactory. At these low levels it is necessary to exclude mains hum from the recorder, so that screened cable must be used between recorder and the L, M terminals of the bridge. For the same reason it is an advantage if the control box is of metal rather than plastic or wood.

With the equipment described above we have successfully separated and identified by comparison with the pure substances halogenated hydrocarbons in mixture, e.g. chloroform, dichloromethane, carbon tetrachloride. For these a 60W bulb was used giving an oven temperature around 90°C. With squalane on celite in the same tube we have separated four constituents of Ronsonol. These were run with the column at room temperature.

Further alleys which we have explored or have still to explore and which could well form the basis of a Sixth Form Project, are:

1./

1. The use of a diaphragm pump to pressurise the carrier gas giving an extended range of flow rates. This is probably worth while if one already has a suitable pump, but not worth the expense otherwise. With the pump we tried, we found fluctuations in flow rate which made readings unreliable.
2. The use of a series of seives to sort the Tide into a narrow band width of granular size. Work is still progressing on this.
3. The effect of a longer separating column. There is enough room in the oven to get a fourth loop on the coil which would make the column about 200cm long.
4. The use of a different carrier gas. We do not recommend hydrogen from the safety aspect; A S.E.D. memorandum is soon to be published strongly recommending that hydrogen cylinders of over 2ft^3 capacity should be permanently housed in an outside store, small quantities of the gas being drawn off as required into suitable containers. But nitrogen could be used, and we have had promising results although its use has not been extensively investigated. It would then be necessary to use a flowmeter in order to keep the results reproducible.
5. The use of a different separating medium. Some experiments have been done on the use of silicone oil and squalane absorbed on celite, and work is still in progress.

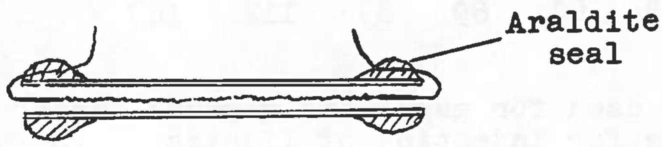


Fig. 1. Filament sealed into glass tube.

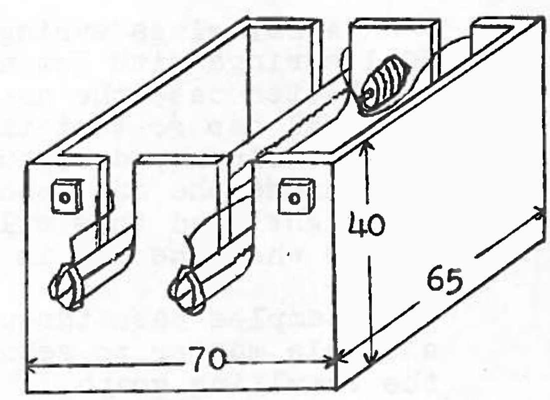


Fig. 2. Katharometer box. Dimensions in mm are for <u>inside</u> of box.

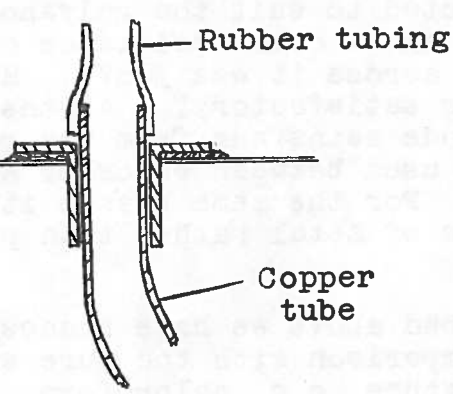


Fig. 4. Method of securing copper coil to oven.

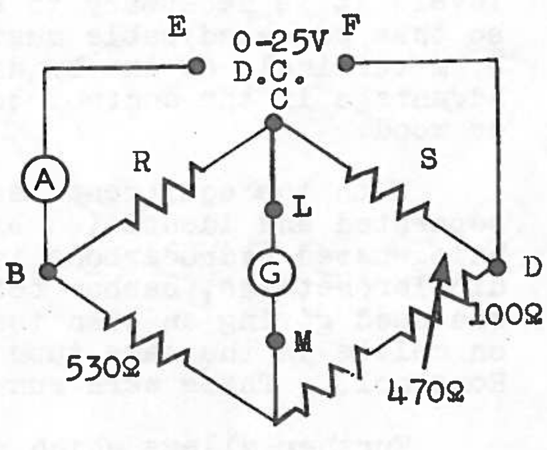


Fig. 6. Circuit diagram.

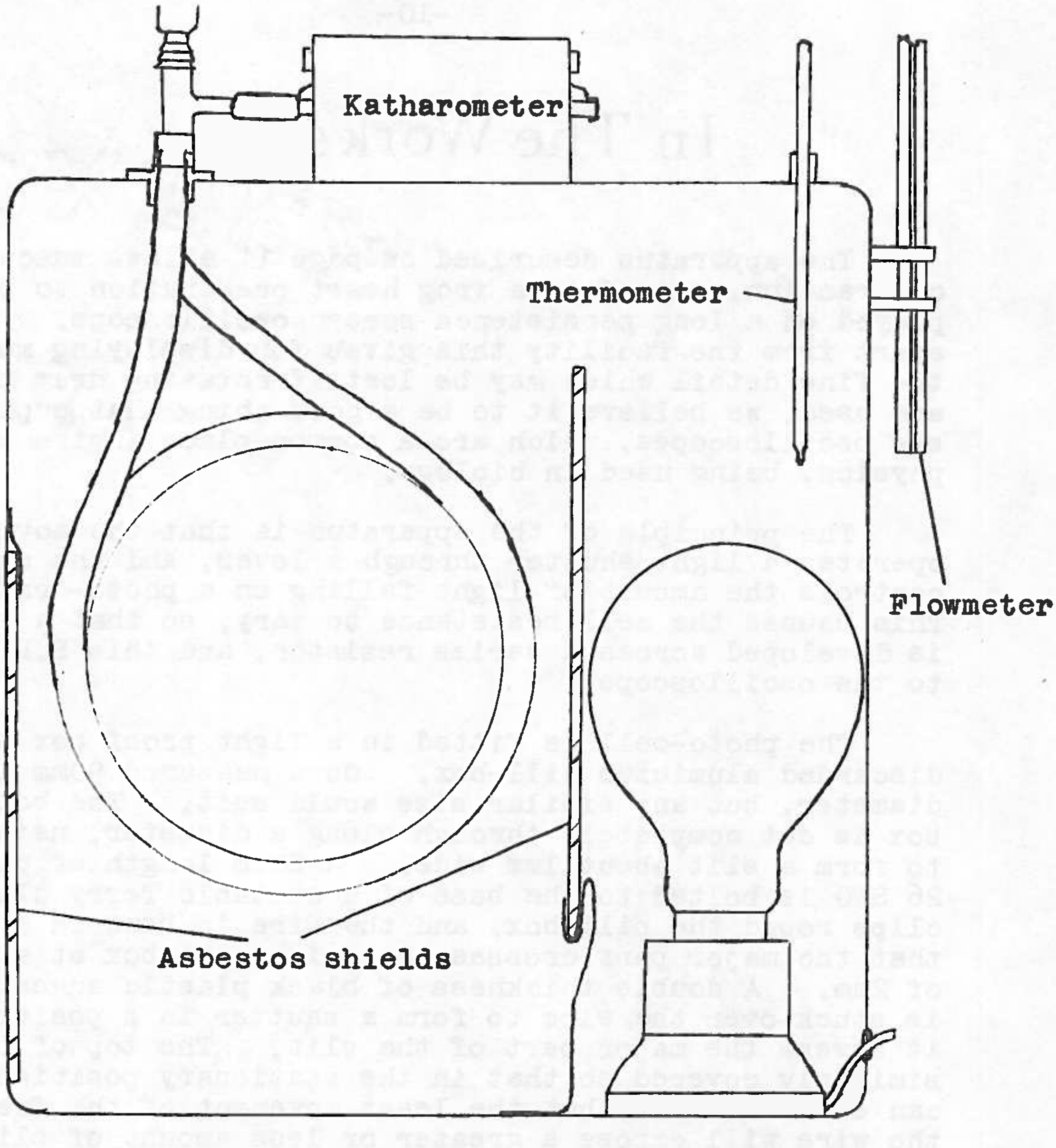
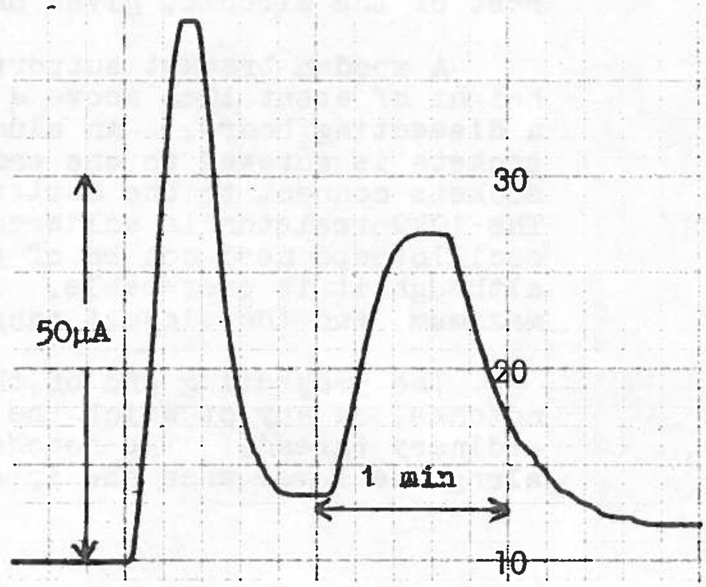
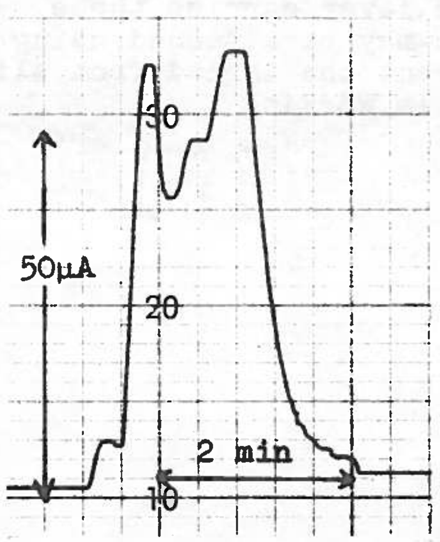


Fig. 3. Biscuit tin oven showing layout. Scale approx. half size. The connection between katharometer and flowmeter has not been drawn in.

Fig. 5. T-piece detail. Full size.





Above. Mixture of dichloromethane and carbon tetrachloride with Tide.

Left. Ronsonol fuel with squalane on celite.

In The Workshop

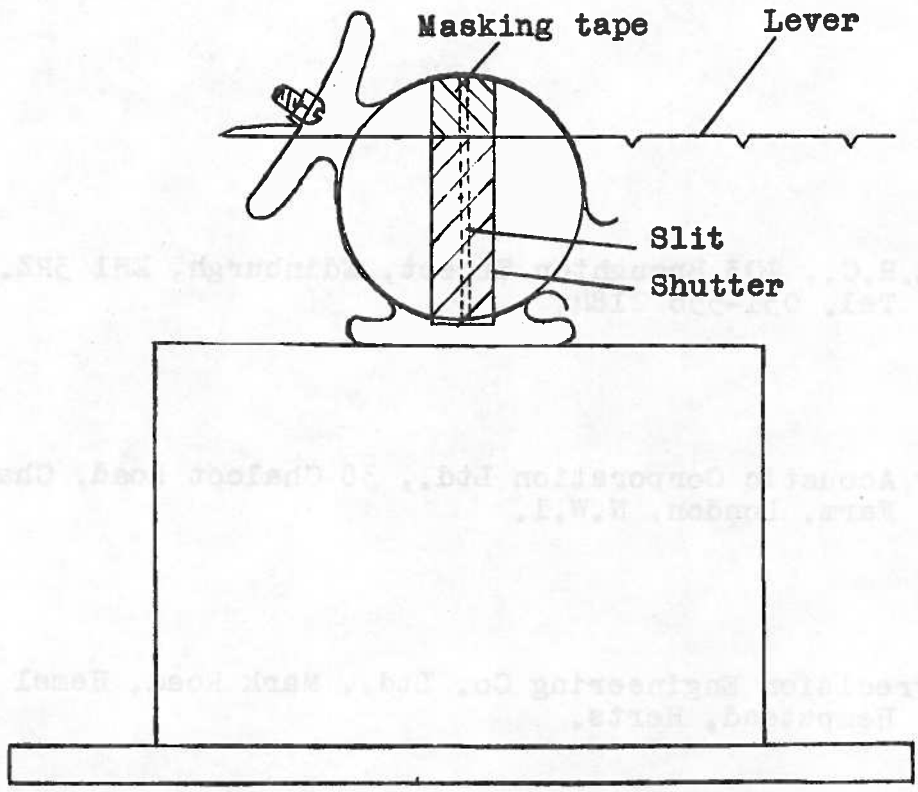
The apparatus described on page 11 allows muscular contraction, e.g. from a frog heart preparation to be displayed on a long persistence screen oscilloscope. Quite apart from the facility this gives for displaying much of the fine detail which may be lost if rotating drum techniques are used, we believe it to be a good thing that pupils should see oscilloscopes, which are a common-place instrument in physics, being used in biology.

The principle of the apparatus is that the moving muscle operates a light shutter through a lever, and the shutter controls the amount of light falling on a photo-conductive cell. This causes the cell resistance to vary, so that a varying P.D. is developed across a series resistor, and this P.D. is applied to the oscilloscope.

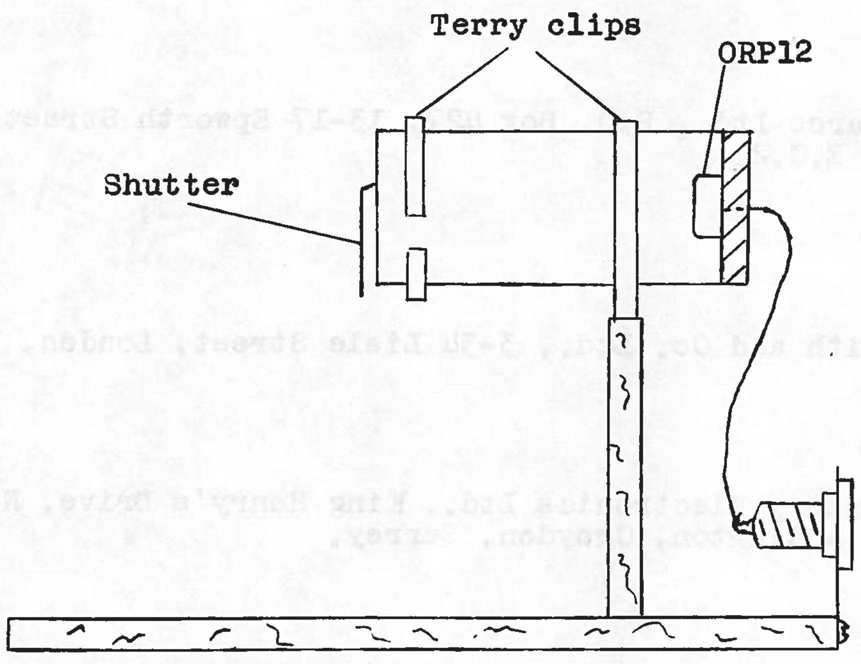
The photo-cell is fitted in a light proof box made from a discarded aluminium pill-box. Ours measured 90mm long x 30mm diameter, but any similar size would suit. The bottom of the box is cut completely through along a diameter, using a hacksaw, to form a slit about 1mm wide. A 20cm length of piano wire, 26 SWG is bolted to the base of a suitable Terry clip which clips round the pill-box, and the wire is bent in a loop so that the major part crosses the end of the box at a distance of 2mm. A double thickness of black plastic adhesive tape is stuck over the wire to form a shutter in a position so that it covers the major part of the slit. The top of the slit is similarly covered so that in the stationary position no light can enter the box, but the least movement of the free end of the wire will expose a greater or less amount of slit to the light. An ORP12 photo-cell, obtainable from Bentley Acoustic Corporation for 9/-, is pushed into a cut-down cork of suitable size so that the connecting wires project outside the tin at the other end. These connections are then soldered into the rest of the circuit, given on page 11.

A wooden bracket supports the box in a Terry clip at a height of about 10cm above a wooden baseboard, which serves as a dissecting board. An aluminium bracket carrying four 4mm sockets is screwed to one end of the baseboard; two of the sockets connect to the battery, the other two to the oscilloscope. The 10kΩ resistor is soldered across these two sockets. The oscilloscope need not be of the long persistence screen type, although it is preferable. The gain should be turned to maximum, and the slowest range of time base speed used.

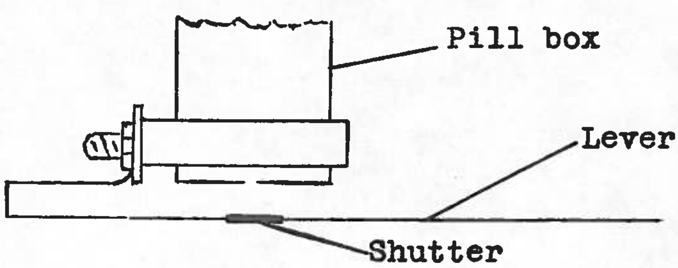
The projecting end of the wire lever carries three notches, to any of which the muscle may be attached using ordinary thread. The notches prevent the thread from sliding along the lever when the apparatus is working.



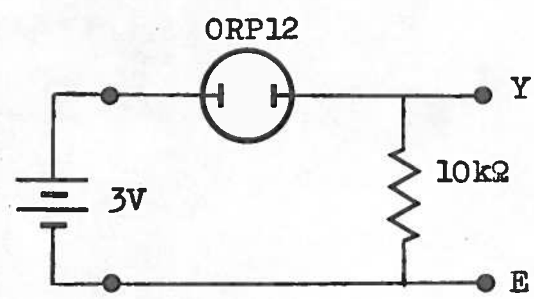
Front elevation.



Side elevation.



Lever detail.



Circuit diagram.

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

Bentley Acoustic Corporation Ltd., 38 Chalcot Road, Chalk Farm, London, N.W.1.

Glass Precision Engineering Co. Ltd., Mark Road, Hemel Hempstead, Herts.

Henry's Radio Ltd., 303 Edgware Road, London, W.2.

Radiospares Ltd., P.O. Box 427, 13-17 Epworth Street, London, E.C.2.

G.W. Smith and Co. Ltd., 3-34 Lisle Street, London, W.C.2.

20th Century Electronics Ltd., King Henry's Drive, New Addington, Croydon, Surrey.

K.R. Whiston, New Mills, Stockport, SK12 4HL.