

SCOTTISH SCHOOLS SCIENCE  
EQUIPMENT RESEARCH  
CENTRE

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# Introduction

With the start of a new session, may we welcome all those science teachers who have just joined the profession? While we try to meet them all during their pre-service training this is never achieved for a variety of reasons, so that there will be some who have not yet learned of our existence. What is more distressing is that we have on occasion met teachers with 4-5 years experience who have not heard of us. Not all of the blame for this situation can be placed with the school, although it does show that the bulletin does not circulate as freely as it should. Some of it must be attributed to our failure to publicise ourselves.

In the past we have always waited to be invited to make a personal appearance in an area, but we would reiterate that we are always pleased to accept invitations to stage an exhibition, or do a lecture demonstration to any group of teachers in any part of Scotland. About the time when this bulletin will appear in the schools we shall be doing both of these things during a two-day stint in Stornoway for the benefit of teachers in the Western Isles. On 1st September we have a similar commitment for Central Region teachers in Stirling, and sometime in November/December on a date still to be arranged we shall be in Dumfries. This programme does not absorb all our capability, and we invite science advisers and others to consider whether a SSSERC exhibition or a lecture on some aspect of our work could be fitted into their Autumn programme of in-service training.

# Opinion

In far off days before the raising of the school-leaving age and the 'O' grade examination, acceleration was introduced to the scientific elite as an element in the equations of motion. Vectors were something one met in the second year of the university course (because the calculus took up most of the first year), and the only apparent reasons for introducing acceleration at all were that without it one couldn't measure little  $g$ , which was thought to be important, or understand Newton's Laws of Motion. The latter were verified experimentally by an elegant piece of equipment based on a mistake, called Fletcher's plane and trolley, and since this could not cope with collisions conservation of momentum was by common consent excluded from the syllabus.

The Russian sputnik changed all this. We were suddenly accelerated educationally into the space age, via the P.S.S.C. and the alternative physics syllabus, which took as its motto 'Physics for All' all meaning the 30 odd per cent of the school population in senior secondary schools. Since then we have had comprehensive education, the raising of the school leaving age, and the Munn report which if put into action could mean that the motto would cease to be an ideal and approximate to a reality, by insisting that science be taught to all pupils up to their

statutory leaving age. Since the introduction of the trolley and the ticker timer, since the linear air-track became respectable and not an expensive toy, we have had little critical appraisal of what we are doing, why we are doing it or indeed whether we should be doing it at all. In the light of the massive investment of time and labour which went into the validation of the S1 and S2 mixed ability course, it seems incredible that we should have allowed an alternative syllabus, which was made so deliberately in order to bypass the validation procedures, to continue for some fifteen years untroubled by any critical assessment.

If I call into question acceleration rather than any other corner stone of the physics syllabus like electron physics or radio-activity, it is that I firmly believe that the cobbler should stick to his last, and mine is certainly not pedagogy. Hence while others are apparently happy with the status quo I will keep any misgivings I might have to myself. However, disquiet about the teaching, or rather the learning, of acceleration has been growing. Notably the staffs in Colleges of Education are amongst the most concerned, and they have more opportunity than most to see day-to-day teaching in action.

From Aberdeen College of Education comes a lengthy report, based in part on a questionnaire and multiple choice test which was set in a number of schools, and which shows a disturbing lack of comprehension of the concept of acceleration amongst 'O' grade pupils. In Bulletin 99 we published a design for a drive unit for a ticker timer which originated in the same college. By switching the timer on for 0.1s every second, it is hoped that this will simplify the calculation of acceleration. During a recent visit to Aberdeen I also saw in the College an inertial transducer fitted to a dynamics trolley. Basically this consisted of a pendulum with lever magnification and an arbitrary angular scale to indicate the displacement of the pendulum from the vertical when the trolley was being accelerated. It seems to me that if we use this to measure the acceleration of the trolley under different forces to establish Newton's Second Law we could be accused of circular argument, and that Fletcher's plane and trolley was rejected on flimsier pedagogic grounds (apart from its providing a demonstration rather than a pupil experiment). Moreover the teacher is going to have difficulty in convincing pupils, who may come to regard it as a black box, that the device does measure acceleration.

A lecturer in Jordanhill College of Education has notified me of a digital velocity meter he has designed to be used with a linear air-track which displays for one second the average velocity of a vehicle during the preceding second. The device is an extension and development of the 'toothed-comb' principle described in School Science Review No. 187, 54, p 351. We know also of one manufacturer who is thinking along similar lines of making a single clock display two velocity measurements in sequence, to allow acceleration to be calculated. We have made our own contribution to linear air-track technology by suggesting (Bulletin 70) the direct use of a high speed chart recorder to measure the passage of a blanking card through a light beam. While our technique has the advantage over the other two described above that it can register two different velocities simultaneously - something which often happens in momentum experiments - it suffers from imprecision, being limited by the 25cm/s maximum speed of the chart paper.

Trolley and ticker tape appear to me to possess two advantages apart from their simplicity (a point which pupils might regard as a relative term): they allow pupil experimentation including, if one wants to do it, all the Nuffield 'play-way' learning like fixing tape to the back of sprinters, Austin Minis etc. As long as the timer continuously punches out dots at 0.01 or 0.02s intervals moreover, one is in theory at least one order of magnitude nearer the mathematician's concept of  $ds/dt$  and  $d^2s/dt^2$ . One could at least attempt to answer the question - Is the acceleration constant? - something which would be difficult to justify where the interval between successive velocity measurements is of the order of a second.

If we have to abandon the trolley and ticker tape, or introduce it through devious ways because it is proving too difficult for a sizeable number of 'O' grade aspirants, ought we not to question whether we should exclude acceleration from the 'O' grade syllabus? If there are teachers who are satisfied and can point to success in their teaching of acceleration, ought not some body such as the A.S.E. or the Institute of Physics institute a search to find them? One teacher on our Development Committee states that his pupils have no difficulty in measuring acceleration, but do experience difficulty in obtaining the direct proportion results which Newton II requires. He achieves this by dividing the dynamics syllabus in two, with a six month interval between them. In the first he deals with velocity measurement and conservation of momentum, leaving acceleration and Newton II until later. The doubt and dissatisfaction of many physicists with the present position does not augur well for the implementation of the Munn science-for-all up to SIV recommendation which apparently is something which many science teachers wish to see, and it would be better if some of the uncertainty were cleared away before a syllabus for the Less Scientifically Motivated Pupil becomes a pressing necessity.

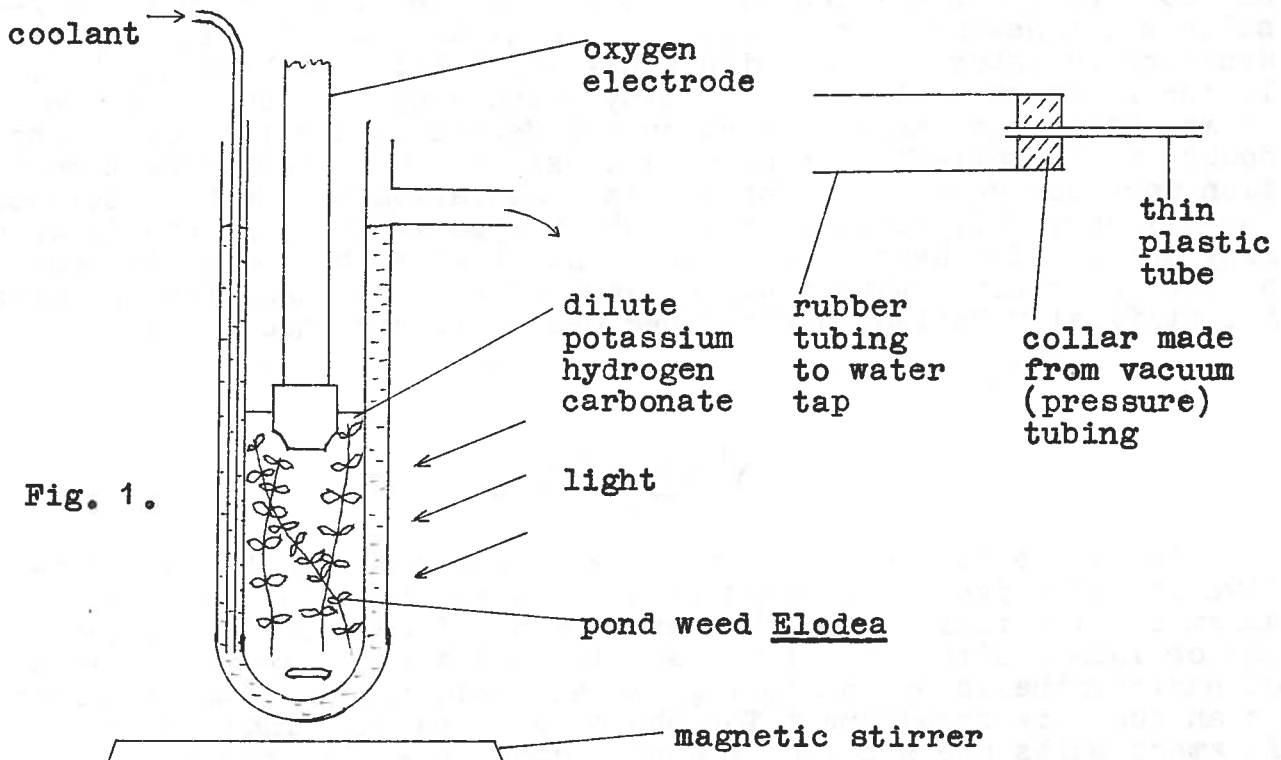
## Biology Notes

In our review in Bulletin 102 we pointed out that the effective use of oxygen electrodes requires a knowledge of their mechanism and limitations and the development of certain techniques. One obvious application of oxygen electrodes is in studying rates of photosynthesis by monitoring oxygen production. However light is an absolute requirement for photosynthesis and since tungsten filament bulbs are a commonly used source this also may mean a fair amount of heat. As explained in Bulletin 102, an oxygen electrode depends for its action on alteration in the current flowing being proportional to the concentration gradient and rate of diffusion of oxygen across the membrane. The oxygen electrodes on the schools market have thin plastic film membranes, usually of polythene or p.t.f.e., whose porosity varies with temperature. The temperature dependence of such electrodes can be very marked, typically 2-3.5% per °C rise. More expensive research type and industrial meters are usually temperature compensated, often incorporating a temperature sensitive device in the probe itself. For school work it is usually easier to arrange the experimental conditions so that temperature fluctuations are minimised.

One method of overcoming the problem is to use a 'cool' source such as fluorescent tubes (see p.3, Bulletin 100). In photosynthesis experiments using tungsten filament sources static heat sinks, in the form of museum jars or large beakers of cold water, are often used. However these have disadvantages especially for longer term experiments. The water in them does slowly heat up and has to be changed at intervals. If they are to be efficient heat sinks, the light path through them may be relatively long when the light losses will be appreciable. For work with oxygen electrodes, such static heat sinks do not give a sufficiently close control of temperature.

After much experimentation we have designed a 'constant temperature' jacket which enables oxygen electrodes to be used to demonstrate oxygen evolution from photosynthesising plants. The particular apparatus described below was designed for use with the polarographic oxygen electrodes sold by WPA and Griffin and George but the principles involved can act as the basis for designs for other types and sizes of oxygen electrode.

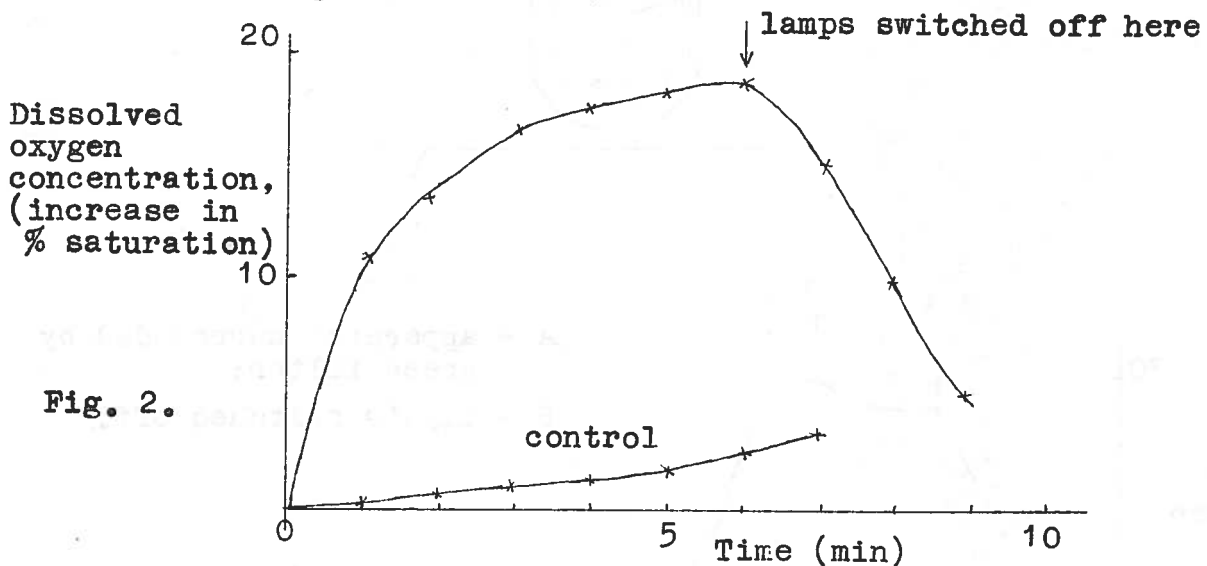
The apparatus used to demonstrate oxygen evolution in aquatic plants is shown in Fig. 1.



The basis of the temperature compensation jacket is a 25 x 150mm sidearm or filter tube forming the outer wall, with a 16 x 150mm rimless test tube forming the inner. Cold water from the tap is fed into the narrow gap between these tubes via a small diameter plastic tube as shown. Some method has to be found of coupling this small diameter tubing to a wider tube which will fit a laboratory tap. One solution to the problem is shown in the inset to Fig. 1 although several other methods can be used. A thin film of water is kept constantly flowing in the space between the tubes and runs to waste via the sidearm. Because of the restriction of flow in the narrow bore tubing, care must be exercised when turning on the cooling water.

The aquatic plant material, Elodea or other oxygenating pond weed is placed in about 10ml of dilute (1-5 per cent w:v) potassium, or sodium, hydrogen carbonate in the bottom of the inner test tube. The volume is kept small in relation to the amount of plant material present, in the hope that the concentration of dissolved oxygen will rise fairly rapidly. In order to avoid local depletion of oxygen near the probe, some form of controlled stirring is desirable. A small magnetic flea (ours was made from steel piano wire fused inside a piece of glass capillary) is placed in the inner tube so that a magnetic stirrer can be used to agitate the contents gently. If a magnetic stirrer is used, care should be taken to ensure that it does not run too hot. An air gap left between the bottom of the outer tube and the stirrer platform will help in preventing undue heat transfer to the apparatus.

If the plastic guard is removed from a WPA or Griffin oxygen electrode it is a fairly good fit in the inner tube and can be lowered down into the bicarbonate solution. In this position it is effectively shielded from the heat of the lamp(s). By controlling carefully the flow of water through the jacket the inner part of the apparatus can be held at a fairly constant temperature even with two 100W tungsten filament lamps close to the apparatus. Sample results with Elodea are shown below together with those for a control with no plant material.



For use with terrestrial plant material the apparatus requires one further, small complication. In order to obtain a measureable increase in the oxygen content of air the volume of the sample should be kept small or very large amounts of plant material will need to be used. The apparatus used with aquatic plant material was modified to allow it to be used with grass or onion leaves etc. by fitting a transparent plastic sleeve over the end of the electrode as shown in Fig. 3. We used a 50mm length cut from a 'Scimitar' 10ml disposable syringe plunger, which fitted over the end of the electrode and remained in position.

Short lengths of grass or onion leaves could be pushed into this tube. When the electrode was lowered into the jacket, so that the ends of these leaf sections dipped into the hydrogen-carbonate solution, a small volume of air was trapped between the surface of the solution and the electrode membrane. Sample results with the grass Poa annua are shown in Fig. 4.

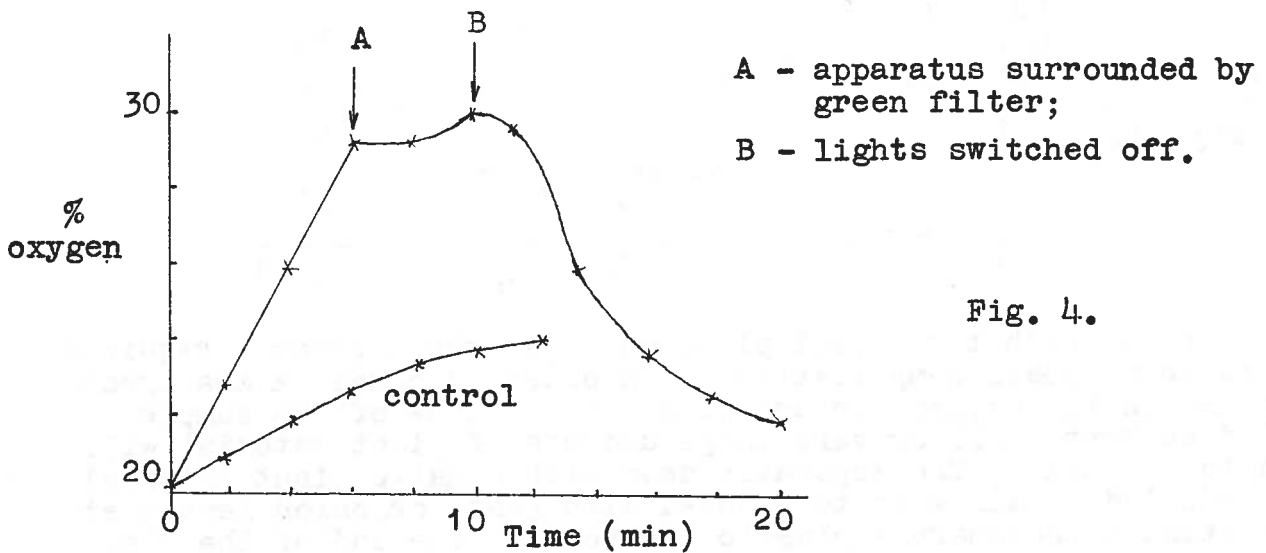
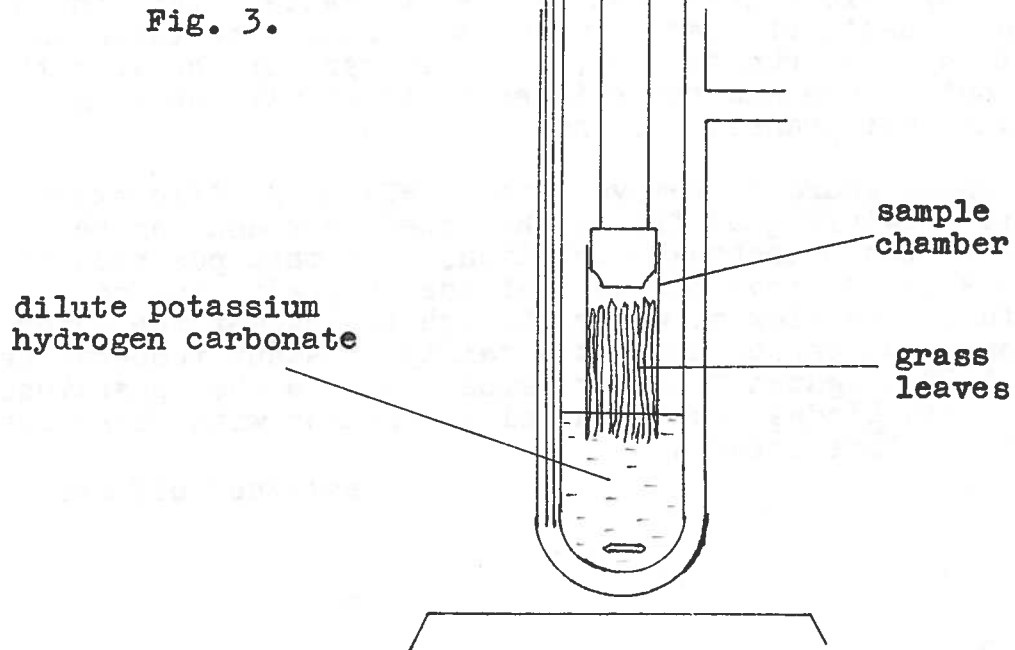


Fig. 4.

## Chemistry Notes

In an earlier bulletin we gave notice that our manual of hazardous chemicals was to be published by Oliver and Boyd, and that two copies of the manual were to be sent to each region so that regional authorities could reproduce the material if they wished and so avoid the cost of buying the published copy. (In



fact it transpires that to Xerox copy the material would cost more than to buy the manual itself). Because of the amount of material to be produced - over 200 pages - Lothian Region Education Department agreed to produce the necessary copies for distribution to the regions. The master we supplied to Lothian Region was a typescript copy of that sent to the publishers so that, in the fashion which publishers always want it had very wide margins, double double spacing between lines etc.

We had imagined that Lothian Region would re-type this material to make it more compact, before reproducing and distributing it. In fact the material was simply photo-copied and sent out, so that each region received a very thick wad of paper. On single spacing and with narrow margins, almost all chemicals could have been accommodated on a single page, but, sent out as we had prepared it, there were about a hundred which carried on to a second page. The inevitable happened, and the collator got the second pages mixed up. We first learned of this when a science adviser phoned us to say that the first aid advice for benzene appeared more applicable to barium. We got a spare copy from Lothian Region, because we had none which they had reproduced, and found a number of discrepancies.

Obviously if the material as supplied has been photo-copied a second time for distribution to schools, and some regions have done this, then the same mistake could occur again. Hence the only way out of the difficulty seemed to be to prepare a key which would allow each second page to be identified and this is what we have done.

The basis of the key is to identify at which part of the description the second page starts, and then to classify further by identifying the different phrases used in the First Aid section, which is where the great majority of second pages start. To use the key to identify a second page, one should see where the page starts. If this is before the First Aid section, the first letter of the code will be one of A-H, excluding E. If the second page starts with the First Aid section, the first letter of the code will be E (for Eyes). If the eye entry starts with the phrase 'Wash with water', and ends with 'Seek medical advice', this part of the code will read EB1. Similar codings are used for the entries under Lungs, Mouth and Skin. When the code has been completed, it is compared with the alphabetical list of codes at the end of this article to identify the chemical.

It would be possible, but tedious, to use the system in reverse, i.e. knowing which chemical was needed, to find its second page, because one would have to search through all the second pages looking for the accumulation of key phrases indicated by the code.

KEY

- 2nd page headed Handling .....A
- 2nd page headed Disposal .....B
- 2nd page starts midway through Disposal section .....C
- 2nd page headed Spillage - Turn off all sources of ignition .....D
- 2nd page headed Spillage - Wear gloves and face shield .....F
- 2nd page headed Spillage - Other than D or F .....G

2nd page starts midway through Spillage section .....H  
First Aid section is divided into four columns headed  
Eyes, Lungs, Mouth, Skin .....E, L, M, S

Eye

Eye entry starts - Irrigate with water .....EA  
Eye entry starts - Wash with water .....EB  
Eye entry starts - Other than EA or EB .....EX  
Eye entry ends with - Seek medical advice .....Appendix 1  
Eye entry ends with - Seek medical attention .....Appendix 2

(Note - These two appendices also apply to entries under lungs, mouth and skin).

Lungs

Lungs entry blank .....LA  
Entry reads - Remove patient from area, rest and keep warm .....LB  
Entry reads - Remove patient from area. Rest and keep warm .....LC  
Entry reads - Remove patient from exposure .....LD  
Entry reads - Remove patient from exposure, rest and keep warm ...LE  
Entry reads - Remove patient from exposure. Rest and keep warm .LF  
Entry reads - Remove patient to fresh air, rest and keep warm ...LG  
Entry reads - Remove patient to fresh air. Rest and keep warm ..LH  
Entry reads - Other than above .....LX

Mouth

Entry starts - Wash with water .....MA  
Entry starts - Wash out with water .....MB  
Entry starts - Wash out thoroughly with water .....MC  
Entry starts - Wash out mouth with water .....MD  
Entry starts - Wash out mouth thoroughly with water .....ME  
Entry starts - Wash mouth with water .....MF  
Entry starts - Other than above .....MX

Skin

Entry starts - Wash with water .....SA  
Entry starts - Wash with soap and water .....SB  
Entry starts - Drench with water .....SC  
Entry starts - Drench with water and remove any penetrating  
particles .....SD  
Entry starts - Drench with water and wash with soap and water ....SE  
Entry starts - Other than above .....SX  
2nd page starts midway through First Aid section in 4 columns .... I  
2nd page starts with First Aid, not in columns ..... J  
1st line reads - Rescuers must wear respirator .....JA  
1st line reads - Contaminated clothing may need .....JB

CODES

A				Ethoxyethane	EA2	LE1	MX1	SX	aluminium (III)
B	EA2	LE1		Carbon disulphide					chloride
B	EA2	LX1		Magnesium	EA2	LX	MX1	SA	methylamine
C	EA1	LX2	MA1	sulphur dioxide	EA2	LX	MX1	SX	(choromethyl)
C	JA			cyanides					benzene
D	EA2	LB1		methanol	EA2	LX1	MA2	SX1	di(benzenecarbonyl)
D	EA2	LE1		ethanoic anhydride					peroxide
EA1	LA	MD	SX	calcium hydride	EA2	LX1	MX2	SC1	benzene carbonyl
EA1	LB	MA1	SA	3-methylbutan-1-ol					chloride
EA1	LB	MA1	SX	petroleum spirit	EA2	LX1	MX1	SX1	di(4-isocyanato-
EA1	LB1	MA1	SB	iodoethane					phenyl)methane
EA1	LB1	MA1	SB1	methylbenzene	EA2	LX2	MA2	SX1	2,4,6-trinitro-
EA1	LB1	MF2	SB1	mercury compounds					phenol
EA1	LC	MA1	SA	pentyl ethanoate	EA2	LE2	MA2	SX1	cadmium
EA1	LE	MA1	SB	methyl 2-methyl-	EA2	LE2	MB2	SX	phenol
				propenoate	EA2	LF	MX2	SC1	sodium hydride
EA1	LE	MC1	SX	butan 2-ol	EA2	LF1	MX2	SC1	sodium peroxide
EA1	LE1	ME2	SB1	benzene	EA2	LG1	MA2	SA	phosphorus (V)
EA1	LG	MA1	SB	pentane					oxide
EA1	LG1	MA1	SB	1,1,1-trichloro-	EA2	LG1	MA2	SA1	ethanedioic acid
				ethane					and ethanedioates
EA1	LG1	MA2	SB1	thallium	EA2	LG2	MA2	SA	sulphur dichloride
EA1	LX	MA1	SB	ethenyl ethanoate					oxide
EA1	LX	MA1	SB1	benzenecarbaldehyde	EA2	LG2	MA2	SB1	1,1,2-trichloro-
EA1	LX	MD1	SB	cyclohexane					ethene
EA1	LX1	MF1	SA	methanol	EA2	LG2	MA2	SB1	phenyl hydrazine
EA1	LX	MX1	SC	bromobenzene	EA2	LH1	MA2	SB1	osmium tetroxide
EA1	LX1	MX1	SX	calcium hypochlor-	EB1	LB1	MA1	SB1	naphtha
				ite	EB1	LX1	MX	SX	mercury
EA2	LA	MA2	SA	strontium	EB2	LB1	MA1	SB1	dimethyl benzenes
EA2	LA	MX1	SA	nitrates	EX	LB	MD	SX	hydrogen fluoride
EA2	LA	MD2	SX1	sodium	EX2	LA	MF2	SB2	barium
EA2	LA	MX2	SC1	sodium hydroxide	EX2	LD	MX	SA1	cyanides
EA2	LA	MX2	SA	chlorates	F	EA2	L1		sulphuric acid
EA2	LA1	MA1	SC	lithium	F	EA2	LA		hydrogen peroxide
EA2	LB1	MA2	SA	phosphorus (III)	F	EA2	LE1		nitric acid
				chloride	F	EA2	LE2		phosphorus (white
EA2	LB1	MA2	SB1	Phenylethene					or yellow)
EA2	LB2	MB1	SB	dichloromethane	F	EA2	LX1		chloric (VII)
EA2	LB1	MB1	SX	ethoxyethane					acid
EA2	LB1	MF1	SB	pentan-1-ol and	G	EA1	LE1		chlorine
				pentan-2-ol	G	EA2	L1		peroxides
EA2	LB1	MF2	SB1	nitrobenzene	G	EA2	LB1		oleum
EA2	LC1	MA2	SA	tin (IV) chloride	G	EA2	LD1		bromine
EA2	LD	MX1	SA1	propan-1-ol	G	EA2	LE2		trichloromethane
EA2	LE1	MA1	SC	lithium hydride	G	EA2	LG1		phosphorus (V)
EA2	LE1	MA2	SA1	hydrogen chloride					chloride
EA2	LE1	MB1	SA1	bromoethane	G	EB1	LA		thermit
EA2	LE1	MC1	SA	tetrachloromethane	G	EX1	LX1		phenylamine
EA2	LE1	MC1	SC	ethanoyl chloride	H	EA1	LX		boron
EA2	LE1	MC1	SX1	silicon tetra-	H	EA2	LA		sodium amalgam
				chloride	I	L1	M2	S1	chromium (VI)
EA2	LE	ME1	SC	1-chlorobutane					oxide
EA2	LE1	ME1	SX	antimony	I	S1			hydrogen bromide
EA2	LE1	MF1	SC1	ethanoic acid	I	SX			chlorobenzene
EA2	LE1	MF2	SX1	1,2-dichloro-	JA				silver potassium
				ethane					cyanide
EA2	LE1	MX1	SD2	beryllium	JB				asbestos
EA2	LE1	MX1	SE2	1-bromoprop-2-ene					

## Physics Notes

Following our article in Bulletin 102 on the 'freezing by evaporation' experiment, we had a note from a first year class in Stromness Academy, pointing out that they had carried out the experiment successfully without using any special apparatus. They had followed the account given in the teacher's guide to Physics is Fun, Books One and Two, something we should have remembered was in it, and were able to produce  $2\frac{1}{2}$ g ice in 10 minutes. When we repeated the experiment we were unable at first to make it work, and after a series of exhaustive (no pun intended) experiments using a vacuum gauge coupled to the system we diagnosed a leaky pump plate. Surprisingly when we changed to top suction in a stoppered bell jar resting on a base plate of duralumin sheet, our results were no better.

We finally succeeded by using as base plate an offcut from a Formica-topped table. We had 40ml water in a 100ml conical flask, and also under the bell jar was a 100ml tall form beaker containing about 40ml concentrated sulphuric acid. In the course of our investigation the vacuum pump had been stripped, cleaned and supplied with fresh oil, although it is not likely that all this preparation was necessary. After 15 minutes pumping the pressure had dropped to 0.015mm of mercury, and subsequent weighing showed that 10g of ice had formed. The earlier failure of metal baseplates raises the interesting question of whether the metals used were too porous for this experiment to succeed. Certainly the final pressure is close to the minimum specified for the NGN rotary pump.

## In The Workshop

Rechargeable U2 cells, usually nickel cadmium, are coming more into use with Worcester circuit boards. They are basically trouble free, but in Bulletin 91 we gave an article on their care and maintenance. Because they have such a low internal resistance, it is possible to pass a very high current through a cell or cells when charging them, so that an ammeter in the charging circuit is necessary. On the other hand, because the e.m.f. rises during a charge, a current which has been set at a safe value at the start of the charge may dwindle away to a very low value before the charge has finished. For this reason it is worthwhile to have a current-limited charger, which means that one does not then need an ammeter; the circuit we describe below was supplied to us by Maxwelltown High School, Dumfries.

This circuit allows any number from one to eight alkaline cells to be connected to any low voltage power supply delivering 12V. The supply does not require to have a smoothed output. The charging current is determined by the value of R. While the charger will be more flexible if R is made a 100 $\Omega$  rheostat, if the chore of charging cells is given to a junior technician or laboratory auxiliary, it will be more foolproof and trouble-free to choose a value for R (quarter or half watt range) which will give

a fixed charging current in accordance with table 1 below, which we prepared from our own circuit.

i (mA)		10	20	30	40	50	60	80	100
R (Ω)	(3 cells)	63	28	18	15	11	10	6.8	5.2
	(6 cells)	47	24	17	12	10	8.0	5.6	4.3

Table 1. Value of R required to give various charging currents into 3-cell or 6-cell load.

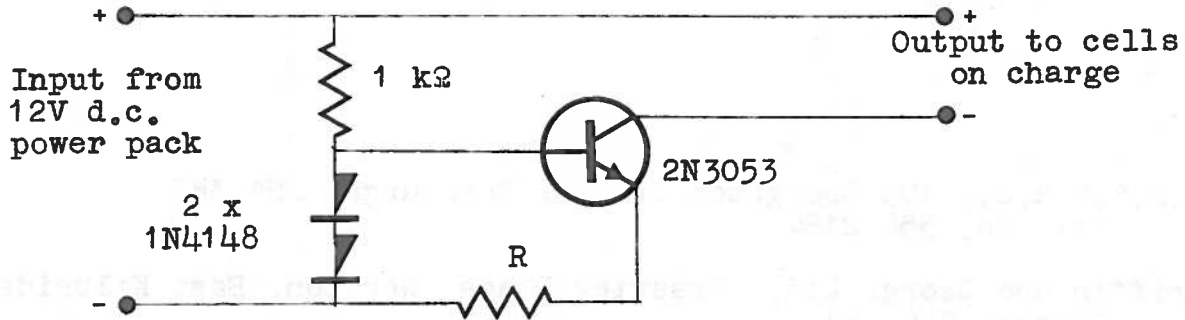
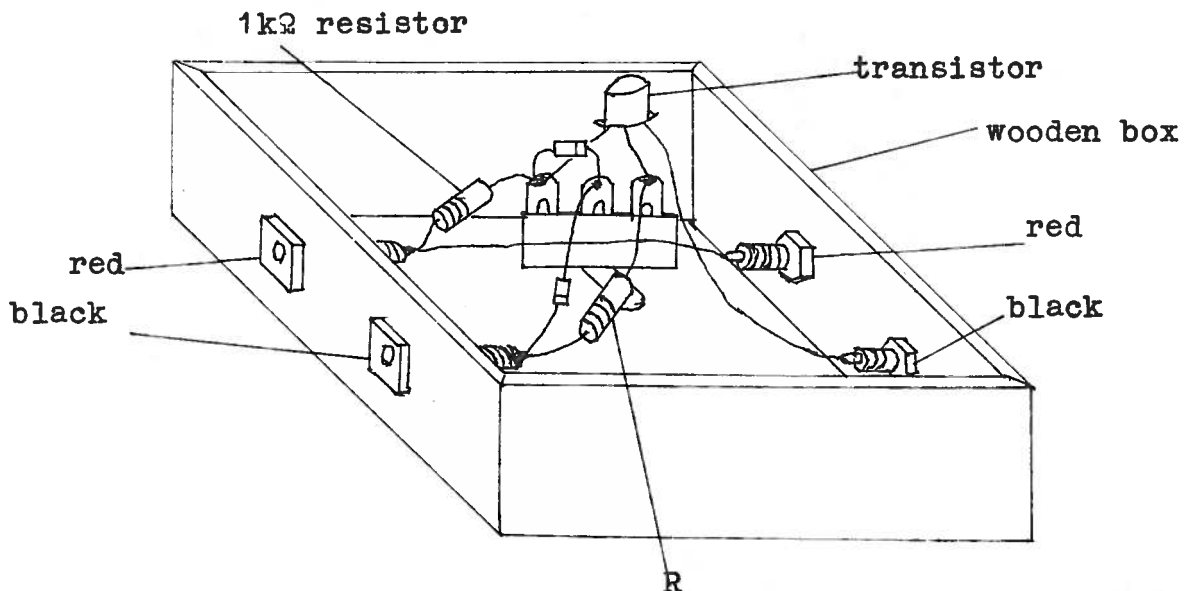


Table 1 shows that there is little variation in charging current when the number of cells on charge is varied. With a fixed 5.6Ω resistance for R, we found the following:

Number of cells	1	2	3	4	5	6	7	8
Charging current (mA)	98	95	92	88	83	78	71	65

The construction presents no difficulties; the circuit can be built on printed board but it is easier to assemble on the two pairs of socket terminals and a 3-tagged tag strip, using a small box to contain everything. The terminals should be colour coded red and black to show polarity of connection, and input and output must be labelled. If R is chosen to give the higher values of current in table 1, then the transistor will benefit from a heat sink (not shown below), e.g. RS Components 401-548. The diodes must be connected the right way round; the dark band at one end marks the cathode.



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