SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 118. January, 1980.

Contents

Introduction

Electrical safety testing of pieces of school equipment using commerical testers like the Clare V141, the Philip Harris C67560/2, or the Irwin Desman EA799 is causing a lot of trouble. From various parts of the country we hear of situations where all the equipment in a school has failed to pass the insulation test, from others that equipment has been ruined as a result of an earth bonding test. The Technical Information Service of the National Audio-Visual Aids Centre has issued a widely distributed circular warning people against using an earth bonding test at 25 or 10A on certain accessible metal parts of audio and visual equipment, such as record player pick-up arms, as they are 'very likely to have its earth protection "blown off" thus rendering it unsafe'. As far as we are able to tell (while reading the document on loan from the reference library) the relevant British Standard, which is BS415:1979 requires that all accessible conductive parts must either be insulated, or able to withstand a 10A earth bonding test. The British Standard itself is not a legal requirement, and particularly in school equipment the HSE may be prepared to accept standards which fall short of this. At the moment we do not know if this is the case with electrical safety testing, or what test should be applied in the situations indicated by NAVAC where the 10A earth bonding test is not advised.

What does a school do with a piece of equipment which fails its insulation test? (One manufacturer's 'throw-away' line - rectify fault and test the equipment again before use - could cause all sorts of problems for the school). What if the equipment passes at 500V, but fails at 1000V? Has anyone who has sought to 'rectify fault and re-test', sent the instrument back to the manufacturer, and how did he fare? What does one do about equipment from W.B. Nicolson, Morris Laboratory Instruments and all those others who have gone out of business?

Has any item of equipment been made unusable as a result of being tested? If so, what fault made it unusable, and was it at the time on insulation or earth bonding test, on 10A/25A, or 500/1000V test? How many items in your school were found to be faulty, and what were they? These are some of the questions to which we would like the answers. We honestly do not mind if we get a reply from every secondary school in the country. It will help us to decide the extent of the problem and what types of equipment are most likely to cause trouble. We will then be in a position to approach manufacturers and the H.S.E. to determine what tests should be applied to school equipment, whether they be the British or any other standard.

* * * * * * *

The results of the W.P.A. apparatus design competition have been announced. This competition which was open to teachers, students and pupils in primary to further education, required the entrants to design, test and produce either a completely new, marketable piece of scientific apparatus, or a novel modification or addition to apparatus currently available. The entry had to include a working example of the design, and details and/or drawings of the apparatus, along with a written account of the development.

The judges for the competition were:

Mr Osborn, South London Science Centre:
Mr Savage, British Educational Equipment Association:
Mr Stewart, Director of SSSERC:
Mr Tawney, Director of CLEAPSE.

In coming to a decision, the judges took into consideration six factors, which are given here not necessarily in order of importance.

1. Presentation of the written account, together with drawings, diagrams, photographs etc.
2. Presentation, design and workmanship of the apparatus.
3. The originality of the design.
4. Its applicability and relevance to science teaching.
5. Its ease of use in the classroom situation.
6. Its marketability.

Fifteen entries were received, and the final placings were:

1. £500 worth of WPA equipment and £75 in cash, to Mr Ellse, Rugby School, for an improved current balance.
2. £250 worth of WPA equipment and £50 in cash, to Messrs McCartney and Little, Musselburgh Grammar School, for a gas chromatograph.
3. £125 worth of WPA equipment and £25 in cash, to Mr Ridge, Stowe School, for a precision timer and frequency meter.

Two runners up who received £70 worth of WPA equipment were Mr Lloyd, Harrogate Granby High School, for a battery box and tester, and Mr Rogers, Harvey Grammar School for tuned circuits.

While we are pleased to find a Scottish school amongst the prize-winners, it is disappointing to say that Musselburgh's was the only Scottish entry received. Our experience of seeing, and sometimes judging the annual technicians' exhibition sponsored by the Scottish branch of the A.S.E. at their annual meeting, and the science fairs we visit from time to time suggest that if other Scottish schools had entered they too might have been amongst the prizewinners.

Chemistry Notes

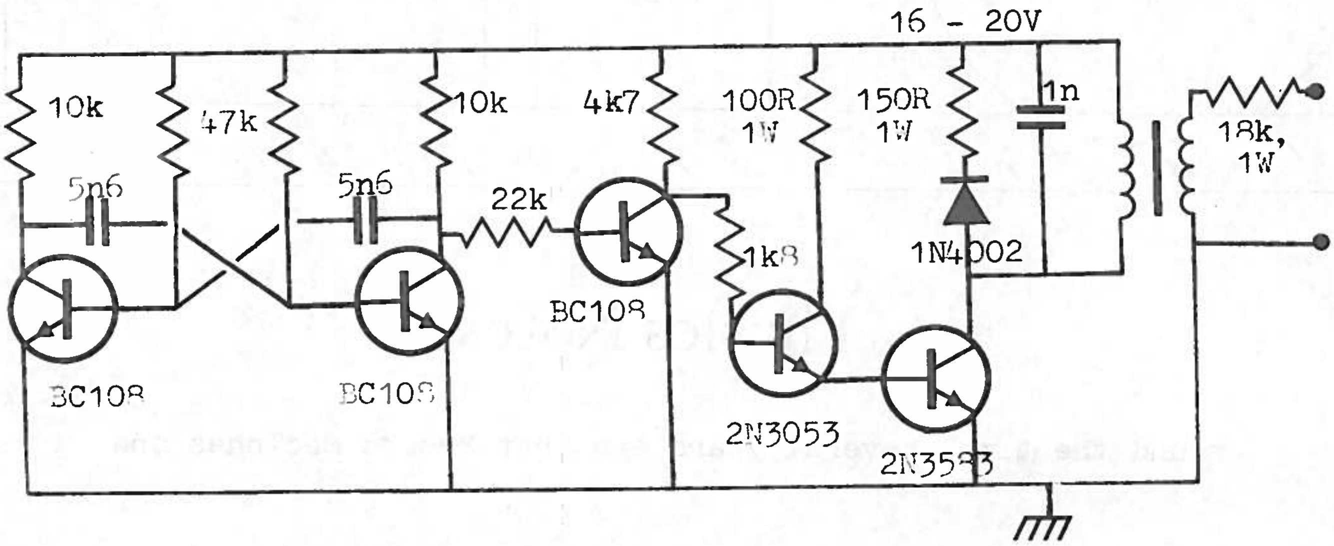
In Bulletin 49 we gave a simple circuit using a relay, for producing a sparking generator for those experiments in chemistry which need one, e.g. the combination of nitrogen and oxygen in air. It used a car ignition coil as an alternative method for producing the high voltage, induction coils being frowned upon even then. Relays have gone the same way as induction coils, and we decided to update the circuit by using electronic ignition.

It is possible, as indicated in Core Chemistry (section 13.2 p. 153), to get a spark generator by supplying the electrodes directly from an e.h.t. unit producing up to 5kV, which the physics department is likely to have. This circuit has some limitations, enough for us to think it worthwhile to provide the alternative described below. E.H.T. power units are limited to a short circuit current of 3mA, and the spark generator is likely to produce 2mA or less. This means that the time taken for a good brown colour to form in the experiment to spark air is rather long, about 1 hour or more.

Secondly the power unit is working under what are virtually short circuit conditions - the output at the spark terminals is about 600V - yet the output voltage control must be kept high (over 4kV) so that if the spark stops it will restart. Hence about 3.5kV or more is dissipated inside the power unit, providing incidentally a much better instance of 'lost volts' than was ever found in a dry cell when trying to calculate its internal resistance. While the power unit should be easily able to withstand such short circuit conditions for an hour or so, it is not certain that colleagues in the physics department who have lent the apparatus will view such use with equanimity.

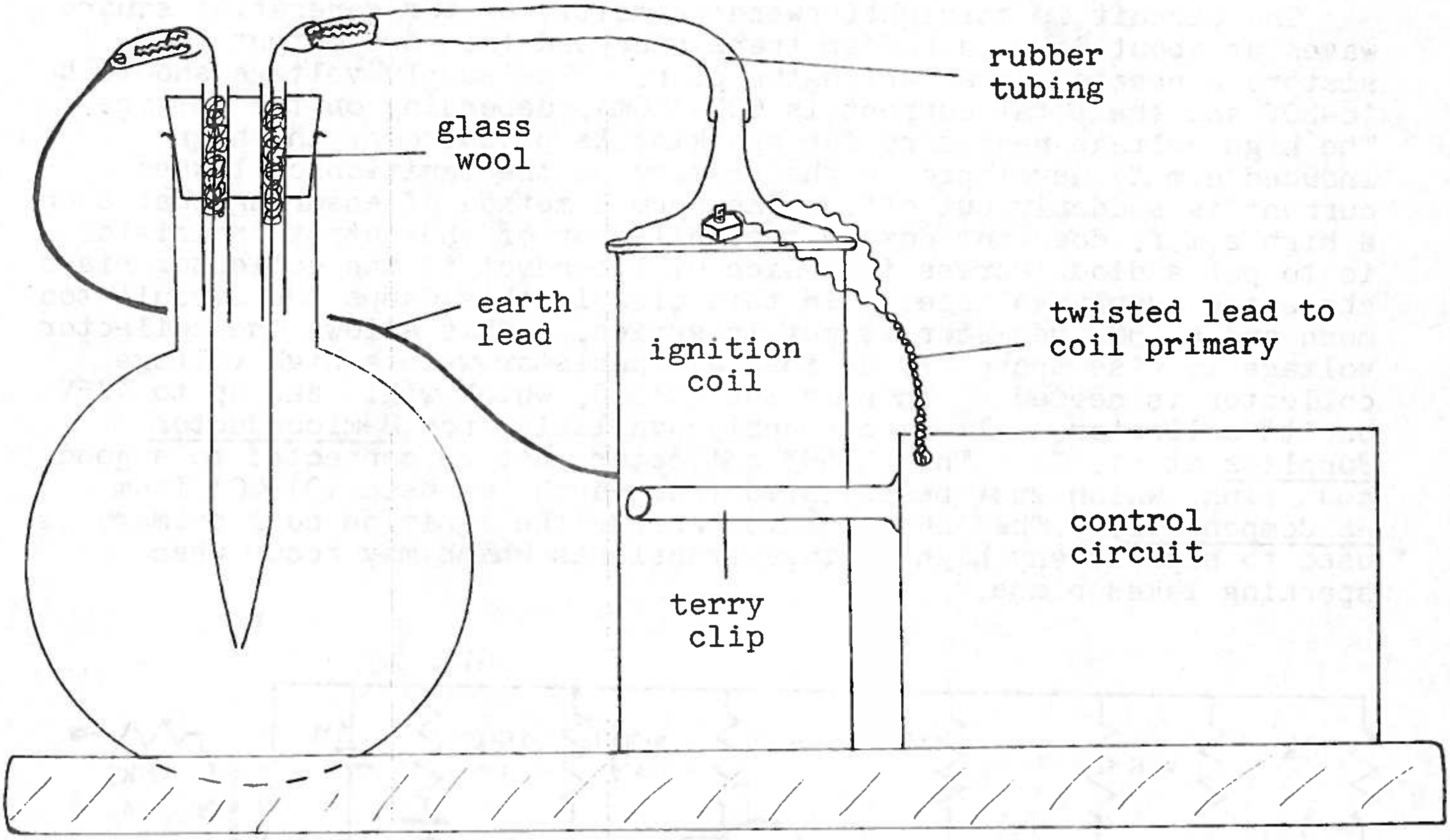
The circuit below gives the detail of our electronic version of the spark generator. As before we use a car ignition coil to produce the high voltage, it being a standard and easily obtainable component. Unlike commercial electronic ignition systems which use d.c. converters and a thyristor at up to 400V, we decided to see of it were possible to use low voltage throughout, except for the ignition coil secondary.

The circuit is straightforward: a multivibrator generating square waves at about 7kHz, a buffer transistor and then two output transistors connected as a Darlington pair. The supply voltage should be 16-20V and the total current is 600-700mA, depending on the voltage. The high voltage necessary for sparking is produced by the high induced e.m.f. developed in the primary of the ignition coil when current is suddenly cut off. The normal method of ensuring that such a high e.m.f. does not damage the collector of the output transistor is to put a diode across it, which will conduct if the collector rises above the supply voltage. In this circuit this damps the circuit too much and a 150Ω resistor is put in series. This allows the collector voltage to rise above V+, so that a transistor with a high voltage collector is needed. This is the 2N3583, which will take up to 175V on its collector. It is currently available from Semiconductor Supplies at £1.10. The 2N3583 collector must be connected to a good heat sink, which must be isolated from earth: we used 401-403 from RS Components. The 1nF capacitor across the ignition coil primary is used to supress any high voltage transients which may occur when sparking takes place.



Although the circuit is not powerful enough to produce a sizeable shock - less than the commercial ignition coil in fact - it is still desirable to make the output as safe as possible. Accordingly we connected the ignition coil to a large Terry clip fixed to the box containing the electrical circuit, and on the same baseboard put a depression to take the r.b. flask containing the electrodes and spark gap. The high voltage output was covered in a red bunsen tubing sleeve, just long enough to go to the top of the flask, with a crocodile clip lead inside the tubing.

The best method of making the electrical connection to the spark gap was by putting the wires, which are nichrome or steel into glass tubing plugged with glass wool, through a two holed stopper. If a rubber or nylon bung is used, with the wires pushed through the bung, leakage of current across the bottom of the bung between the wires occurs and decomposition of the bung means that the resistance decreases so that in a short time the spark gap will not fire. Nichrome or steel electrodes become contaminated after a while, although if they are cleaned before use they will keep the spark going for several hours. If this is thought to be a problem it is an easy matter to silver solder the material from a commercial spark plug onto the ends of the wire electrodes so that the spark passes between this material rather than across the wires themselves.



Physics Notes

Around the time, several years ago that Messrs MacInnes and

Seath of Jordanhill College of Education were developing their air bearing, which subsequently became XBK-400 in the Griffin and George catalogue, we made our own version, inspired by an early prototype which Mr MacInnes demonstrated at a Scottish Branch A.S.E. meeting. In our case we were content to keep it free-running, so that it is not so versatile as the commercial model: for example, it is not possible to demonstrate the factors associated with centripetal force. But it can be used for experiments on angular momentum, and for the rotational equivalents to Newton's Laws. It proved very simple to make, consisting of an air-tight box with perforated roof, no special bracing being necessary. It can support weights up to 2kg on the bearing, if they are symmetrically applied, and it has a free running half life, i.e. the time to lose half its original angular velocity, of over 30 revolutions. Our reason for resurrecting the bearing at this late date is that the arrival of the Philip Harris data memory makes it easier to get quantitative results from the bearing with an accuracy of a few percent.

Most schools will be aware of the advent of the data memory, which was unveiled at the A.S.E. meeting at Reading University. There is also an article on its function in Physics Education (1). Therefore we will confine ourselves here to those functions which we require in measuring the instantaneous velocity of a rotating body. Although the memory has two channels, we use only one for our experiments. The channel input will cope with voltages varying in 6 ranges, in our case either 10V or 3V. A pair of leds give a warning if the input voltage level is either too low or too high, and a zeroing control allows the voltage level to be corrected. The voltage in the input is sampled and stored 512 times during a record. Using the fastest sampling time which we need for our experiments, the samples are taken every millisecond, so that the whole record lasts for about half a second. The information of the voltage level is stored in the memory, and can be reproduced later at any speed we choose, and it is this function which makes the memory so versatile. The speeds are controlled by two clock switches, so that a record may be made and replayed at a range of speeds between 1 every ms and 1 every 20 minutes. One of the switch positions is 'Manual', where the steps are controlled by pressing a button. Another output position allows the record to be displayed on an oscilloscope, and we found this especially convenient in our experiments.

The principle of our rotational experiments is to cover a 30^o sector of the air bearing with black tape, so that the sector overlaps the edge of the bearing. A photo-electric cell at one side, and a lamp bulb at the other side of the tape are arranged so that the light beam is interrupted at each revolution. The memory is kept ready to record until the blanking sector is almost at the beam, when the record is started. Hopefully the whole of the blanked part will then have occurred during the half second when the memory was recording. This can be verified immediately by turning the function switch to 'scope replay', when the record will be shown on the oscilloscope and it can be readily seen where the blanking pulse occurs on the record. The input circuit we used is shown below.

The photo-transistor is put in some kind of metal box to restrict the light, and illuminated by a small lamp bulb. The circuit is normally on, with the input at 3 - 4V, but when the beam is interrupted the current is much reduced. The blanking pulse is negative, and Fig. 1(b) shows what one may expect to get on the oscilloscope if the whole of the blanking pulse is on the record. The bottom of the pulse may be fairly fuzzy, due to variations in the amount of light (it helps in this respect to power the lamp with d.c. rather than a.c.), and there may be one or two steps on the pulse edges, caused by the finite size of the hole in the box. The information we want from the record is the duration of the blanking pulse, which is got by replaying at a much slower speed.

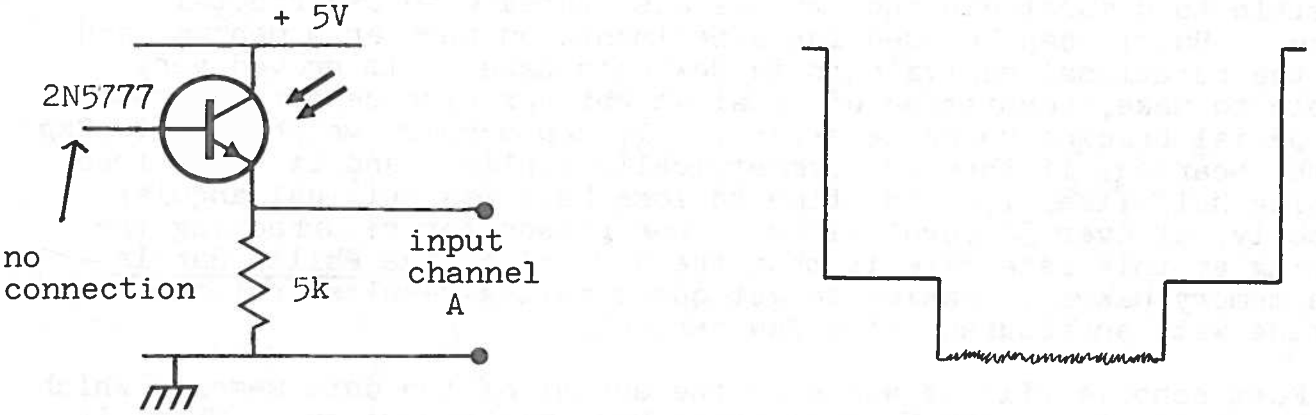


Fig 1. (a) input circuit (b) oscilloscope trace

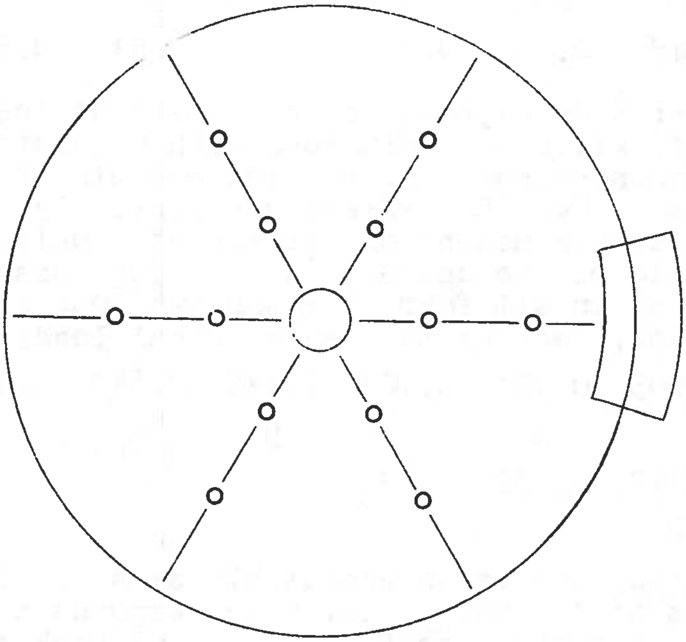
As has already been said, the input voltage is sampled 512 times during the record. The position of a step in the sample is indicated by a row of nine leds, which use binary notation. For example, the 100th step in the record would be signalled by the leds for 64, 32 and 4 being on. The leds switch off and on during record and replay, so that it is possible to show the progress of the record, if the steps are changing sufficiently slowly. Also the record can be interrupted at any point by setting the function switch to 'standby'. It is also useful that the oscilloscope is live when the function switch is on ordinary replay, as well as 'scope replay', so that provided the oscilloscope has a d.c. input the trace will show the voltage level for each step of the record.

Assuming we have a satisfactory record of a blanking pulse as on Fig. 1(b), its duration is found as follows. The clock is put to 1000/min, and the function switch on replay. The hand is kept on the function switch, ready to move it to 'standby' whenever the start of the pulse is shown by the oscilloscope trace moving downwards. When this happens, two or three steps may have gone through before the switch stopped at standby, so that the positional leds are counted, about ten are subtracted to make sure that the start of the pulse has not been missed, and the replay is started again. When the previous number is reached the function switch is put to standby and the clock switched to 30/min. This is slow enough to stop the record at a single step, so that one can stop the record immediately the blanking pulse begins, and note the total of the positional leds. The same procedure is used to tell the end of the blanking pulse, and the difference between the two totals will be the pulse duration in ms. It is a minor inconvenience that the positional leds are in binary rather than decimal notation, and one that is easily overcome with a calculator. After a few practice runs one becomes adept at gauging from the 'scope replay' where the blanking pulse begins and not much time is wasted.

Some expertise is also needed to make a record of the blanking pulse. The air bearing may be rotating quite fast, and the record takes only ½s to complete. Pressing and releasing the function switch so that the record starts at the right place can be critical.

The normal sequence is to press and hold the reset button, switch to record, and then release the button at the right time. For those who may find themselves tensed up at having to release the button, being afraid to release it too early, another procedure is possible. The function switch is put on standby on the position next to the record position, and the reset button pressed and released. All the leds will go out, and the box is set to record. but will only do so when the function switch moves to record. This substitutes a twisting motion of the larger function switch for the normal release button, which may be easier for some people to achieve.

The top of our air bearing carries a 40mm diameter boss to allow a string and weight hanger to be fixed to it. The pattern of holes on the bearing is symmetrically placed, at 60° angles, as below:



Two sets of holes at 50 and 100mm radius respectively are made to fit into circular discs which are used to vary the moment of inertia of the bearing. The masses are of lead, with a brass surround, and are shaved down to have masses of 250 and 500g. These masses are always used symmetrically in pairs. Although the arithmetic attempts to do so, it is an approximation to imagine that such lead weights behave as 'point masses'. At the smaller radius, one of our discs, which have a radius of around 40mm, will be in error by about 11% by considering it as a point mass, and by about 3% at the larger radius. This still makes it possible to graph the inverse variation between moment of inertia and acceleration for a constant torque, and to find from it the moment of inertia of the air table itself.

A blanking sector covering 30° is made from black paper and stuck on the air table so that it overhangs one edge. The starting position of the bearing was such that the middle of the blanking sector coincided with the photoelectric cell. The blanking sector therefore traverses the beam after 1,2,3 ... complete revolutions. In our first experiment, the moment of inertia and the torque were kept fixed, and we measured the duration of the blanking pulse after 1,2,3 etc. revolutions. If the bearing turns with constant acceleration the angular velocity w, and the angle travelled will be related by the equation $w^2 = 2\alpha\theta$ (equivalent in the linear case to $v^2 = 2as$). $w^2 \sim 1/t^2$, so that $t^2\theta$ should be constant.

Result:

Pulse duration, t (s)	0.320	0.228	0.182	0.160	0.146	0.129
Distance, revolutions θ	1	2	3	4	5	6
$t^2\theta$	0.102	0.104	0.100	0.102	0.106	0.100

The easiest way of varying the torque is to vary the hanging mass at the end of the pulley and string. At each step, the pulse duration at the end of the 6 revolutions was measured. As before $w^2 = 2\alpha\theta$. By analogy with the linear case, we can expect that the acceleration should increase with increasing torque, and if they vary directly t^2m should be constant, m being the hanging mass.

Pulse duration t (s)	0.219	0.151	0.132	0.115	0.101	0.093	0.885
Hanging mass m (g)	10	20	30	40	50	60	70
t^2m	0.48	0.46	0.52	0.53	0.51	0.52	0.51

To find how the acceleration depends on the moment of inertia, we again measured the velocity after 6 revolutions with a constant hanging mass of 20g. To avoid inconvenient numbers, the moments of inertia were given arbitrary units. Two 250g masses symmetrically placed at 5cm from the centre were given a moment of inertia of 1 unit. Then two 500g masses at 5cm would be two units, and two 250g masses at 10cm would be four units. Using in all four 250g and two 500g masses we applied various combinations, keeping to a symmetrical load.

Pulse duration t (s)	0.093	0.101	0.107	0.114	0.119	0.127	0.135
Moment of Inertia I	1	2	4	5	6	8	10
	0.142	0.152					
	12	16					

The results of t^2 against I give an acceptable straight line with an intercept on the I axis of 7.7 units, which corresponds to the moment of inertia of the air table itself. Reverting back to SI units, one of our arbitrary units corresponds to a 0.5kg mass at 0.05m radius:

$mr^2 = 0.5 \times (0.05)^2 = 0.00125\text{kgm}^2$. Therefore Moment of Inertia of the air table = 7.7 units = 0.00125×7.7

$= 9.6 \times 10^{-3}\text{kgm}^2$.

We can also measure this quantity directly from the relation torque = $I\alpha$. After passing through 12π angle, a 30° sector passed through the beam in 84ms. The torque, assuming no friction was from a 20g mass at a distance of 22mm from the centre. Therefore torque = $0.02 \times 9.81 \times 22 \times 10^{-3} = 0.00432$Nm. The angular velocity

$w = \theta/t = \pi/6 \div 0.84 = 6.23$ rad/s.

The acceleration is given by $w^2/2\theta = 6.23^2/24\pi = 0.51$ rad/s^2.

Then the moment of inertia of the air table is I = torque/α =

$0.00432/0.51 = 8.5 \times 10^{-3}\text{kgm}^2$.

The difference between the two values can be accounted for by the approximation of point masses. We can also find the moment of inertia theoretically on the assumption that it is a uniform disc. This again will be an approximation, as it ignores the central boss and the pulley boss for applying the torque although these contribute only small amounts. The air table mass is 685g, and diameter 310mm. For a uniform disc the moment of inertia =

$$Ma^2/2 = (0.685 \times 0.155^2)/2 = 8.2 \times 10^{-3}\text{kgm}^2.$$

(1) Muir and Elwell, 1979 'The Harris data memory'. Physics Education, 14, 289.

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In Bulletin 110 we gave an account of how one school had used one of our hour meters to log the lifetimes of overhead projector bulbs. Their investigations and subsequent examination of the failed bulbs by the manufacturers indicated that in many cases failure was caused by the poor condition of lampholders and not by faults in the bulbs themselves.

We have been asked to take this investigation a little further. We would be very grateful to have information from other schools whom we know have bought our surplus hour meters. In particular we would like to have responses to the following questions:

(1) Is the average lifetime of bulbs logged lower than the 75 hours claimed by the manufacturer?

(2) In cases where short lifetimes were discovered were there any instances where this occurred despite recent fitting of a new bulb holder? In other words do bulb-holders become faulty with age or is there an inherent design fault?

(3) A great number of schools have fitted 'dropper' resistors so that lamps are under-run. Does this have any significant effect on the lifetime logged?

(4) Others have converted mains o.h.p.s to run at low voltage. We know that this has a significant affect on costs because low voltage bulbs are generally cheaper. Does it have any effect on actual logged bulb life?

(5) Has anyone compared objectively the bulb lives in the o.h.p.s which are 'exclusive' to particular rooms and do not get moved much with shared projectors which are used by a number of staff and are shunted around the building? It may be that extra projectors could pay for themselves through savings on bulbs.

We would be grateful for any information or comments on these questions. However we are particularly anxious to hear from those who have carried out objective investigations and who can back up their opinions and comments with data. We undertake to collate this data and to carry out investigations of our own. The findings would then be published in the Bulletin so that all our readers may benefit from the exercise.

Trade News

Available from 'Ricas Diamond' are paper wipers 11" square, which may be helpful in dealing with spillages. Although somewhat expensive at £25 per 1,000 they are very absorbent and yet possess wet strength.

Refracpac have recently increased the pack size of their ceramic centred gauzes (see Bulletin 105) from 5 to 25. At the time of writing a pack of 25 gauzes was £6.25. They have also imposed a minimum quantity of 5 rolls on orders for the McKechnie fibre ceramic tape rolls mentioned in Bulletin 107. However, orders for a smaller number of rolls will be accepted if they accompany orders for gauzes. The price of this tape has recently been increased. The 25mm wide roll now costs £1.90 per roll for both the 20m x 1mm thick and 10m x 1mm thick tapes.

In Bulletins 107 and 111 we mentioned the use of disposable pipette tips from Buckley Membranes and of a one piece polythene transfer pipette from Alpha Laboratories. Glass transfer pipettes have the disadvantages that they are easily broken and have sharp points. Polythene transfer pipettes are not only safer in this respect, but they are cheaper than the teats used for making glass Pasteur pipettes. They are also corrosion resistant. We have used them with concentrated mineral acids and with bromine.

Alpha Laboratories now supply two other types of pipette in addition to those described in Bulletin 111.

(i) a polythene transfer pipette graduated 1ml x 0.25ml at £13/500.

(ii) a 3.5ml transfer pipette with a very fine and flexible delivery tube. This is very useful for filling small containers with narrow openings and is Cat. No. LW4020 at £9.60/500.

Gordon Keeble Laboratory Products also offer an ungraduated 3.5ml polythene transfer pipette at £17/1000. Buckley Membranes are offering a similar 3.5ml pipette by Elkay Laboratories, at £11/500.

All the prices quoted above are for non-sterile transfer pipettes.

Fenwick Electronics, Scottish distributors and stockists for a number of electronics manufacturers, including Gould-Advance and Levell Instruments, are also selling a range of second-hand instruments. These include oscilloscopes and signal generators.

J. S. Galbraith Marine Biological Supplies, previously mentioned in Bulletin 101, have produced a new catalogue. This includes a range of equipment such as Swift microscopes, aquarium accessories, dissecting instruments etc. in addition to the specimens previously offered.

Available from BioScience UK (formerly C. F. Palmer) are small boss heads made of Maranyl which are non-magnetic, of low thermal conductivity, highly corrosion resistant and very light. They may have some unusual application and the three size ranges sell at between £5.50 and £7.00 per pack of 5.

OSE (Offord Scientific Equipment) have recently imported a number of PZO microscopes from Poland. Of particular relevance to Scottish Schools are the MS3 and MS4 models suitable for 'H' grade use. Considerable discounts are offered for bulk purchases of these models. We have carried out a preliminary test and can give information and opinions on these instruments.

Bulletin Supplement

Below is a summary of tests carried out on low voltage power supplies. Individual reports on these may be borrowed by writing to the Director. The classifications used are: A - most suitable for school use; B - satisfactory for school use; C - unsatisfactory.

Model No.	EKR-400-010R	EKR-680-010X* EKR-650-010M	P70140/9	EJ1001
Supplier	Griffin and George	Griffin and George	Philip Harris	Irwin Desman
Price	£59.00	£100/£87	£110.04	£33.90
Output control	rotary switch	variable transformer	variable transformer	rotary switch
Output at zero current ac	16.0V	22.5V	26.0V	13.5V
Output at zero current dc	14.2V	25.0V	27.9V	11.3V
Maximum current ac	4A	10A**	10A+	5A
Maximum current dc	4A	10A	8A	5A
Output at maximum current ac	14.8V	20.5V	23.4V	11.5V
Output at maximum current dc	12.6V	16.4V	25.0V	8.3V
Overload protection	thermal cut-out	electronic cut-out	electronic cut-out	thermal cut-out
over voltage lock	yes	yes	no	yes++
Output indicator	none	voltmeter ammeter	voltmeter	none
Smoothing	none	4.7mF	none	none
rms ripple at max. load	-	3.1V	-	-
stacking ability	good	good	good	good
Assessment	B	B	B	A

Notes *EKR-680 and EKR-650 are the same apart from the output indicator.

** 10A for one hour; 8A continuous

+ subject to 200VA maximum

++ fixed at 6V

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

Alpha Laboratories Ltd., 169 Oldfield Lane, Greenford, Middlesex UB6 0PW.

Bioscience UK Ltd., Harbour Estate, Sheerness, Kent ME12 1RZ.

Buckley Membranes Ltd., Chequers Parade, Prestwood, Great Missenden, Bucks HP16 0PN.

Clare Instruments Ltd., Clare Works, Woods Way, Mulberry Industrial Estate, Goring-by-Sea, Worthing, Sussex.

Fenwick Electronics Ltd., 301 Maxwell Road, Glasgow G41 1TD.

J. S. Galbraith, Marine Biological Supplies, Toberonochy, Isle of Luing, Oban, Argyll PA34 4UF

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

Philip Harris Ltd., 34-36 Strathmore House, Town Centre, East Kilbride, Glasgow.

Irwin Desman Ltd., 294 Purley Way, Croydon, CR9 4QL.

Cordon Keeble Ltd., Petersfield House, St Peter's Street, Duxford, Cambridge CB2 4RP.

Offord Scientific Equipment Ltd., 113 Lavender Hill, Tonbridge, Kent TN9 2AY.

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

Refracpac Ltd., Beechwood, Fore Road, Kippen, Stirling FK8 3DT.

Ricas Ltd., 2 Chandos Road, London NW10 6UP.

Semiconductor Supplies Ltd., Dawson House, 128/130 Carshalton Road, Sulton, Surrey SM1 4RS.

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