SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 93. December, 1976.

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Introduction

At the end of October we issued the fifth and last of our experimental guides to the CSYS physics memoranda, that for Memorandum No. 21, Mechanics. Those already issued have been on Alternating Current, Electrostatics, Electro-magnetism, and Oscillations and Waves. As with previous guides, it has been sent to Scottish schools and other organisations on the circulation list of the Scottish Centre for Mathematics, Science and Technical Education which has issued the memoranda. Other U.K. readers who wish to have a copy of the Mechanics guide (or any of the other guides we have issued) will have it sent free of charge upon request.

Following the issue of the last of the experimental guides, and concurrently with this bulletin we have issued with the same circulation as above, a list of physics equipment for CSYS. This list is firmly based on the experimental guides already sent out, and takes no account of any apparatus which might be needed for project work. Equally, apparatus which though desirable is not thought essential to the course - laser, chart recorder , velocity of light apparatus, to name only three - has been omitted. Readers who may be mystified at the catalogue numbers quoted for Philip Harris items in the list will find the explanation when they receive their copy of the new Harris catalogue, whence the numbers have come.

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Fee-paying and independent schools in Scotland, organisations in England and Wales, and manufacturers who subscribe to receive our bulletins should have received a reminder that their annual £7 subscription to SSSERC is now due. This amount includes VAT at 8%, and if any school office should require the information, our VAT registration number is 269 4490 19. As this reminder went out several weeks ago, we propose to discontinue the supply of bulletins forthwith to any who have not yet paid.

* * * * * * *

Our cost index of items of consumable apparatus (= 100 in May, 1974) now stands (17/11/76) at 157.9. This is an increase of 9.6% over the past 6 months, and 13.8% over the year.

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The Centre will be closed Friday through Monday, 24 - 27th December, and 31st December - 3rd January, 1977.

Opinion

It is all too easy these days to be so vigorous in jumping on a fashionable bandwagon that one falls off the other side. In how many school fume cupboards, for example, is asbestos being ripped out in a fashion which creates a greater hazard than if they had been left alone? In how many schools are the hazards, whatever they may be, of worn asbestos gauzes, paper or tape being simply passed on to the school cleaner or dustman? At a time when speculation is rife it is comforting to hear of one Edinburgh science teacher who remained true to his training and sent his asbestos material for analysis to the Asbestosis Research Council. Their reply stated: "The material (paper, tape and hard asbestos mat) does not contain any crocidolite (blue) asbestos, which is generally considered to be the most hazardous type, and if handled in a responsible manner in the extent to which it is used in a school laboratory, it should constitute no risk to health."

Another area in which we are in danger of becoming over-cautious is in hazards to the eyes. The recently issued pamphlet, Safety in Science Laboratories, prepared by the Department of Education and Science and available, price 85p, from H.M.S.O. states (para 52) "Goggles must be worn whenever there is any risk to the eyes. ... This means that whenever any operation with chemicals is performed, goggles must be worn, whether in chemistry lessons, biology lessons, physics lessons, geology lessons, or indeed in home economics or craft."

I would take issue with D.E.S. on two counts. The first is that if I were interpreting the letter of the above statement rather than the spirit, I would wear goggles whenever I stir sugar into my tea, or sprinkle salt on my cold salad. I presume my readers are sufficiently serious minded to dismiss as irrelevant the argument that what I do in my own home is my own responsibility and no one else's, and indeed it is just possible that I may as a pupil be called upon to stir my tea in a home economics lesson. Moreover, if I have the misfortune to get something in my eye which necessitates treatment by another chemical, the D.E.S. diktat places me in a Catch 22 situation. To carry safety to this extreme is bordering on the ridiculous, and will increase the dichotomy between school and the real world outside, as the pupil sees it.

The second point concerns the D.E.S. authority to make such a statement. It is noted that the imperative "must" is used twice, being emphasised by italics where I have underlined it. Now I accept that legislation and practice both differ when one crosses the Border and that however improbable it may seem, this could be the reason for the difference in emphasis. But in Scotland, as confirmed to me recently by an inspector, the Scottish Education Department recognises that the responsibility for safety in schools lies, and always has lain, with each local authority, acting through its Director of Education, science adviser, headmaster, head of department and down to the individual teacher. In these circumstances the S.E.D. does not consider itself competent to issue directives on safety; this is now the function of the Health and Safety Executive. In the memoranda on safety which the S.E.D. issues from time to time, it may use imperatives where it is necessary to point out to teachers what they can or cannot do under existing legislation, as witness the restriction in the use of carcinogenic and radio-active substances. In circumstances where no legislation applies, what the S.E.D. provides is advice, not direction.

Reverting to the D.E.S. pamphlet, one might expect to find legislative authority for the statement quoted above in the

Protection of Eyes Regulations, 1974. It is true that these regulations apply only to factories, but I know of no equivalent legislation which applies to schools, and I understand that the Health and Safety at Work Act is an enabling act which allows the provisions of the various Factories Acts to be applied, inter alia, to schools. The only reference I can find in the 1974 Regulations which could be considered to apply to the school situation is in Part 1, Specified Processes, i.e. processes in which approved eye protectors are required. One of the specified processes (para 12) is "The handling in open vessels or manipulation of acids, alkalis, dangerous corrosive materials, whether liquid or solid, or other substances which are similarly injurious to the eyes, where in any of the foregoing cases there is a reasonably foreseeable risk of injury to the eyes of any person engaged in any such work from drops splashed or particles thrown off."

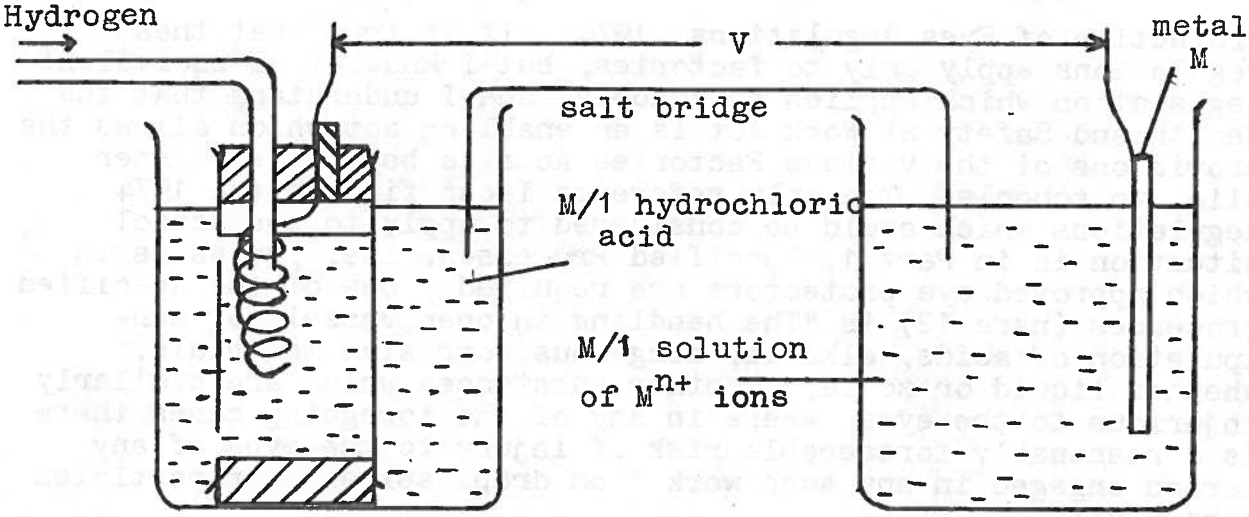
This places the responsibility for deciding when goggles should be worn with the teacher, which is where a responsible profession would wish it to be, and is preferable, in my view, to a blanket prohibition on all chemistry except behind doom-tinted spectacles. We must be careful that when the time comes to throw out the bath water, that is not the only thing we have left, the baby having wasted away in the face of so many hedgings and prohibitions.

Chemistry Notes

The cost and difficulty in use often discourages teachers from using a hydrogen electrode as a standard reference in the measurement of electrode potentials. A commercial Hildebrandt can cost £8 - 9, whereas the cost need be no more than that of a length of platinum wire - about £2 - plus a few pieces of laboratory ware.

The casing for the electrode was a plastic ampoule specimen tube, 25 x 60 mm, dia x height. Two small holes are made in the side, one near the bottom for draining and one about 2/3 up so that about half of the electrode is covered by molar hydrochloric acid. 100 mm of platinum wire is coiled and fitted into a two-holed rubber stopper as shown in the sketch, so that sufficient of the wire protrudes to allow connection to a crocodile clip. The bung holding the wire in place in our case was a No. 5 stopper, but any other material, e.g. glass rod, wooden peg, would suffice. A solid rubber stopper in the bottom of the casing allows it to stand unsupported in a 50 cm^3 beaker containing the acid.

To obtain reasonably consistent results the electrode requires to be specially treated or 'platinised' so that its effective surface area is greatly increased. We are grateful to the chemistry department of Moray House College of Education for supplying the following recipe. The coiled part of the electrode is cleaned by heating to yellow heat in a non-luminous bunsen flame, followed by immersion for a few seconds in aqua regia and rinsing in deionised water. Hereafter the electrode is handled only by the straight, connecting end, and that preferably with tweezers or pliers.



The electrode, and a second piece of platinum wire are placed in an electrolyte consisting of a 2% solution of chloroplatinic acid (IV) in molar hydrochloric acid which contains 0.02% lead (II) ethanoate. A direct current is passed for about one minute, and then reversed for the same time; this process is continued for 30 minutes. The current density for the electrode being prepared should not be greater than 100 mA/cm^3 of surface. For 7 cm of 24 s.w.g. platinum wire (0.568 mm dia.) this works out at 120 mA; for the same length of 28 s.w.g. (0.376 mm dia.) at 80 mA. An alternative recipe for the electrolyte is 1 g platinum (IV) chloride dissolved in 100 ml of 2 M hydrochloric acid, containing 0.02 g of lead (II) ethanoate. The electrode is then copiously rinsed with previously boiled deionised water and left soaking in this for two hours with all air carefully excluded, before being fitted as shown in the sketch.

The electrode is easily poisoned and it is essential that the hydrochloric acid and, if zinc is used to prepare the hydrogen, the zinc be low in arsenic. The electrode prepared as above was used at different times over a period of two months to find its useful working life. The following results were obtained using a 20,000 Ω/volt Avometer to measure V.

Date	6/8	17/8	7/10	12/10
Cu/Cu^{2+} // H^+/H_2(Pt)	+0.29V	+0.30V	-	+0.30V
Zn/Zn^{2+} // H^+/H_2(Pt)	-0.74V	-0.71V	-0.69V	-0.70V
Pb/Pb^{2+} // H^+/H_2(Pt)	-0.16V	-0.13V	-0.14V	-
Ni/Ni^{2+} // H^+/H_2(Pt)	-0.16V	-	-	-
Mg/Mg^{2+} // H^+/H_2(Pt)	-1.98V	-	-	-

Biology Notes

Short practical exercises in genetics can be somewhat difficult to arrange. In Bulletin 91 we described a simple model which allows pupils to follow the sequence of a monohybrid cross. Further light relief can be provided, by carrying out crosses by tossing coins, or by breeding experiments using coloured beads to represent gene pools. This is fine as long as a small number of characters are involved and a limited number of crosses are carried out. Mendel's second law, dealing with the independent assortment of characters in a dihybrid cross, is a little more difficult to simulate. Tossing two sets of two coins, or selecting and sorting beads from two sets of four, requires considerable mental concentration as well as a degree of leger de main. Such an exercise is time consuming, tedious, and likely to put students off genetics for life.

Another solution is to use two crosses cut from cardboard and pivoted compass-needle fashion so that they will rotate easily. They are placed side by side so that one is above the other and so that two arms overlap almost completely. Each arm is colour coded for the two possible alleles in a gamete, and the arms of the upper cross have windows cut in them so that one can see through to the lower when the arms overlap. Both crosses are spun, and then stopped at random by seizing a pair of overlapping arms between a finger and thumb. The genotype of the zygote thus formed is read off from the colour code pair on the top arm and from the bottom 'gamete' seen through the window. This device was shown in the members' exhibition at the A.S.E. meeting at Oxford, and is described in School Science Review, No. 202, p. 60. However, this manual random fertilisation is still fairly time consuming, and we have developed an electronic circuit which rapidly combines gametes in a random manner. The construction of this random fertilisation apparatus is described in detail in the workshop section.

The apparatus has two sets of 4 lights, representing possible male and female gametes, each gamete containing alleles of two independently assorted genes. The flashing sequences of each set are independent and lights of the same sex are lit for equal times. A 'cross' is produced by pressing a stop button which interrupts the flashing sequences and holds on one lamp in each set. As each lamp represents a different gamete, the phenotype can be determined from the two lamps which are on. Normally the flashing rate of the lamps is too fast for the eye to discern which one is on, but a 'slow' switch has been incorporated which reduces the rate to about two per second so that the pupil may see that each lamp in a set is on for the same length of time, so that each has an equal chance of being selected by the stop button.

The lights or 'gametes' can be labelled with any suitable Mendelian characters. However the device is capable of generating 'zygotes' more rapidly than they can be recorded. It is less time consuming for recording purposes to number the lights. If each sequence of lights is numbered 1 - 4, the combinations of numbers can be called out by an operator who can serve a group of recorders. If the first number of the pair called out is always that of the light in the top row, there should be no confusion.

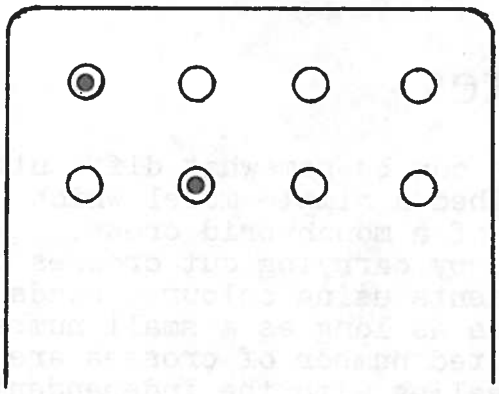


Fig. 1.

♀ \ ♂	TC	Tc	tC	tc
TC	31	18	20	20
Tc	23	22	25	16
tC	20	19	27	30
tc	29	18	19	23

Fig. 2.

In the example shown, the operator would call out "1, 2", and the recorder would make a tally mark in the box on the grid corresponding to column 1, row 2. While this is being done, a second recorder could mark the next combination, and in this way the combinations can be recorded as fast as the operator can call out the pairs of numbers. If the cross being considered was the classic example of tall peas with coloured flowers and dwarf with white flowers, the rows and columns could be labelled as shown in Fig. 2. The data can then be analysed at leisure, phenotypes scored and ratios computed. The numbers in each box of the grid shows the results of one such trial for a total of 360 crosses; these give the ratios
8.5: 3.3: 2.4: 1

Obviously a large number of crosses require to be made to approach the ideal 9: 3: 3: 1 ratio, but we convinced ourselves that it could be done by constructing a box which not only 'sampled' the combinations automatically, but sorted out the phenotypes and scored the totals. This box we have called ARFAR (Automatic random fertilisation and recording) and it has been shown at several exhibitions. Although the sampling is not random, since it is done at a fixed frequency, the results are perhaps sufficiently close to the ideal to be convincing to pupils, as the following examples will show.

903	302	301	100	435	144	146	50
906	301	299	101	452	144	142	50
895	302	303	99	455	151	147	50
901	298	301	100	457	149	148	51

To any teacher who is sufficiently interested in this aspect of genetics (or is it statistics?) we will lend ARFAR free of charge.

In The Workshop

The random selector referred to in the biology notes section of this bulletin requires to do two things. It must produce two similar systems each of which has four possible and equally probable states, and each system must vary independently of the other. Then it must arrange to combine the two systems in a random fashion so that any state in one system has an equal chance of combining with any state in the other. The more elegant, and perhaps more attractive way of doing this is by electronics, using two rows of four light-emitting diodes as indicators. One row is red, the other green and the diodes in a set flash on and off independently and sequentially. Each lamp in the sequence is on for the same length of time, and this can be verified by the user. Hence, when they are flashing at a rate too fast to be distinguished separately, and both sets are stopped simultaneously, the choice of which one in either set remains on is purely random.

The circuit for driving one set of lights is given below. The circuit for the other set is identical, except that the 1 kΩ resistor is replaced by a 1.2 kΩ. This makes the two oscillators sufficiently different in frequency for it to be easily seen in the 'slow' position of the switch.

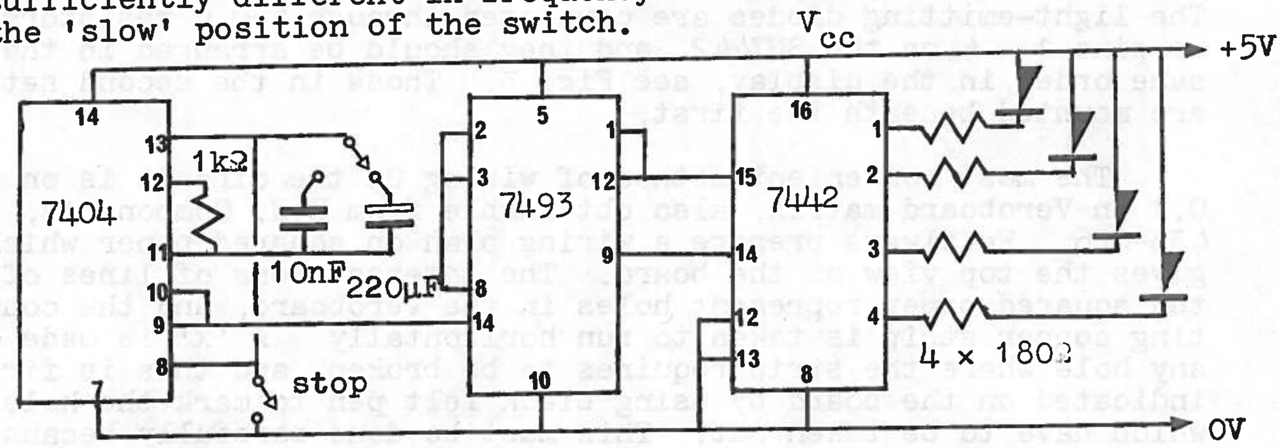


Fig. 1.

The second oscillator can be wired on pins 1 - 6 of the SN7404 in the same fashion as pins 13 - 8 are wired, in the same order. The one difference is to use a 1.2 kΩ resistor between pins 3 and 4, as explained above, to alter the frequency. A double pole, double throw switch - R.S. Components 316-591 - is used to switch the oscillators between 'slow' and 'normal' positions. When both the 220 µF are in circuit, the lights flash at a rate of about 2 per second, which is sufficiently slow for the pupils to see that each lamp is on for the same length of time. With the switch on 'normal', the 10 nF are in circuit and the flashing rate is some kHz so that all the lamps appear to be on. Stopping the sequence is done by closing the switch between pin 8 and ground. This is most conveniently done by a push button switch, so that one with two normally open contacts - R.S. Components 337-920 - is needed.

For those who would like some explanation of the circuit operation, it is as follows. Three inverter gates on the SN7404 are connected in a ring, input to output. One of the inputs however (pin 11) is fed via a capacitor and a resistor. This introduces a switching delay as the capacitor charges or discharges through the resistor, and this allows the circuit to oscillate, producing square waves with sharp edges at pin 10. The frequency is dependent on C and R, so that a 220 µF produces slow oscillations at about 2 Hz.

This circuit is the most economical we know for producing pulses which will be accepted by other integrated circuit inputs. It is good where a single frequency such as for a clock generator is wanted, but less so if the frequency is required to be continuously variable. The range of usable values of R is somewhat limited, and only a frequency range of 3 or 4 to 1 is possible without switching C.

The SN7493 4 bit binary counter is connected for a count to 15, but when the count reaches 4, when its C output on pin 8 goes high, this is fed to the reset inputs on pins 2 and 3 so that the count reverts to 0. A SN7490 could be used equally in place of the 7493 and would be connected as in Fig. 1, except that the 7490 has additional resets on pins 6 and 7 which should be grounded.

The A and B outputs of the 7493 are connected to the corresponding inputs on the 7442. The C and D inputs, pins 12 and 13, are not used and are grounded. The binary information fed to the 7442 is converted to single negative pulses on pins 1 - 4, in that order, and these drive the set of light-emitting diodes. Pins which have not been numbered in Fig. 1, apart from 1 - 6 of SN7404 which are used for the second oscillator, may be left unconnected. The light-emitting diodes are connected through 180 Ω resistors to pins 1 - 4 on the SN7442, and they should be arranged in the same order in the display, see Fig. 3. Those in the second set are mounted beneath the first.

The most convenient method of wiring up the circuit is on 0.1 in Veroboard matrix, also obtainable from R.S. Components, e.g. 433-826. We always prepare a wiring plan on squared paper which gives the top view of the board. The intersections of lines of the squared paper represent holes in the Veroboard, and the connecting copper strip is taken to run horizontally. A 'x' is made on any hole where the strip requires to be broken, and this is first indicated on the board by using black felt pen to mark the holes which have to be taken out. This must be done carefully because one is marking the holes on the copper itself, which is the underside from the point of view of Fig. 2. The marked holes are then drilled out only until the copper strip is broken, using a drill which is about twice the diameter of the strip itself. The board is scrubbed lightly with glasspaper to remove any burrs, and then inspected carefully through a hand lens or similar magnifier. This is very necessary to ensure that all connections which should be have been broken, and that no burrs are left to cause shorts between adjacent copper strips.

In the present case we used a board with 30 strips, each strip having 17 holes. The two circles at top left and bottom right of Fig. 2 are holes for fixing bolts, which can be 6 BA. The position of each chip is shown, and the strips require to be broken between each chip, and between the two rows of pins on each side of a chip. Two strips are left at top and bottom between chips: these are to carry the 5 V d.c. supply needed. The positive side labelled V_{cc} is at the top of each chip, and the negative or ground side of the supply at the bottom. The notch shown at top left of each chip indicates the position of pin 1, and corresponds to the position of the locating dimple or spot on the chip itself. If a chip is plugged in or connected the wrong way round it can be destroyed as in many cases it means that the supply has been connected in reverse.

Connections between chips are then drawn on the wiring plan, as lines joining two Veroboard holes, shown as dots in Fig. 2. In reading the wiring plan, two things should be remembered. Dots in any horizontal row are connected by the copper strip, provided there is no 'x' to show a break; and secondly, the outer two columns of holes within a chip outline connect to the pins of the integrated circuit.

Single, sleeved conducting wire, e.g. R.S. Components 356-331 to 356-432, which is supplied in many colours is used for interconnection. First the V_{cc} strips are connected, then the ground strips. Then each chip has its +ve and -ve supply connected. Each chip is then taken in turn and the rest of its connections made except where these involve additional components such as capacitors or resistors, which are fitted later. As each connection is made, it is ticked off in pencil on the wiring plan.

Wiring is done as follows. A 3 mm length of wire is bared and pushed through the correct hole from the top (wiring plan) side of the board. The wire is bent against the board and a dab of plastic tape stuck on to hold it in place while the board is turned over and the wire soldered into position. The tape is taken off, the route to the other hole decided upon and the wire laid flat against the board. 3 mm beyond the hole the wire is cut, the end bared and pushed into the hole. Tape is again applied, the board turned over and the wire soldered. With experience it will become less necessary to use dabs of tape, but this is a good precaution for the beginner in Veroboard wiring to take. It helps to prevent the kind of mistake which can happen when a wire end which has come loose is replaced in the wrong hole. The wire joining two holes need not follow the exact path shown on the wiring plan; wires can be run close together, and they can run across those parts of the board which are shown as having a chip fitted, provided that not too many cross-overs of wires occur under the chip. The wire should also be laid so that it does not cover any holes into which a chip will be inserted.

The next step is to fit the integrated circuits. While these can be soldered directly onto the board we would strongly recommend that dual-in-line (d.i.l.) sockets be fitted. Experience has shown that i.c. chips can go faulty in use, and it is then a great convenience to be able to replace a chip quickly without de-soldering 14 pins at once. The extra cost is not large; about 1p per pin for d.i.l. sockets, and even cheaper if one uses socket strip (R.S. Components 401-699).

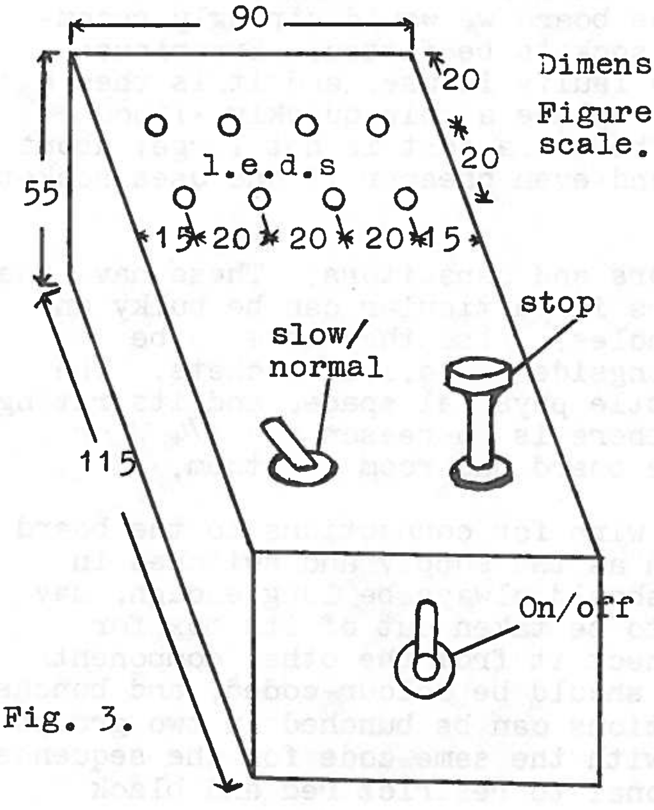
After this come the resistors and capacitors. These have been left until now because capacitors in particular can be bulky and therefore cover many Veroboard holes. Also they have to be physically fitted between or alongside the d.i.l. sockets. The 1/8 W resistor takes up very little physical space, and its rating is adequate for i.c. work, but there is no reason why 1/4 W or larger should not be used if the board has room for them.

It is best to use stranded wire for connections to the board from components outside it, such as the supply and switches in the present case. These leads should always be long enough, say 15 - 20 cm, to allow the board to be taken out of its box for access without having to disconnect it from the other components, in case a fault develops. They should be colour-coded, and bunched into groups. The l.e.d. connections can be bunched in two groups of four, one for each set, and with the same code for the sequence 1 - 4. It is safe, if conventional to restrict red and black colours for V_{cc} and ground respectively.

Apart from the above, the only other connections to the board are those for the switches S_1 and S_2, shown alongside Fig. 2. Since the same capacitance values are used on both oscillators, it does not matter which way they are connected to the switch, as long as both high value capacitors go to one side, and both low value to the other side of the switch. The push button 'stop' switch S_2 has two normally open contacts. One side of each of these is wired to the change-over contacts of S_1 and both other contacts go to ground.

The supply needed is 5 V at 80 mA, and is provided by a PP7 battery. The supply circuit diagram is shown in Fig. 5, and consists of a 27 Ω resistor to drop the battery voltage down to 5 V, and a 2200 μF smoothing capacitor. Figs. 3 and 4 show the dimensions and layout of components in the box in which we built the unit. If bought from R.S. Components, the light-emitting diodes are supplied with a plastic collar which push fits into a hole of the right size drilled in the box top and this serves to hold the diode in position.

S_1 and S_2 are both mounted on the box top, and the on/off battery switch on the side. The smoothing capacitor is clipped in position against the bottom of the box, and the battery is padded and held in position by two pieces of plastic foam. The diodes have wire ends; all the anodes are connected together and a sleeved lead taken from them to the positive terminal of the capacitor, which is V_{cc}. Heat shrink sleeving is used to cover each of the cathode joins, and as an additional precaution against shorting a broad piece of plastic tape is stuck to the underside of the box lid to cover all connections to the diodes.



Dimensions in mm
Figures not to scale.

Fig. 3.

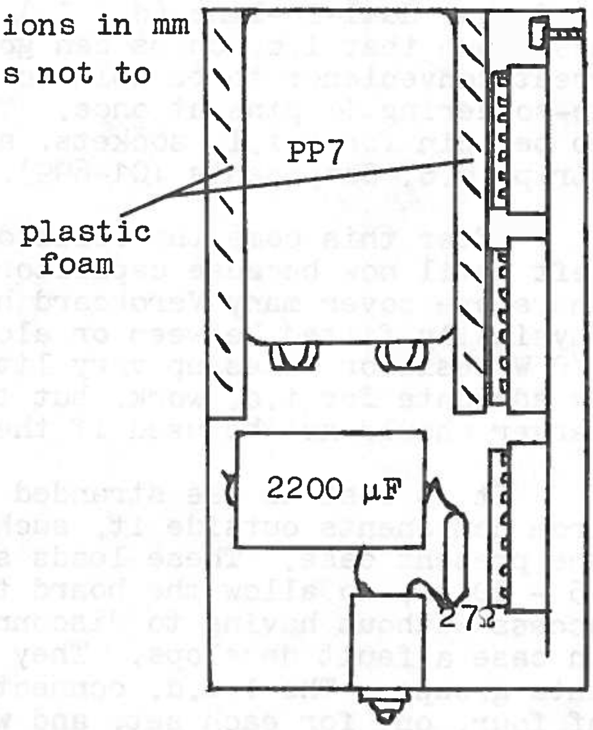


Fig. 4. Component layout.

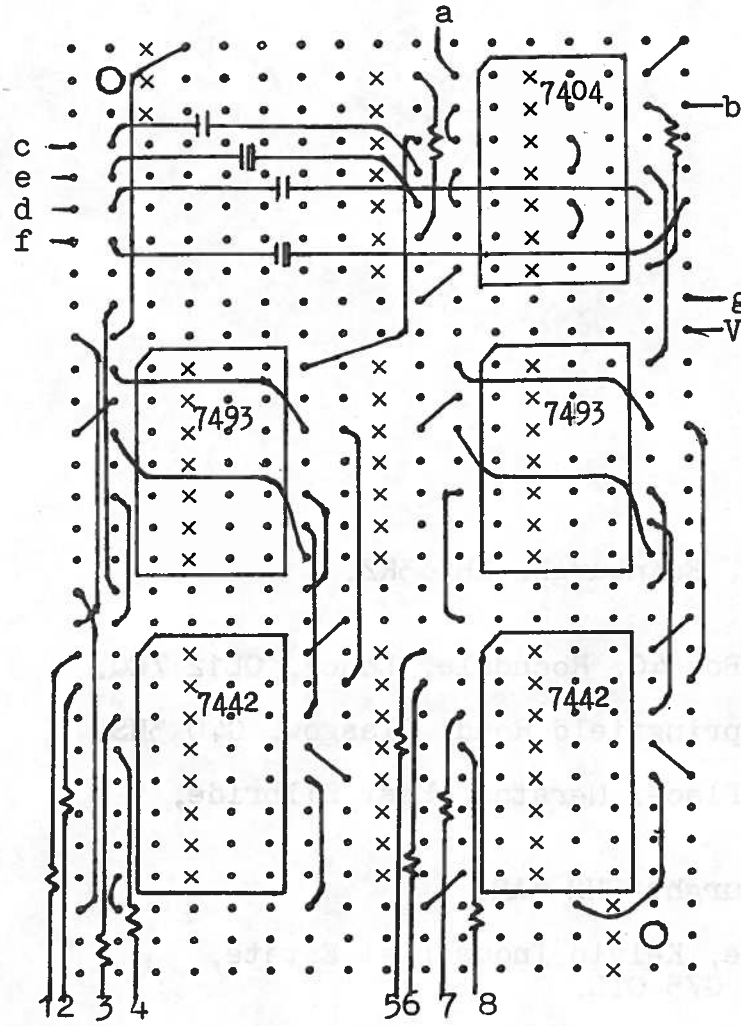
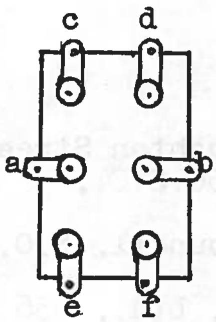
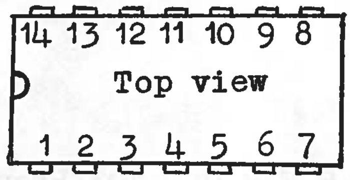


Fig. 2. Veroboard wiring diagram. Points 1 - 4 go to one set of l.e.d.(green); points 5 - 8 to second set (red). Points a - f go to double pole change-over switch wired as below. The two halves of the stop switch connect points a and b to ground.





I.C. pin connections.

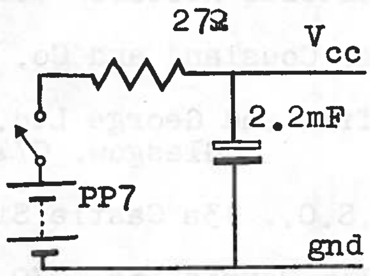


Fig. 5. Power supply.

Trade News

When we intimated in Bulletin 91 (September) that 5 in² stainless steel wire gauze was available from Begg, Cousland at 20p we did so in good faith, having confirmed that price by telephone just before sending the bulletin to the printers, and in fact we had bought from them at 17p in July. The firm has reneged on that price, and now quotes 35p for quantities under 100; 31p for 500 - 999, down to 21p for over 10,000. Minimum order charge is £15.

Some teachers found difficulty last session in obtaining trout eggs. We investigated the position then, and have recently confirmed that West of Scotland Trout Farm, and Solway Fishery can both supply eyed ova at an approximate cost of £1 per 100. Both firms require to be notified a week in advance of delivery, and preferably more.

Griffin and George have asked us to indicate to schools owning their hydraulic press, L27-250 that under certain circumstances the glass cylinder may break. They ask to be informed when they will send the school a protective cover free of charge.

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

Asbestosis Research Council, P.O. Box 40, Rochdale, Lancs, OL12 7EQ.

Begg, Cousland and Co. Ltd., 636 Springfield Road, Glasgow, G40 3HS.

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

H.M.S.O., 13a Castle Street, Edinburgh, EH2 3AR.

Philip Harris Ltd., 30 Carron Place, Kelvin Industrial Estate,
East Kilbride, Glasgow, G75 OTL.

R.S. Components, P.O. Box 427, 13-17 Epworth Street, London,
EC2P 2HA.

Scottish Centre for Mathematics, Science and Technical Education,
College of Education, Gardyne Road, Broughty Ferry,
Dundee, DD5 1NY.

Solway Fishery, New Abbey, Kirkcudbright.
Tel 038 785 235.

West of Scotland Trout Farm, Bridge of Weir, Renfrewshire.
Tel. 0505 612324.