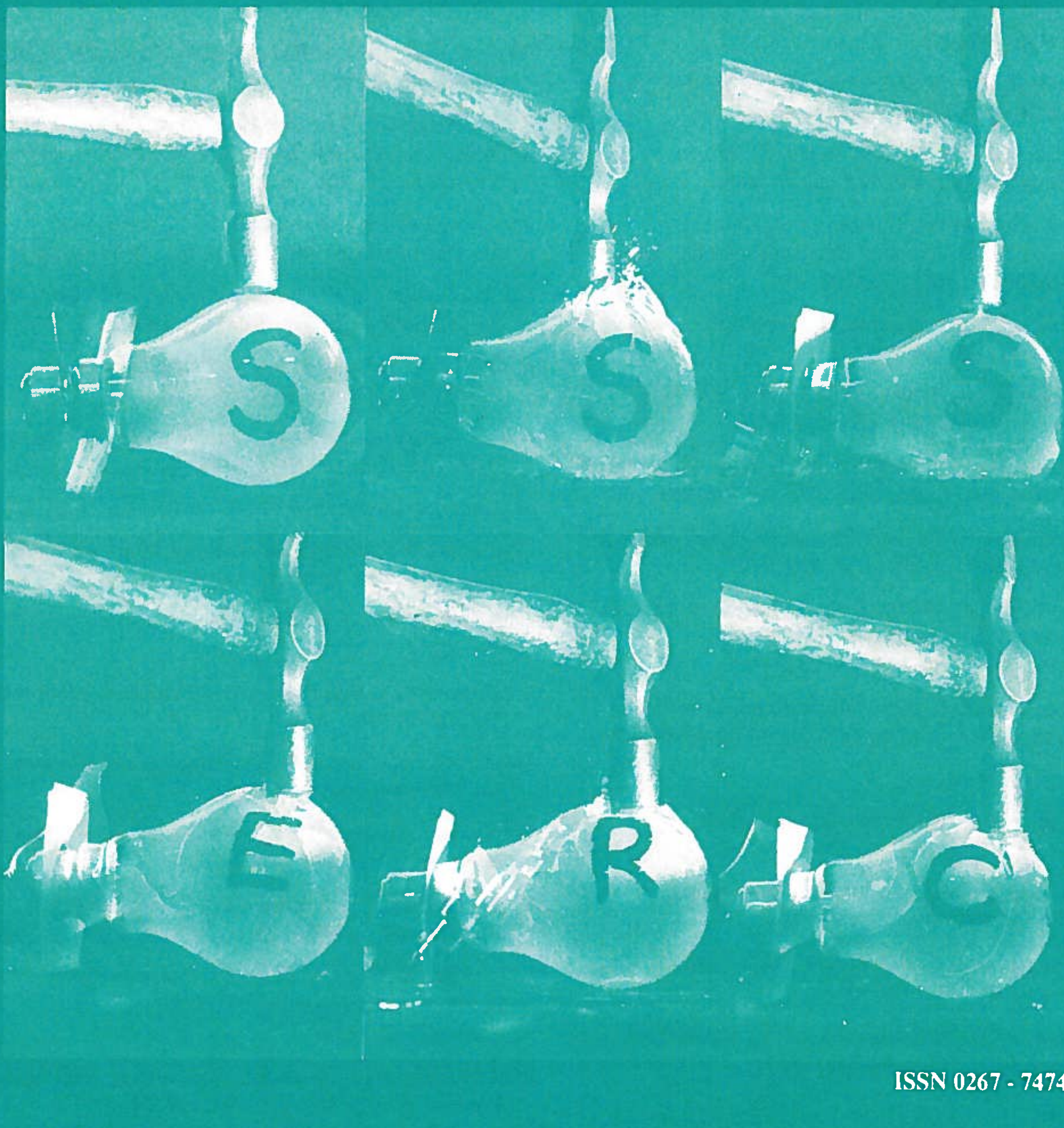
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



ISSN 0267 - 7474

Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences

Number 167 September 1990

SSERC, 24 Bernard Terrace, Edinburgh EH8 9NX; Tel. 031 668 4421.

Alner Hamblyn Electronics Limited (Radford equipment), 3 Boultons Road, Kingsway, Bristol BS15 1RU; Tel. 0272 614239.

Alpha Electronics (Scotland) Limited, Unit 6, Newbroom Park, Granton Park Industrial Estate, Edinburgh EH5 1HS; Tel. 031 552 0753.

Analog and Numeric Devices Limited (New Solex), Unit 25, Cottage Lane Industrial Estate, Broughton Astley, Leicestershire LE9 6PD; Tel. 0455 283486.

BDH Limited, Burnfield Avenue, Thornliebank, Glasgow G46 7TP; Tel. 041 637 2333.

Beebug Limited, 117 Hatfield Road, St Albans, Hertfordshire AL1 4JS; Tel. 0727 40303.

Beverley Group Limited (Locktronics), Unit 1, Avonside Road, Avonside Industrial Estate, Bristol BS2 0UQ; Tel. 0272 724102.

Cirkit, Park Lane, Broxbourne, Hertfordshire EN10 7NQ; Tel. 0992 444111.

E & L Instruments, Rackery Lane, Llay, Wrexham, Clwyd LL12 0PB; Tel. 0978 853920.

Farnell Instruments Limited, Sandbeck Way, Wetherby, West Yorkshire LS22 4DH; Tel. 0937 61961.

Jim Fraser Caravans Limited, 55 Lanark Road West, Currie, Midlothian; Tel. 031 449 3185.

Griffin and George Limited, Bishop Meadow Road, Loughborough, Leicestershire LE11 0RG; Tel. 041 248 5680, or 0509 233344.

HCCS Associates Ltd., 575 Durham Road, Low Fell, Gateshead, Tyne & Wear NE9 5JJ; Tel. 091 487 0760

Philip Harris Education:

2 North Avenue, Clydebank Business Park, Clydebank, Glasgow G81 2DR; Tel. 041 952 9538;

Lynn Lane, Shenstone, Lichfield, Staffordshire WS14 0EE; Tel. 0543 480077.

Irwin Desman Limited, 294 Purley Way, Croydon CR9 4QL; Tel. 081 686 6441.

Microprocessor Training Systems (MTS), Ballmalloch House, Kilsyth, Glasgow G45 9AD; Tel. 0236 822 472.

Morley Electronics Limited, Morley House, West Chirton, North Shields, Tyne & Weir NE29 7TY; Tel. 091 257 6355.

C.E.Offord (Microscopes), Ticehurst Road, Hurst Green, Etchingham, Sussex TN19 7QT; Tel. 0580 200739.

Omega Electronics, 12 Oxhill Road, Middle Tysoe, Warwickshire CV35 0SX; Tel. 029588 455.

Opitec, Educational Materials Limited, 7 West Road, Woolsten, Southampton SO2 9AH; Tel. 0703 446515.

Radleys, Shire Hill, Saffron Walden, Essex CB11 3AZ; Tel. 0799 513320.

Rapid Electronics Limited, Heckworth Close, Severalls Industrial Estate, Colchester CO4 4TB; Tel. 0206 751166.

RS Components Limited, PO Box 99, Corby, Northamptonshire NN17 9RS; Tel. 0536 201201.

Saffron Specialised Plastics, Goldstone Lane, Hove, East Sussex BN3 7BB; Tel. 0273 722286.

SCCC, Gardyne Road, Broughty Ferry, Dundee DD5 1NY; Tel. 0382 455053.

School Science Service, 41 Orchard Bank, Edinburgh EH4 2DS; Tel. 031 332 7447.

Sheffield Insulations:

Righead Industrial Estate, Melford Road, Bellshill ML4 3NA; Tel. 0698 841111;

Broadfield Road, Bridge of Don, Aberdeen AB2 8EE; Tel. 0224 825825;

Upper Mill Street, Blairgowrie, Perthshire PH10 6AG; Tel. 0250 3611.

Tait Components Limited, 20 Couper Street, Glasgow G4 0BR; Tel. 041 552 5043.

Technomatic, Techno House, 468 Church Lane, London NW9 8UF; Tel. 081 205 9558.

Unilab Limited, The Science Park, Hutton Street, Blackburn, Lancashire BB1 3BT; Tel. 0254 681222.

WPA Limited, The Old Station, Cambridge Road, Linton, Cambridgeshire CB1 6NW; Tel. 0223 892688.

Watford Electronics, Jessa Ho., 250 Lower High Street, Watford WD1 2AN; Tel. 0923 37774.

The Centre is an independent national advisory service, solely controlled and largely financed by Scottish Regional and Islands Councils as Education Authorities. It currently incorporates the Science Equipment Research Centre and the Scottish TVEI Joint Support Activity Project:

STERAC (Science and Technology Equipment Research and Advisory Centre).

This issue of the Bulletin was produced using Acorn DTP on Acorn Archimedes computers. Resolution is 510 dots per inch.

OPINION

There is a saying familiar to managers and particularly so, I suspect, to those in education:

"When you're winning, keep your mouth shut".

This general principle probably lies behind the somewhat anodyne nature (by our standards anyway) of more recent "Opinion" articles. I again feel moved to have an old fashioned, SSERC, literary tantrum - a lying on the floor kicking and screaming job.

For two years or so, things seemed to be going well. There were some good new courses and, for the Centre, new premises after what only now we realise were weary years in that dingy old building in Broughton Street. With recruitment of extra staff we at last seemed able to meet long standing demands and pressures to serve technology as well as science education. We were even looking forward to the prospect of servicing both areas at primary level once Review and Development Group 3 reports on Environmental Studies at 5 to 14.

Now, over a few short months, the scene has changed to one of loss of staff on the back of uncertainties over future funding. Having, after years of striving, taken three steps forward we now look like going back at least two. All this is tied up with cuts (sorry! - "rephasing") in Central Government expenditure, and what looks to us like general indecision and uncertainty over strategic issues in training and staff development.

All is but part of a more general misery. Not for a moment would I suggest that SSERC, of all places, should escape it. On the contrary, I begin to think that the general rot might be so widespread and deep-seated that we are, perish the thought, increasingly irrelevant.

Without reforms and proper funding the day is coming when it might be kinder and more effective to simply close this place. EAs could then re-distribute the revenue to Scottish schools (not that I believe there would be the remotest chance of such a redistribution). While they were about it, the Authorities might as well send every Science and Technical Education Adviser, CDO, and Health and Safety Co-ordinator up the road (some seem already to have made a start).

Schools need funds to buy equipment. LMS (or whatever else you choose to call it) may result in them getting some more money with which to do so, but probably not enough. There is also the chance, remote as yet, that it and other market-led developments might also sweep away local and national resource support structures which exist to ensure that money is wisely spent and equipment can be effectively used.

Having money for equipment and getting access to support and training in its selection, use, maintenance and repair are not alternatives but mutually compatible requirements. None would deny though that the former is a pre-requisite for the latter.

The point is that all such support services are more and more marginal to the real needs of schools. None should ever have got into that position and many have done so for entirely the wrong reasons. It is like the "dirty" coal-fired power stations argument used to justify expansion of nuclear power. The entirely separate and rational action would be to clean up coal-fired emissions.

A few examples of some current absurdities should illustrate the thesis:

Centrally held EA funds are being committed to health and safety activities when spending by some individual schools is getting so low that they cannot afford to carry out the practical work to which such essential health and safety provisions are intended to apply.

We know of cases where annual central expenditure per school in disposing of surplus or proscribed chemicals outstrips the sum spent by that school per year in actually buying its chemicals.

In SSERC we test items of apparatus, many of which should be mandatory in updating science and technology teaching and not just "optional". We now do so in the certain knowledge that the whole annual per-capita allowance of many a department would not buy that department one single example.

The day this article suggested itself, BBC Radio Four (sorry! it drifts across the border on Long Wave) carried a "You and Yours" programme, a large part of which dealt with the way English students were avoiding, or dropping out of, 'A' level science and technology courses. They were doing so because the equipment they were expected to use "looks more like something out of a Frankenstein movie than the modern apparatus we should have".

Radio Scotland could have as easily carried a similar feature, but on CSYS projects. We have evidence, as yet merely anecdotal, that numbers of SYS students are unable to carry through their choice of project because the school does not have the necessary equipment. Yet others experience disillusion and frustration because what equipment the school does hold is old, tired and incapable of producing results of a reasonable precision. We know personally of one Scottish secondary where much of the more up-to-date apparatus used by pupils of physics was constructed by a teacher at home in his own garage workshop.

Schools face such difficulties at a time of rising general inflation compounded by the threat of cuts in educational expenditure because of the non-collection of poll tax and for other reasons, many of which seem outwith the control of Scottish EAs.

We have initial evidence that things are even worse than trends in the general Retail Price Index (RPI) might suggest. The results of up-dating our costings for courses such as Standard Grade Chemistry suggest that science equipment inflation is again about to well outstrip the RPI - possibly by as much as a factor of two to three in the short to medium term.

A lot thus remains rotten in the state of science and technology education on which so much of our future welfare - environmental, political and spiritual as well as economic - depends.

Cosmetics, the odd high profile project here and privately funded technology education facility there, are not the answer. They may hide the spots and boils but they will do nothing to cure an apparently endemic disease and, within a Western European context, one almost uniquely British. This is the malaise of chronic under-funding and the, now all too common, uninspired and uninispiring science and technology teaching of which it may be a root cause.

We grow immeasurably weary of those in positions of influence and power who seem always more concerned with the appearance of doing something to sort out such problems than they are with actually buckling to and acting.

In present circumstances it would not be unreasonable to argue for a Royal Commission to examine and report on the whole damnable mess.

INTRODUCTION

(The Waffly bits)

Errata

"Who can spare the time to think whether ......the facts are accurate, or the principles well elucidated?" [1]. Funny, isn't it, how pontifications get punted straight back and flaws flung in your face?

We confess that in Bulletin 166, we walked straight into the trap set for ourselves in issue 165. We were so preoccupied with trying to get the layout and presentation right, we were less than punctilious in our proof reading. The results were seen in the *Technical Articles* section where the same diagram was printed twice within the motor driver article and a chunk of text and a diagram were omitted from a chemistry article on d.i.y. electrodes.

Corrections are provided on page 35 of this issue. We would ask you to photocopy, trim and paste in the relevant bits so that you may cover up the offending parts of Bulletin 166. Meanwhile we will award ourselves B- and under remarks - "Must try harder and concentrate more".

Reference:

1. "Opinion : DTP Addiction", SSERC Science and Technology Bulletin, Issue no. 165, March 1990.

Saturday openings

Saturday morning opening will operate throughout the session according to our usual arrangements - from 9 a.m. till 1 p.m. on the first two Saturdays of the month, except for July and August, when we do not open on Saturdays, and on any national holiday, of which there are none this session that would stop us opening on the first two Saturdays of the month.

Surplus equipment is available for sale or uplift on these occasions. If specialist advice is sought it might be best to ring up beforehand to find out who's on - it may be Muggins!

More farewells

In over 16 years in this game, I can't recall as short a period with as great a flux in Scottish senior science and technology education posts.

It could be dangerous to go too deeply into the reasons behind some of this turnover in personnel. I just might become one of those statistics. It certainly would be unwise to use phrases like "great stirrings of the pot" or "nights of the long knives".

So, I won't. The phenomenon is indicated so that you will understand our problem. This bit of the next Bulletin (168) may well carry the sub-header "*Yet* more farewells".

Danny Burns

Danny will be leaving his Senior Project Officer post, part of the Centre's Joint Support Activity (JSA) project for TVEI in Scotland, with effect from the 29th of August. He was made an offer he couldn't refuse (in the nicest sense) and will take up teaching again in the new school session as Head of Technology at Dollar Academy.

In his - to us old lags relatively short - time with SSERC Danny has done much to enhance our *street cred*[1] with Scottish teachers of technology. Much of his apparently boundless energy has been spent in developing in-service training materials for Technological Studies and then trialling same with groups of teachers. Ian Buchanan and he became an irrepressible double act, the Laurel and Hardy of INSET. It was not unusual for them to tutor daytime sessions in Renfrew and then drive over to Galashiels the same afternoon to take a twilight class.

We will miss Danny and wish him all the best with his next challenge - equipping and building up a new technology suite at Dollar. The results should certainly be interesting.

Plan Z

The show will go on. Our outstanding committments for in-service for 'H' grade Technological Studies will be met by a new troupe of *artistes*. Ian Buchanan will carry on tutoring for most of these courses, assisted by Graeme Paterson (National Course piano keyboard [and other sorts of] *artiste*) for some and, or, Clive Semmens our one remaining[2] Senior Project Officer for others.

Again, advisers - adieu

To add to our farewells to Messrs Cattan and Pirie in the last issue we now have to mark our appreciation of the efforts over the years of two more well-kent bodies. Jim Fulton and Bill Ross both have taken advantage of the great western upheaval (shoot-out?) and early retirement. Their presence and effort, the one in technical education for Ayr Division the other in science for Lanark, will be sorely missed. We wish them all the best in what should now be a somewhat less stressful existence (mind you, one of them is talking about doing some teaching).

Hugh Maclaren HMI

The formal reason for it is lost in the clichéd *mists*, but we have always found it useful to have an SED Assessor serving on both our Steering Group and Governing Body. Now normally it's not the done thing to pay personal tributes to individuals whose role in life is selflessly to serve the interests of the Crown. However it has by no means always been our good fortune to have the SED's

[1] "Street cred" - okay, pedants - it just made the latest edition of the "Concise Oxford Dictionary".

[2] Hint, hint, nudge, nudge to anyone out there in the Training Agency, Scottish Enterprise, ADES, IDS, SCOSDE, SDA or whoever it is who is supposed care about long term, strategic staff development for technology education.

persona so quietly, politely and - above all - so efficiently represented by one such as Hugh Maclaren HMI.

By the time you read this, Hugh will have retired after some 21 years service in the Inspectorate. An Aberdeenshire man he kept up what is now a waning Scots tradition, reading Natural Philosophy at his local University. There was also a period of army service with REME, where Hugh rose to the rank of Captain.

He came south in the late fifties to teach at Dalkeith High. There followed two spells as a Principal Teacher of Physics, first at West Calder High and then at the High School of Stirling. That ten or so years spanned the period of the last great Scottish science education reforms and the introduction of the revised, modern syllabuses.

Hugh's contemporaries thus included those to whom we have previously given honourable mention in these pages, folk like John Emery of Glenalmond, Jim Jardine, John Hughes, Donald McGill and Bill Ritchie.

His first years in the Inspectorate were spent back up in the Highlands with Northern Division. When he came south again it was as a national specialist inspector in Science. This was in time temporarily to take charge of enabling the development of Science as a Standard Grade subject before eventually again reverting to physics as a specialism and to leading the HMI Science Panel team.

That first spell with Science was in a difficult period, with much professional unease, unrest even, and the reputation of the Inspectorate hardly at its zenith. He needed all of his quiet, gentle powers of persuasion and diplomacy to see that work through.

Therein lies the key to our affection and respect for Hugh. Always one to gently back out of the limelight, not a flash-bang-wallop, quick-fix, here's the latest jargon, not-my-problem careerist, but ever ready to work quietly and efficiently behind the scenes to find acceptable solutions to problems. That was our direct experience of the way he dealt with SSERC and that was our observation also of the way in which he related professionally to others.

Scottish Education could do with more folk like Hugh. We wish him a long, happy and fruitful retirement.

- and, finally!

Thanks are due to all those who took the time and trouble to complete and return our questionnaires on eye protection and electronics systems boards. Your time wasn't wasted. We will be publishing something as a result of each of these surveys.

We admit to surprise though at the level of response given that, unlike for the Evaluator's questionnaire, we hadn't supplied an SAE and stamp. English readers take note of the explosion of the mean Scots myth. Mind you we didn't like to separately count the Aberdeen returns[3]

[3] Joke - Grampian - don't cut your SSERC contribution!

SAFETY NOTES

Pressure vessel checks - new regulations

Autoclaves, model steam engines, compressors

Made under the Health and Safety etc. at Work Act 1974, the "Pressure Systems and Transportable Gas Containers Regulations, 1989" [1] came into force with effect on the 1st of July 1990. Like several other sets of Regulations made under the 1974 Act, these replace Factories Acts provisions, which effectively did not apply to schools although some educational employers had arranged regular inspections of pressure vessels in accordance with them.

These present Regulations are aimed more at industrial and commercial operators of steam, chemical, gas and pneumatics plant and pipelines. A major consideration behind their drafting was clearly some of the large scale industrial incidents in recent years where pipeline fractures or pressure vessel failures were a prime cause. Indeed, the HSE's explanatory literature describes even fairly large scale compressors and pipework as "minor plant".

Nonetheless, as with those other sets of Regulations, education gets caught up at the fringes. In this case, trustfully, the Regulations will merely clarify existing requirements, which were ill-defined under the Health and Safety etc. at Work Act.

What equipment?

Under the Regulations any vessel or system containing a *relevant fluid*, i.e. a compressed or liquiefied gas, or steam, at more than 0.5 bar relative pressure (1.5 bar absolute) is affected. Although a vessel is exempted if the product of its volume and pressure is less than 250 bar litres, this exemption does not apply if the vessel contains steam.

This means, for schools and non-advanced FE establishments, the following types of equipment must comply with the Regulations:

- portable laboratory autoclaves;
- pressure cookers of domestic pattern as used in schools in microbiology or home economics;
- model steam engines used to demonstrate energy conversions;
- compressors used to drive systems used in teaching about pneumatics provided that there is a receiver able to hold a sufficient volume of air (typically at 7.5 to 8 bar) that the 250 bar litre limit is breached;
- possibly certain kinds of gas cylinder regulator equipment which is the property of the EA rather than of the hirer or lessor of the cylinders.

What kind of safety check?

Such items of equipment are to be regularly, visually inspected by a "competent person" against written schemes of inspection drawn up by persons competent to do so. Some employers may wish to use the services of professional surveyors, for example from their insurers, to carry out such examinations, but there is *no requirement* for this under the Regulations. Annual checks are likely to be sufficient for most equipment categorised above. In the case of pneumatic compressors with receivers where the 250 bar litre limit is exceeded a more sophisticated system of examimation may be needed but such inspection is likely to be at biennial intervals. Many Scottish EAs already follow such a routine in meeting the requirements of earlier advice and standards (see reference [2]).

Educational employers may wish to appoint suitable individuals already in their employ to carry out the simple checks needed for equipment at this scale and level of sophistication. To assist such in-house schemes of inspection, SSERC will be issuing, through the relevant advisorate staff, suitable written schemes of examination with suggested formats for record keeping.

References:

1. "Health and Safety Commission : Safety of Pressure Systems and Transportable Gas Containers Regulations 1989 : Approved Code of Practice (ACoP)" COP 37, HMSO, ISBN 0 11 885514 X.

2. "Pneumatics - compressors and air supply arrangements", Equipment Notes, SSERC, Science & Technology Bulletin No.166, June 1990.

Electrical Safety

HSE Guidance Note GS23 revised

The Health and Safety Executive Guidance Note on electrical safety in schools [1] was first published in September 1983. As indicated in Bulletin 166 [2] a 1990 revised version has been available through HMSO since April or May of this year. Also as previously indicated, this version bears the sub-title "(Electricity at Work Regulations 1989)" so emphasising the *de-facto* statutory backing which this revised version of GS23 has now received. This is effectively given through the need to follow such appropriate codes of practice in meeting the requirements of the 1989 Regulations.

We are aware that many Scottish EAs have had for some time systems to ensure the regular, routine checking, testing and repairing of electrical apparatus. Most of those same EAs have arranged suitable training for those staff, usually in the technician service, who carry out this work.

Taken with the 1989 Regulations, the revised GS23 has led a number of such EAs to begin to re-examine some of their practices. In particular, some Senior Resource Support staff have been considering the need to ensure that technicians are so trained as to be competent to carry out the work.

In particular they wish to ensure that they have met the supervisory requirement the Regulations place on them, through their employer, to ensure that staff have the "technical knowledge and experience necessary to prevent danger or injury" [2].

As a result, in these EAs, technician training courses are being improved. They are to be even more professionally organised and are to include descriptions of those learning outcomes to be taken as evidence of competence. Assessment is being proposed for some of these training schemes.

"Competent persons"

This term is used in a number of Regulations made under the HSAWA that have appeared over the last year or so (too many! - we hear you cry - and you have our sympathy). Many Regulations stop short of actually defining what is meant by "a competent person", but suggest rather than prescribe.

For example, for some of the more demanding examinations of pressure systems required under the Regulations discussed above, a "competent person" is suggested in the guidance to be someone of engineer or equivalent status. Whilst no-one is saying that this kind of strong hint is transferable to the simple checking and testing required by GS23, it does point to a growing need to think more carefully about practical competencies and about training programmes deliberately designed to identify and bestow them.

GS23 merely describes a competent person to be one "who possesses sufficient technical knowledge, experience and skills to be able to carry out the specific task and prevent danger or injury arising during the course of the work, or as a result of the work".

There are different levels at which this might operate.

At one level school technicians need to be competent to carry out visual inspections of electrical apparatus, and simple mechanical and electrical tests. Further to that they need to be able to put right certain faults or defects in the apparatus.

At another level technicians need to be competent to put right faults which are beyond the scope of the first level of technicians. There is clearly the need for some to be competent to carry out live working. This second level of technician might work from a regional repair centre rather than within a school. Another reason for this job splitting - quite a separate issue, but again a part of electrical safety - may be the difficulty in identifying a suitable workspace within a school where live working might be undertaken in reasonable safety.

At a different level teachers need to be competent to be able to demonstrate experiments and supervise practical work undertaken by senior pupils where there are uninsulated live conductors at voltages above 25 V from apparatus capable of delivering a dangerous current.

Is the present test of that competence - an appropriate university degree and college of education certificate together with two years probationary training - sufficient?

The area of competence is one on which individual employers may have to make a ruling.

GS23 errors

We may be thought churlish, but we cannot leave the subject without pointing to a number of errors in the revised version. Some of these are printer's errors - minor irritations where symbols and pictograms are missing from the schedule of tests and inspections which make up an Appendix. An illogicality present in the sequencing of the tests is more serious and remains unchanged from the 1983 edition, even though it was pointed out to HSE soon after publication of that original version. Worse still is the uncertainty in how several passages are to be interpreted.

Apparently HMSO were aware of the printer's errors and, we were given to understand, had withdrawn faulty copies. This did not stop us getting a copy with errors from the Edinburgh HMSO bookshop weeks after the original publication date. We were since sent another faulty copy purchased in Glasgow.

These errors and questions of interpretation are being pursued by the Centre with HSE at the moment.

Since GS23, at all of 8 pages, now costs pounds rather than the pence we paid for our 1983 edition, you would think they might have got it right. It is, after all, a Government publication and this Government hasn't been slow to preach to us scientists and technologists about market forces and customer satisfaction.

Conclusion

Errors and all, GS23 as revised is an important wee document. For those EAs already with suitable systems, the changes will mean minor adjustments in actual practice but bring a need to be more overt in linking the content of training courses to the necessary levels of practical competence. For those few educational employers who have yet to take seriously the requirements of the original edition, it may mean a lot more work - work that cannot now readily be avoided given the existence of the Electricity at Work Regulations.

References:

1. "Electrical safety in schools (Electricity at Work Regulations 1989), Health and Safety Executive, General Series 23, September 1983, revised February 1990, HMSO, ISBN 0 11 885426 7.

2. "Safety Notes : Electricity at Work Regulations 1989", in SSERC "Science and Technology Bulletin" No. 166, June 1990, ISSN 0267- 7474.

Disposal of chemicals

The general problem of waste disposal will always be with society as long as materials and products are made, purchased and used. Work in laboratories is no different. We expect that many schools follow the advice contained in Hazcards [1]. However this advice needs qualifying. A recent communication from an Environmental Health Officer drew our attention to one way in which information on Hazcards may be being misinterpreted by some.

The quantities listed against each chemical on the cards are the maximum amounts that may be disposed of via drains provided they do not exceed the permitted discharge rates which have been determined by the local River Purification Board. They do not refer to the quantities which you might place in ordinary refuse. This is discussed below under the heading of Special Waste Regulations.

Much of this article is based on an occasional paper written by Centre staff and made available to EAs as an Annex to the original Chapter 13 of Topics in Safety in 1982 [2]. Whilst it is still the employer's responsibility to see that disposal is carried out properly, it is in fact the case that much of this work happens directly at school level. For that reason our advice given to EA managers is repeated here. Besides, it is comforting to be in a position to know whether or not you are keeping within the bounds of the law.

Disposal via drains

Permitted levels of discharge will vary greatly from area to area. We would suggest that each EA finds out this information from the local River Purification Board and supplies it to its schools and FE colleges. As public awareness of the health of the environment increases and as EC Directives begin to bite, the permitted levels will probably be revised from time to time. It seems to operate a little like a rationing system; we have sometimes found the permitted levels of discharge to be lower in industrial areas where the burden already placed on treatment plants and waterways is higher than in rural areas. Other factors, such as the capacity of the treatment plant, will also affect the size of your ration.

As an example one board does not permit the discharge

(i) to have a pH beyond the limits of 6 and 10;

(ii) to contain any hydrocyanic acid or compounds upon which acidification give rise to it;

(iii) to contain any substance likely to cause fire or explosion;

(iv) to contain any degreasing solvents (mono, di and trichloroethylene, mono-, di- and trichloroethane types named);

(v) to contain carbon disulphide or calcium dicarbide;

(vi) to contain more than:

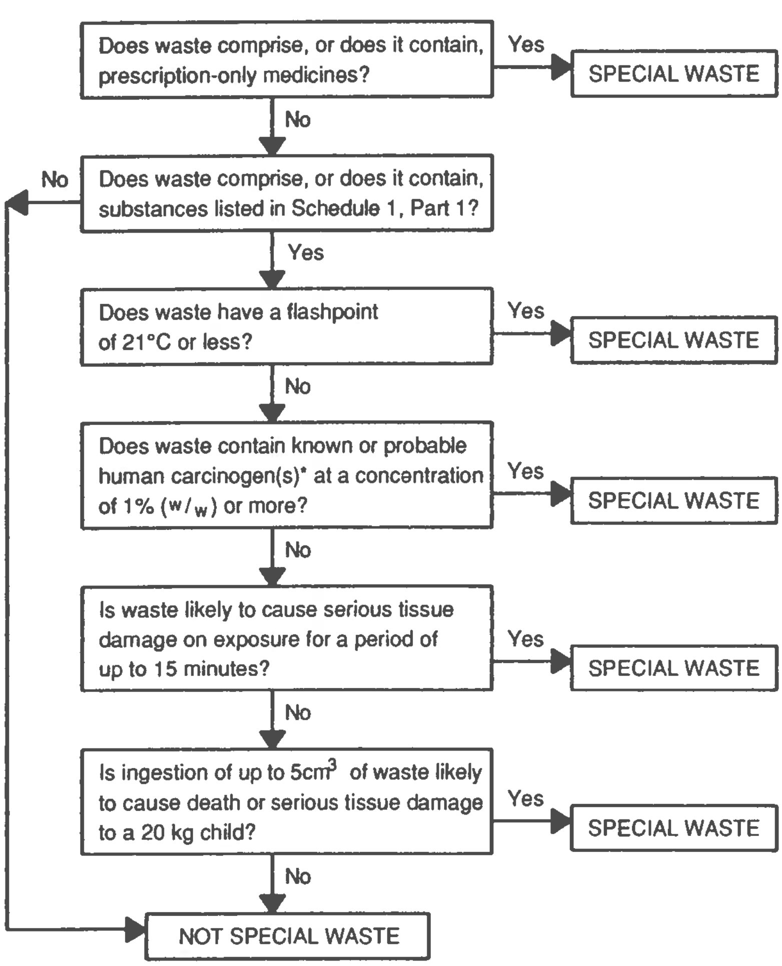
5 mg l^{-1} of sulphide (as S)
1000 mg l^{-1} of sulphate (as SO_3)
20 mg l^{-1} of total toxic metals
50 mg l^{-1} of free oil
25 mg l^{-1} of biodegradable synthetic detergent.

For instance, with reference to the toxic metal limit listed above, to reduce the concentration to 20 mg l^{-1} would require 500 litres of water to be added to 10 g of metal. Simple calculation would show that a typical laboratory tap with a flow rate of 10 litres per minute would have to run for $^3/_4$ hour to achieve this dilution. In practice this can be greatly reduced when allowance is made for water from other sources leaving the school. There is clearly a moral and legal responsibility to ensure there is no damage done to the treatment process and to water industry workers, or to the environment at large.

Disposal via ordinary refuse - Special Waste Regulations

Materials defined as special waste by the Special Waste Regulations 1980 [3] may not be placed with ordinary refuse. They may only be disposed of via licensed contractors. Special waste is defined as those substances listed in Part 1 of Schedule 1 of the above Regulations which are either dangerous to life, or have a flashpoint of less than 21°C.

ASSESSMENT PROCEDURE DIAGRAM ANNEX 2



Waste is regarded as being dangerous to life if:

- a single dose of not more than 5 cm^3 would be likely to cause death or serious damage to tissue if ingested by a child of 20 kg weight; or
- exposure to it for 15 minutes or less would be likely to cause serious damage to human tissue by inhalation, skin contact, or by eye contact.

Listed substances

acids and alkalis
antimony and antimony compounds
arsenic compounds
asbestos (all forms)
barium compounds
beryllium and beryllium compounds
biocides and phytopharmaceutical substances
boron compounds
cadmium and cadmium compounds
copper compounds
heterocyclic organic compounds containing oxygen, nitrogen or sulphur
hexavalent chromium compounds
hydrocarbons and their oxygen, nitrogen and sulphur compounds
inorganic halogen-containing ompounds
inorganic sulphur-containing compounds
laboratory chemicals
lead compounds
mercury compounds
nickel and nickel compounds
organic halogen compounds, excluding inert polymeric materials
peroxides, chlorates, perchlorates and azides
pharmaceutical and veterinary compounds
phosphorus and its compounds
selenium and selenium compounds
silver compounds
tarry materials from refining and tar residues from distillation
tellurium and tellurium compounds
vanadium compounds
zinc compounds

The list specifies many particular substances, but the term 'laboratory chemicals' must be a catch all. The flow chart (left), reproduced from Waste Management Paper No. 23 (DOE) [4], will aid in deciding whether or not a material is special waste. Only those laboratory chemicals which are dangerous to life as defined above, or are flammable (Flash point < 21°C), are special waste.

Definitions

Some means of deciding whether a material is to be classed a carcinogen, a toxic, or a corrosive substance is needed. It is a great pity that definitions for the Risk phrases placed on labels as required by the Classification Packaging and Labelling Regulations 1984 (CPL Regs.) [5] do not coincide with those used in the Special Waste Regulations.

Carcinogen - a substance recognised as a human carcinogen or as an experimentally proven animal carcinogen should be classed as special waste. The material safety data sheets (or MSDS) provided by chemical suppliers should provide such information. Such data will be based on up to date information from the International Agency for Research on Cancer (IARC). Certainly all those bearing the Risk phrase "R45: May cause cancer" will be special waste.

Corrosive - include those so labelled by the CPL Regulations which bear the Risk phrase and pictogram on the label plus others which are strongly irritating, i.e. substances for which less than 100 mg causes severe eye irritation. Mild or moderate irritants are not to be included as special waste.

Toxic - this is a difficult criterion to apply since, for obvious reasons, data on humans is only available for a small number of substances. The LDLo (the lowest published lethal dose expressed as mg of toxic reagent per kg body weight) can be used where available, or some form of extrapolation made from animal experiments using

- the acute oral LDLo (the lowest published for a susceptible mammal);
- the acute oral LD50 for a susceptible mammal.

Waste Management Paper No. 23 recommends that if extrapolation is used it is more reliable to take the child LDLo as being $^2/_7$ths of an adult LDLo than to extrapolate upwards from data on infants. Where different values for LD50s are available for the same substance, then the lowest should be used. The LD50 is the single dose which, under conditions of the test, results in the death of 50% of the animals to which it is administered. The NIOSH RTECS (Registry of Toxic Effects of Chemical Substances) [6] is probably the best single source of such toxicity data. Much is reproduced on MSDSs, but anyone having difficulty should contact the Centre.

Substances such as marble chips or glucose will not rank as special waste, but to make a decision in the case of many chemicals, a calculation using the toxicity data is needed. The formula used below is a simpler form than that used in the Waste Management Paper No. 23. The latter deals mostly with mixtures in industrial wastes, whereas most waste materials being disposed of by schools will be at least 90% pure. A substance is to be regarded as special waste on grounds of ingestive toxicity if:

5 cm^3 (spoonful) is lethal to a 20 kg child,

i.e. if (5000 x *d*) mg contains more than (20 x LDLo) mg where *d* is the density in g cm^{-3}, or if (250 x *d*) mg $\geq$ LDLo.

Thus substances with densities close to 1 g cm^{-3} will be regarded as special waste if the LDLo, or equivalent toxicity data, is less than or equal to 250 mg kg^{-1}.

Substances with relative densities of 2 and 3 (true for many salts) will be special waste if their LDLos are less than or equal to 500 and 750 mg kg^{-1} respectively.

Some worked examples

1. Zinc sulphate $ZnSO_4{\cdot}7H_2O$ has an LDLo of 221 mg kg^{-1} and a density of 2.0 g cm^{-3}. Since the LDLo is less than (2 x 250) mg kg^{-1} zinc sulphate is regarded as special waste. However if diluted with a harmless material so that its concentration becomes less than (221/500 x 100), or 44%, it will no longer be defined as special waste.

2. From the data on several metal sulphates given below a decision can be made about each of them:

	animal	LDlo (mg kg^{-1})	density (g cm^{-1})
aluminium sulphate	mouse	270	1.6
iron (II) sulphate	child, oral	390	1.9
magnesium sulphate	mouse, oral	5,000	1.68
manganese (II) sulphate	human, oral	500	2.16
sodium sulphate	rabbit	4,470	1.47

The sulphates of aluminium, iron(II) and manganese(II) are special waste on the grounds of ingestive toxicity. Sufficient dilution of these solids with sand, vermiculite, or mineral absorbent like cat litter, demotes them from special waste category and the mixture can be disposed as solids with ordinary waste. In all of the above cases an equal volume of dilutant will be more than adequate. In addition to being sufficiently toxic the corrosiveness of aluminium sulphate will class it as special waste. In practice the preferred route of disposal for these compounds will be that of flushing to waste.

In summary

Small amounts such as washings from flasks and test tubes can be washed to waste, or traces of insoluble solids formed in test tube preparations, e.g. the oxides or sulphides of copper or zinc oxides, can be placed with ordinary refuse. The solid refuse collection system cannot however be used as a means for the planned disposal of large amounts of substances without first consulting your local Environmental Health Officer (a district council officer in Scotland).

References

1. "Hazcards", 1989, CLEAPSS.

2. "Topics in Safety", 1988, Association for Science Education, ISBN 0 86357 104 2.

3. The Control of Pollution Act (Special Waste) Regulations 1980, S.I. 1980 No. 1709.

4. "Waste Management Paper No. 23: Special wastes: a technical memorandum providing guidance on their definition", 1981, Department of the Environment, ISBN 0 11 751555 8.

5. The Classification, Packaging and Labelling of Dangerous Substances Regulations 1984, S.I. 1984 No. 1244.

6. "Registry of toxic effects of chemical substances 1981-82", National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 83-107.

Brown Mushroom Demo

We have had a report of this demonstration going wrong and spraying a teacher with concentrated nitric acid. This teacher demonstration is described in Topic 1.5 (f) on page 5 of Volume 1 of the Standard Grade Chemistry Practical Guides.

When hypo crystals (about 4 g) are added to nitric acid (5 to 10 cm^3) in a conical flask there is normally a delay of several seconds before the reaction erupts to give a nice wee cloud of nitrogen dioxide and a lump of bright yellow sulphur. In this case there was no delay. Further investigation revealed that anhydrous sodium thiosulphate(VI) and not the crystalline pentahydrate had been used.

The general laboratory grade pentahydrate is usually available in fairly chunky crystals with the largest dimension being of the order of 3 mm. This was confirmed for BDH, Hoggs and Harris. Griffin supply only AR grade hypo, which comes in the form of small crystals. A sample was purchased and tested. Surprisingly the delay was much longer than is the case with the chunkier crystals - about 8 seconds as opposed to 2 or 3. Can any physical chemists out there explain that?

In summary, the advice is to:

- only use the crystalline forms; some photographic grades may be of different crystal size; the end of a jar may contain some dusty fragments and should not be used;
- not use anhydrous hypo, which is available from BDH and might have been ordered instead of the pentahydrate;
- use a small safety screen in the fume cupboard in addition to the wearing of gloves and goggles, or even a faceshield;
- keep to the small quantities suggested in the Guide; and
- test any new sample beforehand.

Oven Fires

We have heard of a fire caused by a fault in a glass drying oven in a university. The oven, of a type often used in schools, had been set at about 100°C at the time and held a full load of glassware. What seems to have happened is that the thermostat stuck in the on position. The resulting continuous supply of heat radiating from the heating element situated below the floor of the inner compartment was sufficient to cause the bench to char and then ignite.

Many ovens have little or no insulation to keep the base, which is usually made of a thin sheet of steel or aluminium, from reaching high temperatures. When the thermostat is functioning normally, the heater is never on continuously for long enough for this to happen.

Obviously this malfunction is a most infrequent occurrence, but clearly it can happen. Therefore we would recommend that:

- a large thermal insulation mat be kept under every oven, and that
- ovens are not left on overnight unless this is absolutely essential.

The cheapest source of such materials are thermal insulation boards available from builders' suppliers. Typical prices found for 9 mm sheets (8′ × 4′) of a range of different insulation boards, Tacfire, Supalux, Masterboard and Masterclad, were in the region of £25. Some DIY shops sell smaller sizes, e.g. 12 mm thick Durapanel ranged from £21.45 for an 8′ × 4′ sheet to £7.46 for a 4′ × 2′. Supalux and Tacfire seem to be a bit tougher than the others, but for superior resistance the preferred product would be 12 mm Monolux at £52.78 for an 8′ × 4′ sheet. The larger sheets can be cut down to size, but care should be taken to reduce the levels of dust generated. Dampening the surface helps, and hand sawing produces less fine particles than does sawing with powered bench or jig saws.

Local builders' suppliers can usually provide these materials. In case you have any difficulty the address of one main agent, Sheffield Insulations, is given in the address list.

That dangerous music power supply again!

Our last bulletin carried a warning that a mains to 12 V power supply being retailed by the Music Centre, 48 Campbell Street, Hamilton, and from a branch in Paisley, is of shoddy construction. We have since learnt that this same appliance was also available from a Glasgow company, McCormacks Musical Limited. Strathclyde schools have been circulated by their Regional Council with a warning that a Multiple Outlet Power Supply bought from McCormacks should not be used.

The warnings should therefore be widened. The dangerous units might well have been, and may still be, available from quite a number of different retailers.

Applications of Information Technology

Foreword

This section of the Bulletin contains a family of articles on computer applications in science and technology education. It is our intention to continue this general theme over a number of issues.

An Overview

Experience shows us that we will be addressing a readership with mixed interests and needs. Some science and technology teachers are already approaching the Centre for advice on the new generation of 16/32 bit computers. Others have yet to seriously begin exploiting the facilities of the old 8 bit Beebs. Too many have yet to be given even reasonable access to, never mind provision of, a single machine for their classroom or lab. Possibly there may be only one machine for the whole department and in extreme cases no computer at all.

We will do our best to cater for a range of levels of need and interest. Obviously there is little we can do for the few who have reached the "Frankly, my dear, I don't give a damn!" stage. The hope is however, that the new generation of computers, dataloggers, interfaces and software may generate a parallel renaissance of interest. Indeed one aim of the series will be to publish some material useful to those faced with making the transition from 8-bit Beebs and Masters to Archimedes. To that end this issue carries an initial article on just that topic.

History

This will not be the first time we have run such a series. In the early to mid eighties we published a number of articles on interfacing and on the application of data-logging devices both commercial and DIY.

DIY interfacing still has a place, even with such a sophisticated machine as the Archimedes. The Bulletin will therefore again be carrying occasional articles on that subject.

Educational criteria

In much of our earlier writing, certain ideas came up time and again. Many of them are still relevant. More importantly, our criteria for proper and successful educational usage may now have found their time.

Friendliness

For example, an early preoccupation was with what has since become universally known as *user-friendliness*. We looked also for consistent use of conventions, both for the steps required of operators and in documentation. We have seen some suppliers make great progress to meet such needs, even in their software for the BBC B and Master with their non-WIMP[1] environments. It has to be said that other firms have progressed hardly at all. With the advent of the Archimedes series and RISCOS[2] there is now a real prospect of interfacing and control software which is truly easy to use. (There being no such thing as a free lunch, of course, RISCOS may bring with it other limitations).

Versatility

The other *big* idea we kept banging on about was that the power of a microprocessor based device may lie, not in any one thing which it can do but rather, in combinations of several or all of the many facilities it can offer. One test, therefore, of any educational application of such devices is against a checklist of the features of computing etc. which are actually in use. Such criteria include exploitation of:

- the speed and *patience* of the device in transient or long term data logging and control applications
- the ability to simultaneously log, or control, numbers of separate parameters without *losing the place* as might a human observer or operative
- the potential accuracy and precision of microprocessor based devices
- software engineering facilities to simplify tasks such as calibration, signal conditioning and display, which would otherwise call for the use of many more hardware components
- the available combination of the gathering, processing, manipulating and display of numerical data in ways which enhance students' understanding of mathematically based concepts.

Unless several of these computing facilities are so exploited by each application, you have to ask "Is the game worth the candle in terms of time, effort and expense?".

If the above criteria are valid, then it is only in the last three or so years that we have begun to see many worthwhile computer based applications in science and technology education appear in the relevant journals.

Folk are now also beginning to exploit the trend towards the integration of spreadsheets with databases and other software tools. In particular some are using to a much greater extent the *number crunching* power of the current generation of machines. (Several articles on this topic have recently appeared in journals like the *School Science Review*).

[1] "WIMP" - Windows, Icons, Menus and Pointer

[2] "RISCOS" - Acorn's Reduced Instruction Set Computer Operating System

That is not however to recommend that pupils be allowed to escape all mathematical sweat and slog. So that they appreciate what it is that the computer is doing for them, it is necessary for pupils to be familiar with taking readings manually, calculating for themselves the derived quantities and plotting graphs by hand.

The transfer to computer work, in our opinion, best begins with an experiment which can first be undertaken without the computer, but where considerable tedium can be avoided by using it. That in turn may lead to consideration of experiments which are only feasible using the computer.

Some commercial suppliers are enhancing their data-logging packages to allow more sophisticated data-handling and analysis. One of the articles in this Bulletin section provides some illustrations of the use of such additional data manipulation facilities as provided by the Philip Harris *Datadisc Plus* package.

Other uses and users

Despite the emphasis on pupil or student use implied in most of the above, there are many potential professional and administrative tasks with which the computer can assist. For example, our Chemistry Equipment and Chemicals databases (announced in Bulletin 166) provide useful management tools. Similar databases may be made available for other science and technology courses.

The latest SSERC development is a *Graphics Library* for use with the Archimedes *DRAW* software in the production of teaching materials. The facilities offered by this library are described in the following article.

SSERC Graphics Library for Archimedes computers

Do you prepare curricular material - OHP slides, worksheets or examination scripts? No more test tubes akin to buckets, beakers on the scale of basins, or bunsens that look like candles!

Amongst the freebie software you get when you buy an Acorn Archimedes is an extremely useful graphics editor called *Draw*. Don't think that because it is free it can't be up to much. On the contrary, SSERC has found it a boon in the preparation of graphics for training material and publications. We have used *Draw* to create a library of oft-used apparatus, instruments, and electronic components so that compiling new figures is mostly a matter of joining the bits together. Forget the pedestrian Apple Mac for doing worksheets and the like, and try out the speedy Arc with graphics that look like real apparatus. All figures compiled with *Draw* can be incorporated in desk-top-published work.

£15 a disc

SSERC is now making this library available on a $3^1/_2$ inch disc, with full instructions, for £15 including p. & p. It is, for the present at least, of interest to teachers of Chemistry, Physics and Electronics. We hope to cover other subject areas in the future. Everything is drawn to scale - bungs fit test tubes, and an electronic layout drawing will look like the assembled circuit.

What's on the disc?

The disc has the following directories which classify the shapes into logical groupings:

Basic - equipment essential to any science-based lab. Stands, clamps, tripods, bungs, test tubes, etc.

Beakers - tri-pour plastic and glass beakers from 50 to 1000 cm^3. Graphic 'liquids' for filling them.

ElecSymb - electronic component symbols for drawing circuit diagrams. British Standard except where the Scottish Examination Board prefers an alternative.

ElecDraw - scale drawings of electronic components, breadboards, etc., for making layout diagrams.

ElecTools - drawings of electronics tools, etc.

Flasks - various sizes of conical, standard volumetric, round-bottomed and filter flasks. Bungs and gas delivery tubes to fit as appropriate.

GasEvolve - apparatus for the laboratory production of gases. Arculus tube, gas delivery tubes, fermentation lock, reduction tubes, etc.

General - equipment essential to any chemistry lab and used widely throughout Standard & Higher Grade Chemistry. Burette, gas syringe, filter funnel, U-tube, separating funnel, stirring thermometer, etc.

Interfaces - the Philip Harris 4-channel Analogue Port Connector, VELA, EMU, djb, and Unilab Interface. Others such as LogIT, MESU and Unilab Simple Logger will be included at a later date.

Meters - digital multimeter, colorimeter and conductivity meter so far.

Sensors - Philip Harris range including light, oxygen, pulse, temperature, pH and position, and home-made sensors including thermistors and thermocouples.

Other figures may be included by the time you order your disc.

Most of the graphics in this Bulletin and the last were drawn using this library. To get the best from it, you need Acorn's *Outline Font Manager*, which comes with all the DTP programs for Archimedes, and some other packages. A selection of the individual figures are shown on page 13.

Where appropriate, the directory names have been chosen to tie in with the Item names shown in the SSERC Equipment Database for Standard and Higher Chemistry. For further details of this and the Chemicals Database see Bulletin 166.

The transition from Master to Archimedes

Quite a lot of people are taking our advice - or otherwise coming to the same conclusion - and purchasing Arcs (hereinafter including A3000s) for science or technology applications. We think it might be useful to pass on a few things we ourselves have learnt in the transition.

The Arc is so much more powerful that many applications are available that simply weren't possible on the Master (hereinafter including Model B). Many others, such as DTP and CAD, were so severely straightjacketed on earlier machines that our advice is to start completely afresh, and abandon any earlier work. This article isn't about these applications.

Another thing it isn't about is hacking commercial software to run on Arcs. By the time you read this, that will be illegal under the new Computer Misuse Act. If your existing software will run *without modification*, you may use it, as long as you have a licence for the total number of machines. You may fiddle with the Arc's configuration, or run an emulator, to make unmodified software run. It appears, however, to be illegal even to investigate the inner workings of commercial software so as to work out what features are necessary in your configuration or emulator. This will presumably be policed by some new breed of supersleuth!

Some software will run without modification, perhaps under emulation; but most requires minor modifications. Most BBC software is now available in Arc versions, some modified just enough to run, some completely rewritten to take advantage of the superior facilities. You will have to pay again - with luck only an upgrade fee[1]. If it isn't available, that's probably because it wasn't very good and didn't sell well.

Transferring files

Particularly if you will ultimately have a mix of Masters and Arcs, you may need to transfer data from one to the other. An experiment may have been interfaced to a Master, but you want to process the data from it on an Arc; or you may want to transfer a text file from a Master to an Arc for DTPing. Some people even write programs on Arcs, and transfer them to Masters!

Econet is undoubtedly the easiest way; but it's also much the most expensive if you haven't got it already. Both Arcs and Masters can save to any filestore, and load any file.

The next best thing is to use a combination $3^1/_2$" / $5^1/_4$" dual disc drive on a Master. $3^1/_2$" discs formatted to the ADFS 'L' format can then be used with both Arc and Master. Unless you're an expert or a masochist, this is the only method you should consider if you haven't got Econet. If you've only got Model Bs, you'll need to fit an ADFS ROM in one machine.

[1]You may find it necessary to hack some old in-house or public domain software - this is beyond the scope of an article like this. If you know enough to have a bash but need some help - you know our telephone number!

It is possible to attach an external $5^1/_4$" drive to an Arc. It involves fitting a disc drive buffer in the Arc. If you must do this, use the Beebug buffer: the problems are even worse with other products - in some cases you could even need to buy a special $5^1/_4$" drive. It is of course cheaper than getting the combination drive. Software is available to enable an Arc to read DFS discs, so you wouldn't need to fit ADFS in a Model B; but the software we've seen so far cannot be described as entirely satisfactory.

Finally, you can transfer files directly from one machine to the other via the serial link. This is the cheapest option, but much the most complicated to get working. Again, the software we've seen for this is not very helpful, and we've ended up writing our own - very simple, inefficient, and unfriendly, but working. Even so, it's only worth setting up for a batch of long files. If you have an A3000 you will need the serial upgrade.

Costs and suppliers

combination $3^1/_2$" / $5^1/_4$" dual disc drive	- £185
Acorn ADFS ROM	- £ 25
Beebug Disc Drive Buffer for Arc (0795C or 0784C)	- £ 33
$5^1/_4$" disc drive	- £122
Beebug Arc DFS reader (0102B)	- £ 10
Beebug serial link kit (0796C)	- £ 17
A3000 serial upgrade	- £ 21

We recommend the Beebug items where specified. All the other items are available from Technomatic, Beebug or Watford among others.

Translating data

If you are running the same (or corresponding) software on both machines, in general data can be used as soon as it is transferred. In other cases it is likely that the format of the data will be different. For example, you may prepare text using Wordwise+ on a Master, but want to merge it into a document in 1stWord+.

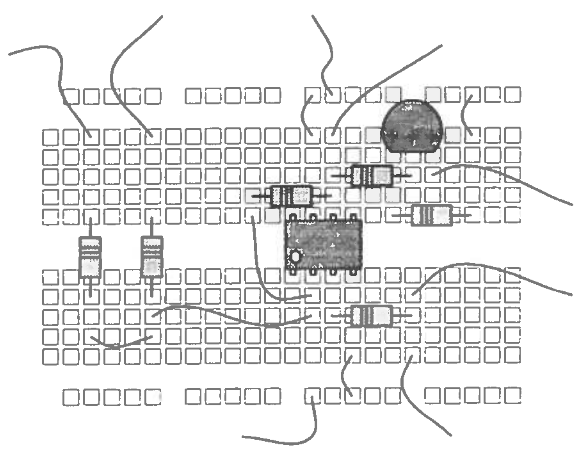
Some applications are designed to read files in 'foreign' formats: Pipedream, for example, can read Lotus files; most DTP packages can read several different text and drawing file formats. There is some third party software available to convert files from one format to another, but this is generally not very good, and we don't recommend it. Otherwise, either the conversion is easy enough given the right clues, or more trouble than it's worth. We've done a fair amount of this: give us a ring. We may publish a table of known 'conversion clues' (sample opposite) if there seems to be enough interest.

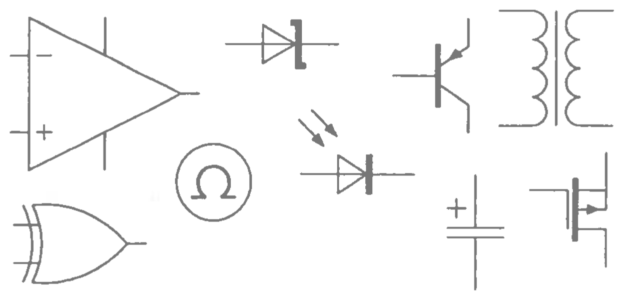
Converting Wordwise+ files to 1stWord+:

- edit out all 'embedded commands' in WW+
- save file and transfer to Arc
- load file into 1stWord+ (by dragging the file to the 1stWord+ icon)
- change to WP mode (an option in the Edit submenu)
- find and replace <space> with <space> (ditto)

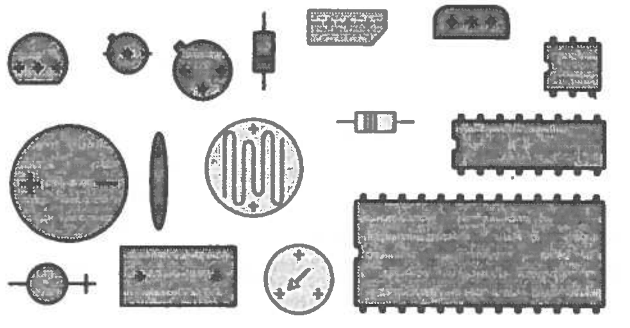
This last strange operation converts WW+ spaces to 1stWord+ spaces - otherwise 1stWord+ takes them to be fixed spaces, and won't break lines at them when reformatting.

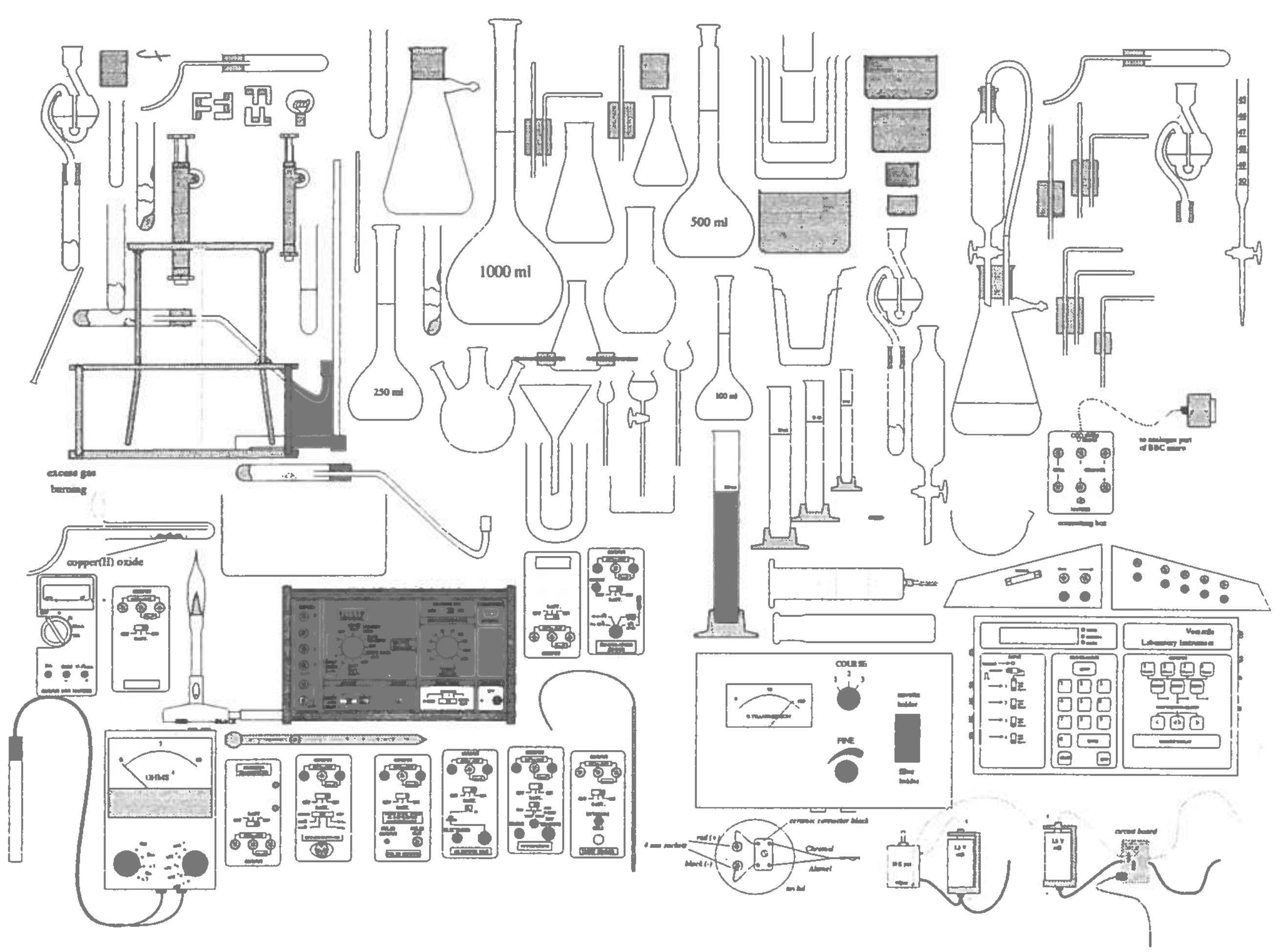
All this assumes that you have RISC OS. If not, get it quick!





SSERC Graphics Library: Above, a selection from ElecSymb; below, a selection from ElecDraw; left, a layout diagram using ElecDraw. All circuit diagrams in both this Bulletin and the last used ElecSymb.





A selection of items from the SSERC Graphics Library

Manipulating data with Datadisc Plus - some chemistry applications

The use of some of the *Mathematical Utilities* in the upgraded data-logging software *Datadisc Plus* is illustrated in two applications for Scottish senior school chemistry courses. Data-handling techniques described include calculation of derived values from raw data, log plots, differentiation, integration and X-Y plots. These techniques may also interest those in other science disciplines.

Background

Over the past year or so there has been renewed awareness amongst teachers and some curriculum developers of the potential range of applications and resultant usefulness of computers in the sciences.

In particular the Arrangements for Standard Grade Chemistry [1] mention the use of computers - mainly for computer simulations and plotting of statistical data, e.g. from the Periodic Table, but also for datalogging.

The revised CSYS Chemistry Arrangements [2], for implementation in and after 1992, specifically require that, in at least one set experiment, a computer is used to log the results. At Standard Grade we have been largely interested in qualitative assessment of results and graphs. At Higher and CSYS level there is a need for a more quantitative approach - a quick browse through the treatment of experimental results in SCDS Memorandum 16 [3] should confirm this. SSERC, in conjunction with others, has been invited to assist with a revision of Memorandum 16 to take account of the new data handling techniques. We hope to publish sample pupil work material and technique sheets, based on the two chemistry experiments shown here, in Bulletin 168 or 169.

Interfacing at CSYS level is only the starting point for using the computer the way it should be used. Once the data is in the computer it is ripe for manipulation. The extent to which this may be carried is limited only by the sophistication of the software and the imagination of the user. Software from Philip Harris, *Datadisc Plus*, provides us with the means to log and analyse data. The purpose of this article is to illustrate how these features can be usefully exploited.

Not just for chemists

The readership we trust this article reaches will number more than chemistry teachers. In Bulletin 163 [4] we included the idea of manipulating data using *Grapher* and *Datadisc Plus* within a Higher Grade Physics article on distance and velocity sensors. The related mathematical techniques shown here, although principally written for chemists, are of equal benefit to physicists and others interested in the application to experimental data of software-based mathematical utilities. In particular, data logging software which can perform differentiation and integration can reveal features and trends hitherto unobtainable without a great deal of mathematical slog - for example, converting distance/time into speed/time and thence acceleration/time graphs via differentiation - or in the opposite way via integration.

Here we describe two chemistry applications to illustrate some of the possibilities using *Datadisc Plus*. By using the computer we discover different ways of analysing the results, new teaching points and novel means by which experiments might be performed. Data manipulation can replace some of the functions of electronic hardwiring that may have been necessary in the past.

It is assumed that the reader is familiar with the menu structure of *Datadisc Plus* but may not have explored all the detailed facilities.

Application 1 - The determination of the reaction order and rate constant for the hydrolysis of 2-bromo-2-methylpropane

Description

This reaction is described in SCDS Memorandum 16 [3] as experiment G2. It proceeds according to the following equation:

$$\underset{\text{alkyl halide}}{(CH_3)_3CBr} + H_2O \rightarrow (CH_3)_3COH + H^+ + Br^-$$

The traditional method requires samples to be withdrawn and discharged into ice-cold ethanol prior to titration with sodium hydroxide solution. The extent to which hydrogen ions (H^+) are formed, and hence the volume of standard NaOH solution required for neutralisation, is a measure of the extent of the reaction.

In the computer-assisted methods described here the extent of the reaction was followed by measuring the conductivity of the reaction mixture. This is complementary to the concentration of unreacted 2-bromo-2-methylpropane i.e. [alkyl halide] at any given time. The next section explains the mathematical and chemical background to the operations performed.

Mathematical Description

If ρ_t is the conductivity at time t, and

ρ_∞ is the final conductivity once the reaction is complete, and

[A] is the concentration of alkyl halide at time t and

$[A_0]$ is the initial concentration of alkyl halide then

$(\rho_\infty - \rho_t) \propto [A]$ and $\rho_\infty \propto [A_0]$

If two substances A and B react to form a product Z· thus

$A + B \rightarrow Z$

then reaction rate $v = k[A]^\alpha[B]^\beta$

where $[A]^\alpha$ and $[B]^\beta$ are the α^{th} and β^{th} power of the concentrations of reactants A and B respectively and k is the specific rate constant.

If $\alpha = 1$ then the reaction is first order with respect to the concentration of substance A. For a first order reaction the units of k are s^{-1}. This is derived from dividing the rate by the concentration:

moles $dm^{-3}s^{-1}$ / moles dm^{-3}

Then $d[A]/dt = -k[A]^\alpha$

Integration method
(single run for extended time)

$$\int_{[A_0]}^{[A]} d[A]/[A] = -k\int_0^t dt$$

$$\ln[A] = -kt + \ln[A_0]$$

$$\log[A] = -kt/2.303 + \log[A_0]$$

Differential method
(multiple, short time runs)

$$\log v = \log k + \alpha \log[A]$$

v - rate of reaction
k - specific rate constant
α - order re. [alkyl halide]
[A] - concentration of alkyl halide
t - time

In this experiment the concentration of the alkyl halide is followed by measuring the conductivity of the reaction mixture. Therefore conductivity is the measurand.

The voltage signal from the conductivity meter used to follow the reaction is proportional to the conductivity. The computer logging the reaction measures voltage. Therefore transposing the symbols from ρ to V the integration equation

$$\log(\rho_\infty - \rho_t) = -kt/2.303 + \log\rho_\infty + \text{constant}$$

becomes

$$\log(V_\infty - V_t) = -kt/2.303 + \log V_\infty + \text{constant} \quad \{\text{Equation 1}\}$$

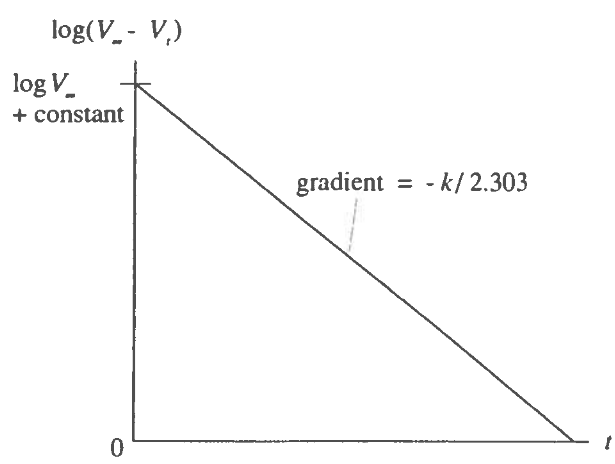


Fig.1 Graph of log of concentration vs. time

This provides a means of measuring the specific rate constant k. It also is a means of finding out whether a reaction is first order.

Another means of finding k is by differentiating Equation 1 with respect to time. The derivative should be time independent, but if we plot the derivative against time (Fig.2) and average out the minor variations we should therefore obtain a fairly true value of k from our data.

From equation 1 $d(V_\infty - V_t)/dt = -k/2.303$

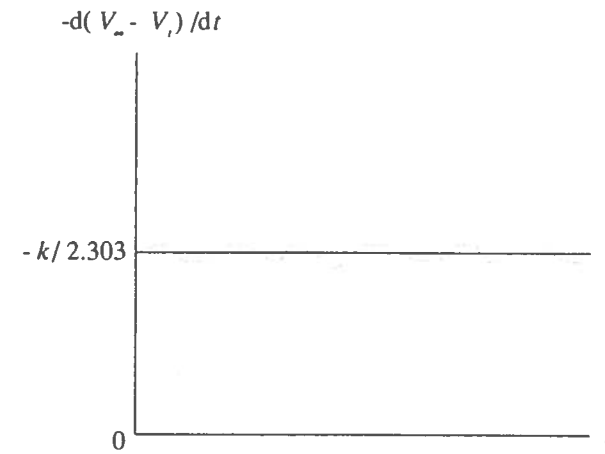


Fig.2 - $d(V_\infty - V_t)/dt$ vs. time

The differential method can be used to find the rate constant k and the reaction order only if the initial concentrations of alkyl halide are converted to units of moles $litre^{-1}$ and the rate data converted to moles $litre^{-1}s^{-1}$. From the differential form of the rate equation, $\log v = \log k + \alpha \log[A]$, where v is the rate, k is the rate constant and α is the order, a plot of log(rate) versus log(initial concentration) should yield a straight line graph whose slope is the order of the reaction. See Fig.3.

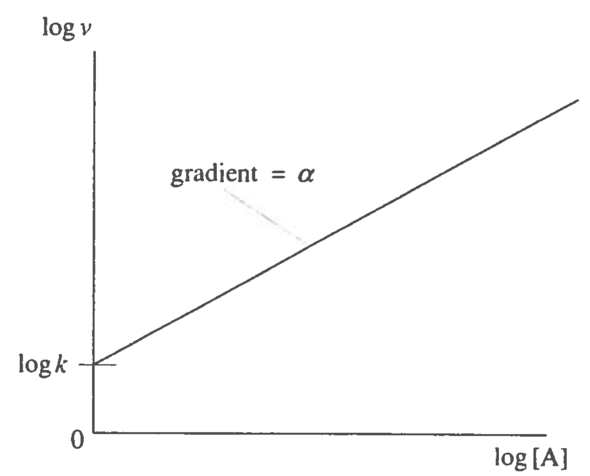


Fig.3 $\log v$ vs. $\log[A]$

In the method shown here we confine ourselves to an inspection of an X-Y plot of the rate vs. initial volume of alkyl halide (Fig.9) - a doubling or tripling of the initial volume of alkyl halide results in a doubling or tripling of the reaction rate. This is indicative of a first order reaction.

Why not calibrate for conductivity?

The default units chosen and plotted by *Datadisc Plus* are volts. A plot of log(voltage$_\infty$ - voltage$_t$) is therefore satisfactory and is as valid as log(titre$_\infty$ - titre$_t$) as shown in Memorandum 16. In all analyses shown here we have simply measured the voltage V. Therefore the voltage at time t is written as V_t .

If however, you wish to make your graphs strictly correct, it is a simple matter to calibrate the analogue channel in siemenses. Access the *Calibrate input channel* on the *Main Menu*:

With the dip-cell in air, enter the first set-point as zero and, in a standard solution of potassium chloride enter the second set-point as the known conductance of that solution.

If calibration has been carried out, any graphs displayed will have the Y-axis related to siemens.

Note:- a similar method to that shown here may be used to follow the alkaline hydrolysis of ethyl ethanoate (Experiment G1 in Memorandum 16).

Summary

The reaction order and rate constant can be investigated by either of the following experimental methods:

- single run for extended time
- multiple, short time runs

Single run for extended time

The integrated form of the rate law for a first order reaction is assumed. A plot of LOG[alkyl halide] vs time[1] yields a straight line whose gradient is $-k/2.303$ where k is the specific rate constant. Additionally, a plot of - d[alkyl halide]/dt versus [alkyl halide] produces a straight line graph (first order) whose gradient is k.

For those who want a quick impression of what the software can do here is a summary of the important steps. See also the relevant figures for the results:

1. calibrate analogue channel on Beeb for conductivity (optional)
2. start reaction and datalog voltage V_t at time t. Plot V_t vs. time (Fig.5)
3. record voltage V_∞ some hours later
4. derive complementary voltage (V_∞ - V_t). Plot this vs. time (Fig.6)
5. derive LOG(V_∞ - V_t) and plot it vs. time (Fig.7)

6a. plot best-fit straight line (Fig.8). Calculate rate constant k for the slope **or**

6b. derive d(LOG(V_∞ - V_t))/dt. Plot this vs. time, measure average gradient and calculate rate constant k (Fig.9).

Another method of analysing the results from a single run may be summarised as follows. Follow steps 1-4 as in the first method:

5. derive the rate -d(V_∞ - V_t)/dt at time t and plot this vs. time
6. X-Y plot rate vs. (V_∞ - V_t) (Fig.10)
7. plot best-fit straight line & gradient is rate constant k (Fig.10)

Note that there are three methods of analysis given here. Initially it may be sufficient to use just the first to get started and move on to the others later.

Multiple, short time runs

The initial rates for different initial volumes of alkyl halide are calculated. The initial rate is then plotted against the initial volume. An inspection of the straight line plot indicates the reaction is first order with respect to the concentration of alkyl halide i.e. doubling the initial volume of alkyl halide results in a doubling of the rate (arbitrary units). The important steps are summarised as follows:

1. calibrate analogue channel on Beeb for conductivity (optional)
2. start reaction and datalog voltage V_t at time t. Plot this vs. time
3. repeat step 2. for 3 other initial concentrations of 2-bromo-2-methylpropane
4. superpose 4 plots of conductivity vs. time on same graph (Fig.11)
5. select first 2 minute part of above 4 graphs (Fig.12)
6. derive best-fit straight line plots for each concentration and note down the gradient or initial rate for each
7. plot initial rate vs. initial volumes of 2-bromo-2-methylpropane (Fig.13)

Experimental details

Reagents

ethanol (industrial)
distilled water
2-bromo-2-methylpropane

Apparatus

bath, water (thermostatically controlled[2] at any temp. 20 - 30°C)
thermometer, -10 - 110°C

[1] From this point on there is a potential for confusion over the meaning of log (as in datalogging) and log (as in logarithms). If you come across "log" we mean the former and "LOG" the latter. This is because the entering of mathematical functions to the Mathematical Utilities of Datadisc Plus requires the use of BASIC expressions such as LOG(...).

[2] Although a thermostatically controlled water bath is specified in Memo 16 and was used to obtain the results shown here (at 27.7°C) it is not really required. Reasonable results may be obtained at room temperature provided that does not vary greatly during a run, or between consecutive runs.

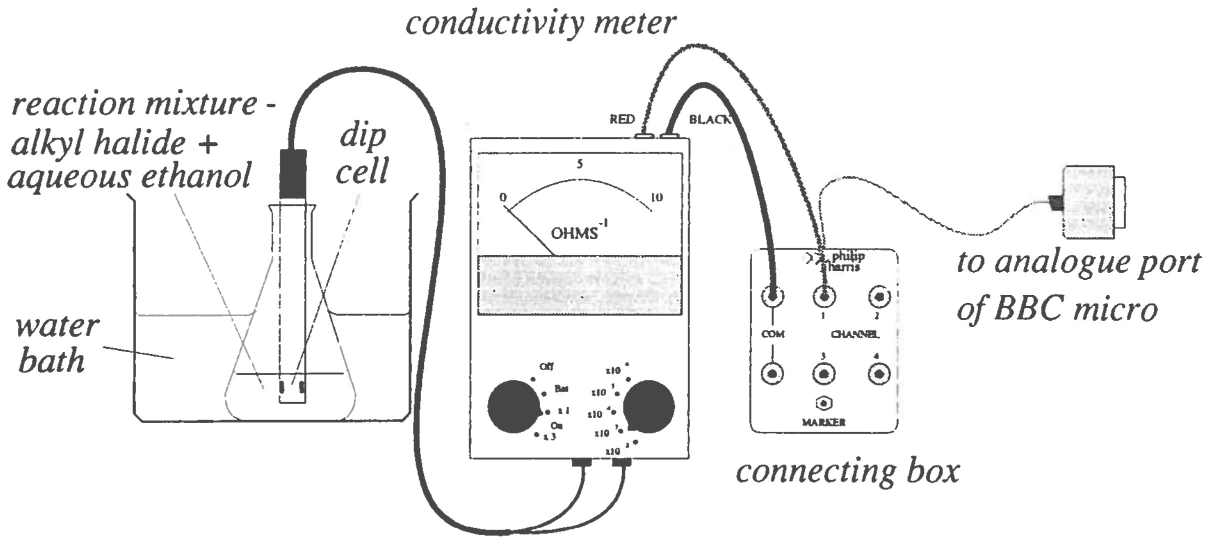


Fig.4 Datalogging 'conductivity'

flask, conical (100 cm^3)
flask, conical (250 cm^3)
flask, volumetric (50 cm^3)
leads, low voltage
2 x measuring cylinders, glass (100 cm^3)
2 x pipettes, glass (1cm^3 bulb or graduated)
pipette filler (plastic pump)
interfacing equipment, 4-Channel Connecting Box and software (see end of article)
meter, conductivity
probe, conductivity

A WPA conductivity meter (Cat. No. CM35, £140) and dip-cell probe were used (Fig.4). The meter has a 0-1 V output corresponding to the full-scale-deflection of the conductivity range selected. This output can be connected to either a datalogger or an Analogue Port connector on a BBC Micro. Note that it is necessary to stick to one range on the conductivity meter. By not doing so, conductivity versus time graphs would be meaningless. For your meter and probe the best range can be found by trial and error. We found, for this particular experiment anyway, the most suitable range was that giving an indicated 0 - 1 x 10^{-3} S.

Procedure - single run for extended time

Approximately 100 cm^3 of aqueous ethanol was prepared in a dry 250 cm^3 conical flask by mixing 80 cm^3 of ethanol with 20 cm^3 of distilled water. This was placed in the water bath to equilibrate the temperature with that of the bath.

1 cm^3 of 2-bromo-2-methylpropane was pipetted into a clean, dry 100 cm^3 conical flask, stoppered, and the flask then placed in the water bath. A standard 50 cm^3 volumetric flask was filled to the mark with the aqueous ethanol then 1 cm^3 removed by pipette, stoppered and placed also in the water bath. Therefore the total volume of ethanol and 2-bromo-2-methylpropane will be close to 50 cm^3. When constant temperature was reached in the two flasks, the aqueous ethanol was added to the alkyl halide, mixed well and the conical flask placed in the water bath with the conductivity dip-cell in the reaction mixture.

The logging was started simultaneously and the voltage V_t at time t logged for about one hour and then the mixture left overnight to obtain an approximation of the voltage V_∞ at time ∞, (Fig.5). It is not necessary to have the meter connected to the computer overnight as the voltage output at time infinity can be taken next morning by connecting a voltmeter or multimeter to the meter output. The voltage at any given time is proportional to the concentration of H^+ ions [H^+].

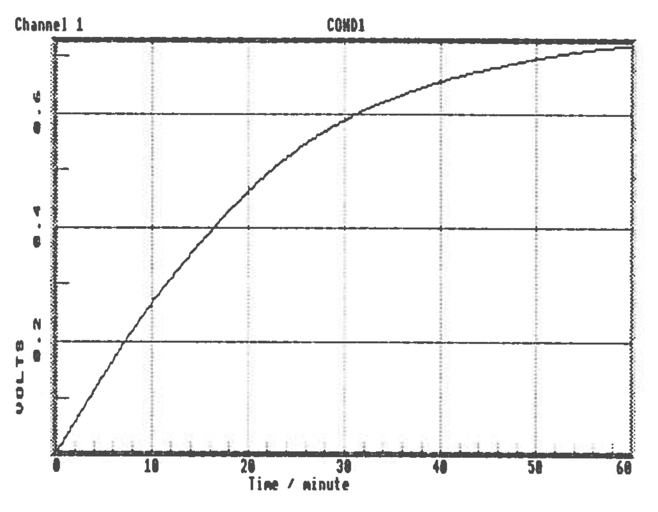


Fig.5 - V_t vs. t

Adopting the treatment in Memorandum 16, (V_∞ - V_t) was plotted against time (Fig.6) as this gives a measure of the concentration of 2-bromo-2-methylpropane [alkyl halide] at any given time. V_∞ had been found to be 0.763 V, using a digital multimeter. The derived data was obtained, in the example shown, by entering the right

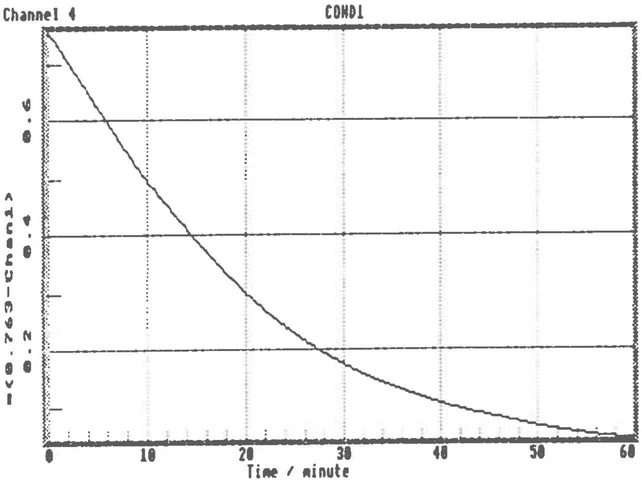


Fig.6 $(V_\infty - V_t)$ vs. t

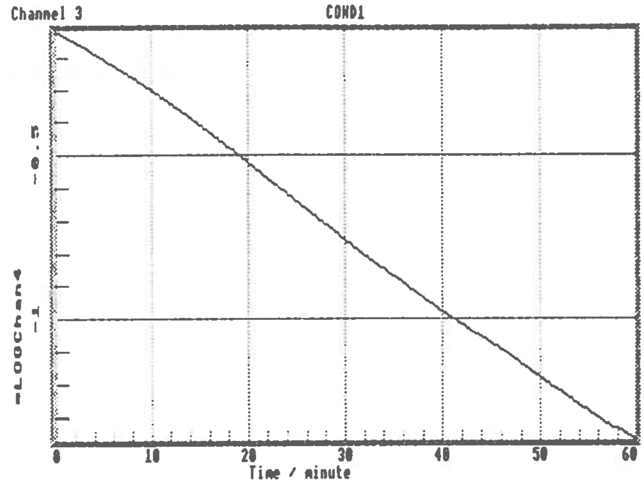


Fig.7 LOG$(V_\infty - V_t)$ vs. t . . .

hand side of the following expression to the *Calculate related data* section of the *Mathematical Utilities Menu* in *Datadisc Plus* [3]:

New value = 0.763 - *x*

The computer assigns the symbol x to the original data on channel 1 (Fig.5) representing conductivity and calculates a new channel of data on channel 4 (Fig.6)[4].

A straight line relationship between LOG$(V_\infty - V_t)$ and time would indicate that this is a first order reaction with respect to 2-bromo-2-methylpropane. The *Calculate related data* section of the *Mathematical Utilities Menu* is used again:

New value = LOG(y)

where y is the variable assigned to channel 4. The resulting graph is shown as Fig.7. Once you become familiar with these techniques you can combine the last two steps with a single expression:

New value = LOG(0.763-x)

The gradient of the LOG$(V_\infty - V_t)$ vs. time graph (Fig.8) is directly related to the rate constant k by:

gradient = $-k/2.303$ {Equation 2}

The rate constant and information about the order of reaction can be obtained from the related data in Figs. 6, 7 and 8 by further mathematical manipulation using *Datadisc Plus*. This was achieved by use of the following analyses:

Analysis 1 - As the LOG(0.763 - x) vs. time graph appears to be more or less a straight line relationship we can conclude the reaction follows first order kinetics with

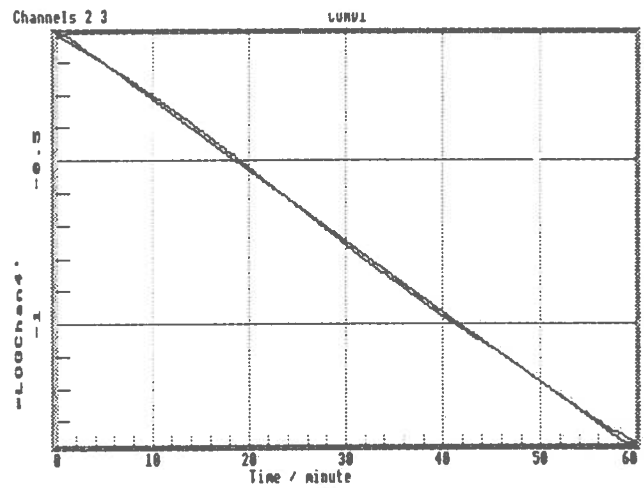


Fig.8 . . . with best straight line

respect to the concentration of alkyl halide. The *Least squares fit* procedure from the *Mathematical Utilities Menu* can be used to calculate a best straight line based on the expression $y = mx + c$ where y and x are variables assigned to any two channels of data, or one channel of data with time as the other variable. In this case x is time and so T is entered. The software then asks which channel represents y. You enter the channel number containing the LOG$(V_\infty - V_t)$ data. The data is processed and an equation of the straight line and correlation coefficient are displayed:

y = -3.609E-4x - 0.09865

Correlation coefficient = 0.998

Substituting for the gradient in Equation 2 we can calculate the specific rate constant k:

$k = 2.303 \times 3.609 \times 10^{-4}$

$= 8.31 \times 10^{-4}\ s^{-1}$

The straight line graph is assigned to another channel if one is available. Fig.8 shows the original LOG$(V_\infty - V_t)$ data displayed with the best straight line. There isn't much daylight between them!

3 The centred italicised text shown here illustrates what actually appears on screen when you access the Datadisc Plus menus mentioned.

4 The symbols x, y or z are variables assigned to data on e.g. channels 1, 2 and 3 respectively. They should not be confused with the X and Y-axes. For example the data on channel 1, assigned the variable x, could be plotted on the Y-axis of a graph.

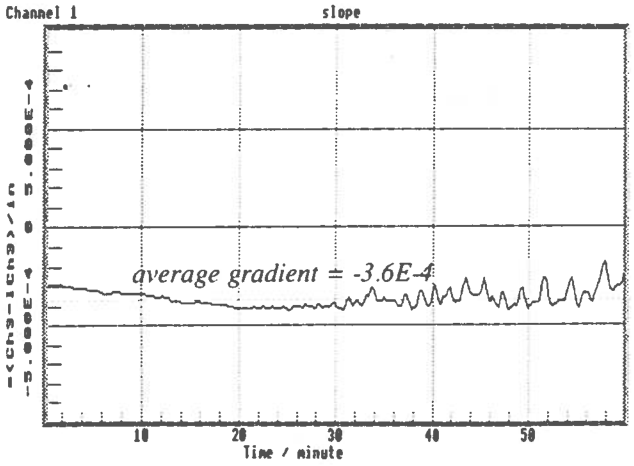


Fig.9 Gradient vs. time

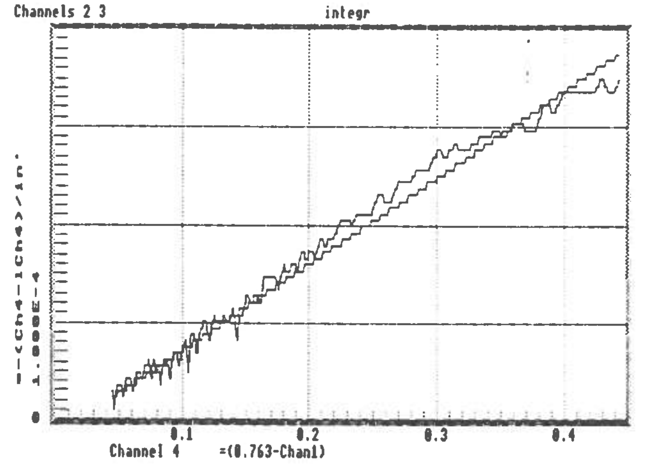


Fig.10 -d(V_∞ - V_t)/dt vs. (V_∞ - V_t)

Analysis 2 - A major development from the original *Datadisc*, when it was upgraded to *Datadisc Plus*, is the provision of a number of variables in addition to the *x*, *y* and *z* channel variables. These include:

t the time corresponding to a point (in s)

lx, *ly* or *lz* the last value of *x*, *y* or *z*

lv the last expression value computed

A new constant *in* is defined as the time interval between points (in seconds).

These additional variables allow us to manipulate and calculate related data in ways not possible with simple BASIC expressions. If the LOG(V_∞ - V_t) data is first smoothed a couple of times with the *Smooth data* utility this irons out any wrinkles. We can then mathematically differentiate and derive a gradient vs. time graph. This was done by entering the right hand side of the following expression to the *Calculate related data* section of the *Mathematical Utilities Menu*:

New value = (y - ly)/in

where *y* represents the variable of the channel holding the LOG(V_∞ - V_t) data. Remember *ly* is the value of the data previous to the present point and *in* is the time interval between consecutive data points. With a little adjustment of the Y - axis scaling a graph similar to Fig.9 can be obtained. The horizontal line across the graph ties in nicely with the gradient -3.6 x 10^{-4} achieved in Analysis 1.

Analysis 3 - Returning to the treatment in Memorandum 16, it can be assumed that for a first order reaction:

Rate $\propto$ [alkyl halide]

i.e. - d[alkyl halide]/dt $\propto$ [alkyl halide]

therefore -d(V_∞ - V_t)/dt $\propto$ (V_∞ - V_t)

The differential of the data in Fig.6, (V_∞ - V_t) vs. time, was obtained by the same method as shown in Analysis 2. This was done by entering the right hand side of the following expression to the *Calculate related data* section of the *Mathematical Utilities Menu*:

New value = (x - lx)/in

where *x* represents the variable of the channel holding the (V_∞ - V_t) data. Remember *lx* is the value of the data previous to the present point and *in* is the time interval between consecutive data points. The resulting data was X-Y plotted against (V_∞ - V_t) to give Fig.10. The gradient of this line can be read directly as *k*, the specific rate constant. Using the *Least squares fit* procedure from the *Mathematical Utilities Menu*, the slope was calculated to be 8.84 x 10^{-4} s^{-1}. This corresponds well with the value obtained by Analysis 1.

Procedure - multiple, short time runs

In this method a number of runs are done with different initial volumes of 2-bromo-2-methylpropane. These will be directly proportional to different initial concentrations. The method of preparing the reaction mixture was the same as that used in the first procedure for a single run. Vary the initial volumes[5] of alkyl halide between 0.25 and 1.5 cm^3, and adjust the volume of aqueous ethanol accordingly, to make a total volume of 50 cm^3 each time.

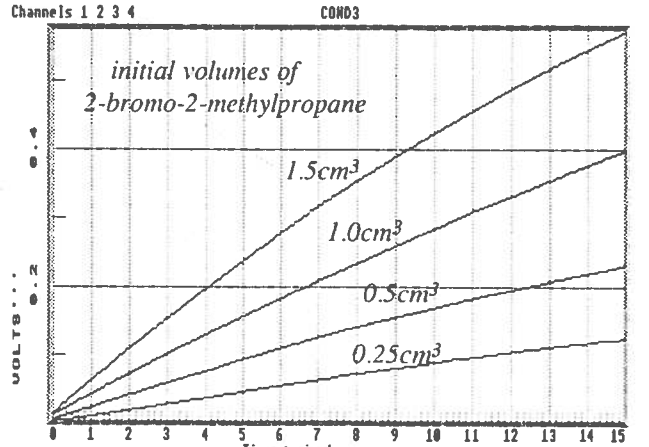


Fig.11 Voltage vs. time for 4 different initial volumes of 2-bromo-2-methylpropane

[5] Figs.11 and 12 show only four plots logged at different initial volumes of alkyl halide whereas Fig.13 shows six derived values of rate vs. initial volume. This is because Datadisc Plus can display a maximum of four channels at any one time. We also included rate data from initial volumes of 0.75 and 1.25 cm^3 not shown in Fig.12.

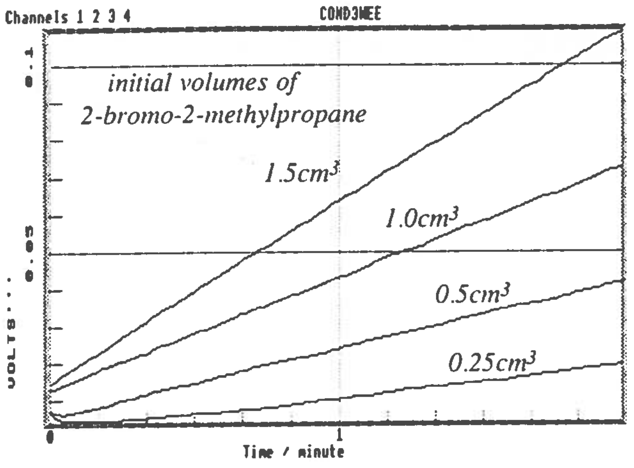


Fig.12 First 2 minutes from Fig.11

Two minutes datalogging for each is enough to determine the initial rates. Fig.11 shows four voltage vs. time plots for four different initial volumes of 2-bromo-2-methylpropane. With the *Select part of data* on the *Display Utilities Menu* we select only what happened in the first two minutes for analysis (Fig.12). Calculating the gradients of these lines in the same way as in Analysis 1, we are able to plot initial rate (arbitrary units) versus initial volumes of 2-bromo-2-methylpropane. It can be clearly seen from Fig.13 that any increase (e.g. doubling or tripling) in the initial volume of alkyl halide results in a consequent size of increase in the rate. This is indicative of a first order reaction with respect to the concentration of alkyl halide.

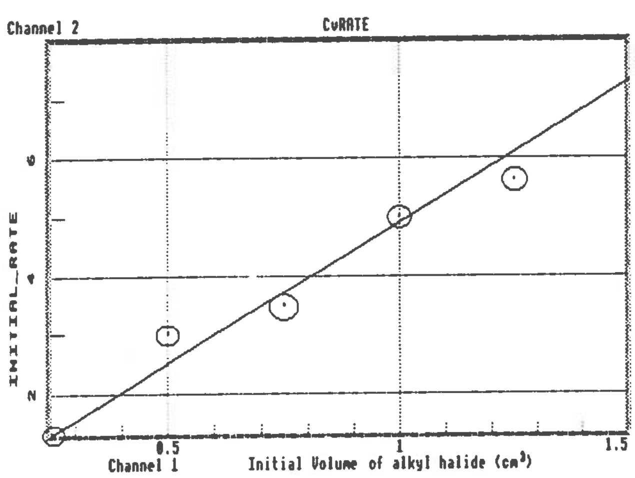


Fig.13 Initial rate (arbitrary units) vs. initial volume of 2-bromo-2-methylpropane

Application 2 - The iodine coulometer

This experiment is described in the SCDS Memorandum 16 [3] as experiment D1. The concentration of an unknown thiosulphate solution is determined by the reaction with coulometrically generated iodine in the presence of starch as an indicator. Therefore once an excess of iodine is generated the solution goes blue/black. A light sensor is used to determine exactly when this occurs. The iodine is generated in the coulometric cell according to:

$$2I^-_{(aq)} \rightarrow I_{2(aq)} + 2e^- \quad \{\text{Equation 1}\}$$

The iodine reacts with the thiosulphate ions thus:

$$I_{2(aq)} + 2S_2O_3^{2-}{}_{(aq)} \rightarrow 2I^-_{(aq)} + S_4O_6^{2-}{}_{(aq)} \quad \{\text{Equation 2}\}$$

The traditional method requires a constant current supply, or someone to attend the apparatus and manually keep the current constant. A DIY constant current supply circuit, to replace the discontinued Griffin model, was shown in Bulletin 166 [5]. The charge transferred was simply calculated by multiplying current I (in amps) by the time t (in seconds).

In this method the software can replace some of the previously required hardware as well as providing a number of useful new teaching points. The method could also see application in determining the relationship between charge transferred and the mass of metal plated i.e. onto an electrode.

Here we use a variable d.c. power supply with a large value smoothing capacitor (2200 µF) connected across the output. Because we can use the *Mathematical Utilities* of the *Datadisc Plus* software to work out the area ($I*t$) under the curve, the current can be allowed to vary during the course of the experiment. This can be by design or just as things happen. In the example shown (Fig.16) the current was varied greatly between 0 and 20 mA by the operator. If high currents are used, an increase in the amount of wispy blue colour can be seen around the platinum electrode. Remember the teaching point is that it is the charge transferred that is ultimately important and not the time it takes.

Another difference here is that the platinum foil electrode normally used is replaced by a coil of platinum wire - made by winding a length of wire round a pencil (our foil electrode fell apart just before the CSYS Chemistry National Course and we had run out of foil). This alternative was found to work just as well.

Measuring 'current'

Dataloggers or Analogue Port interfaces cannot measure current directly. They can only measure voltages. The current supplied to the coulometer cell was measured by monitoring the voltage drop across a digital multimeter set to the 20 mA scale. The impedance of the meter (10 Ω) produces a voltage drop of 0-0.2 V corresponding to a current measured of 0-20 mA (Fig.14). Fig.15 shows the circuit diagram.

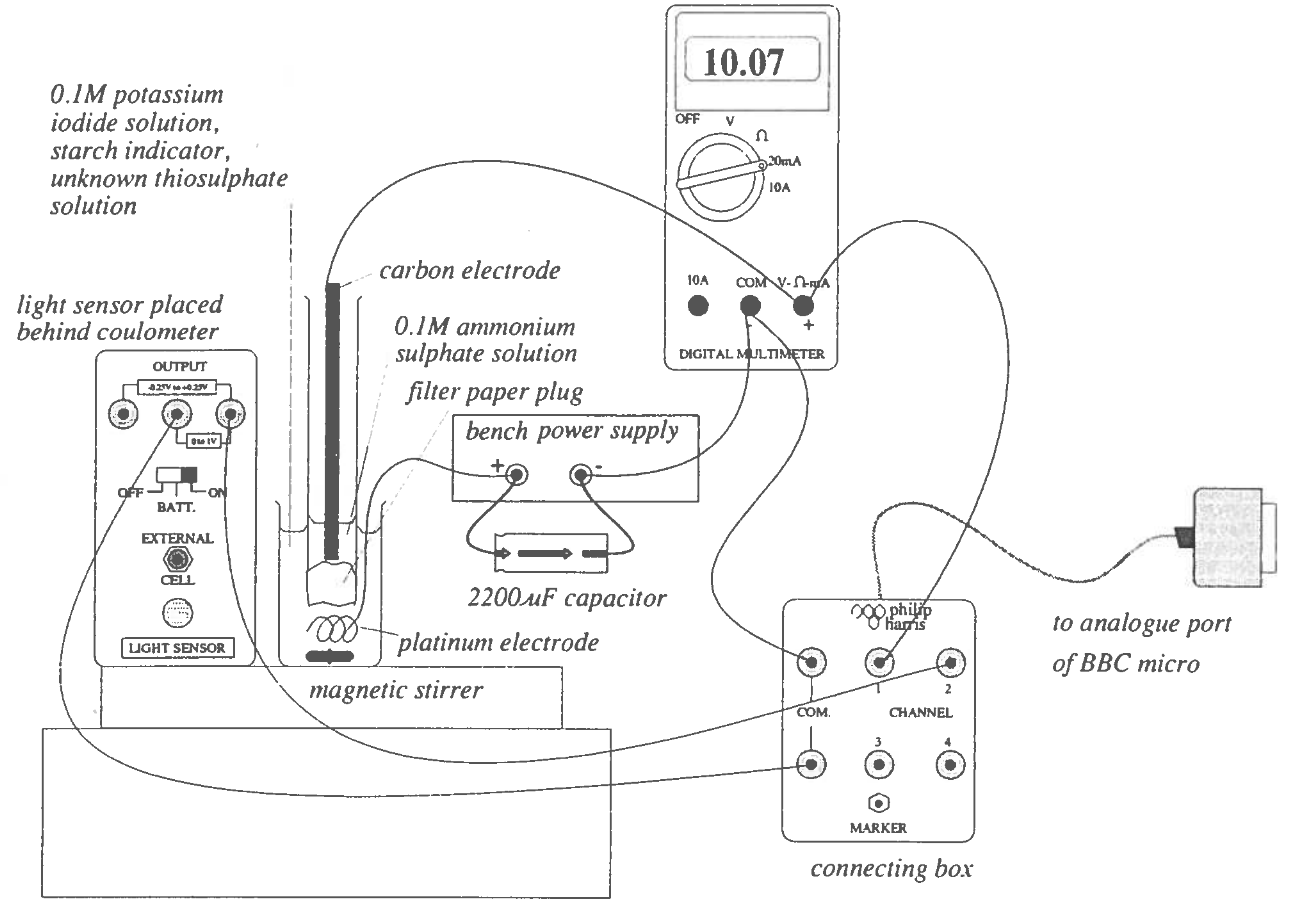


Fig.14 Apparatus (schematic) for interfacing coulometer cell

As in Application 1, the important steps in the experimental procedure and analysis may be summarised as follows:

1. calibrate channel 1 on Beeb for current
2. start experiment and datalog current and light level (both as voltage) vs. time
3. derive charge passed. Plot both current and charge passed vs. time (Fig.16)
4. plot charge passed and light level vs. time (Fig.17)
5. X-Y plot charge passed vs. light level (Fig.18)

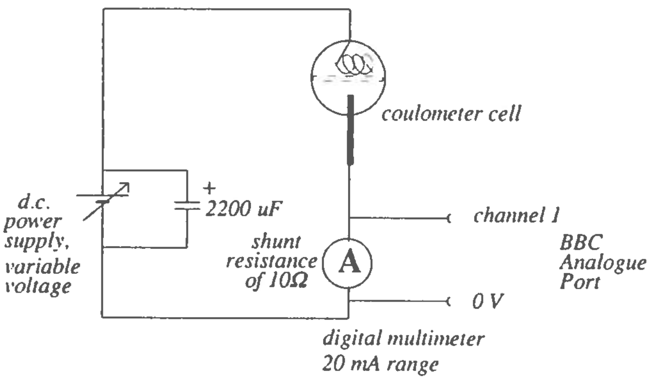


Fig.15 Circuit diagram - measuring 'current'

Experimental details

Reagents

sodium thiosulphate, 0.1M (unlabelled, to be used as unknown)
potassium iodide, 0.1M
ammonium sulphate, 0.1M
indicator, starch solution (freshly prepared)

Apparatus

power supply, d.c. (low voltage, variable)
capacitor, electrolytic (2200 µF)
beaker, glass (100 cm^3)
multimeter, digital (on 0-20 mA scale)
carbon rod
platinum wire (150 mm length x 0.5 mm diam.)
boiling tube (hole in end with filter paper plug)
crocodile clips
leads, low voltage
sensor, light
flea, stirrer
stirrer, magnetic
pipette, glass (1 cm^3)
pipette filler (plastic pump)
2 x droppers, plastic
interfacing equipment, 4-Channel Connecting Box and software (see end of article)

Calibration

Channel 1 of the Analogue Port was calibrated by accessing the *Calibrate input channel* selection on the *Main Menu*:

Type in <Current (A)> as the units for calibration. With the power supply switched off, enter <0> (zero) as the first set-point. Make sure the beaker (100 cm^3) contains 1 cm^3 of the unknown e.g. 0.1M sodium thiosulphate solution as well as the other solutions in Fig.14. Switch on the magnetic stirrer and carry out the next few steps as quickly as possible - switch on the power supply, adjust the voltage till a current of 10 mA is displayed on the multimeter and enter <0.01> as the second set-point. Remember our unit for this channel is the ampere! Switch off the power supply immediately after calibration.

Position the light sensor such that the beaker is between it and a window or some other light source. Connect the sensor to channel 2 of the Analogue Port Connector.

Procedure

A total logging time of around 20 minutes at an average of 10 mA should be sufficient to see a change in potassium iodide solution primed with 1 cm^3 of 0.1M sodium thiosulphate solution. Once logging is started, the power supply can be switched on at your leisure and the current adjusted initially to around 10 mA.

Fig.16 shows a current vs. time plot where the current was deliberately varied between 0 and 20 mA over the course of the experiment in order to show how the integration could cope with a non-constant current.

Analysis

When the reaction is complete the current vs. time graph can be mathematically integrated to produce a charge transferred versus time plot. This was done by entering the right hand side of the following expression to the *Calculate related data* section of the *Mathematical Utilities Menu*:

$$New\ value = lv + (x * in)$$

where x represents the variable of the channel holding the current data, *in* is the time interval between data points and *lv* is the last expression value computed. In other words the cumulative total of each current * time interval calculation for each data point is plotted vs. time. The diagonal plot on Figures 16 and 17 represents the charge transferred (in coulombs) vs. time. Figure 17 also shows how the light level varied with time.

It can be clearly seen from Figure 17 that the charge transferred when the light level abruptly dropped was about 11 coulombs. To illustrate this even more clearly the *Display utilities* can produce an *X-Y plot* (Fig.18) of charge transferred vs. light level.

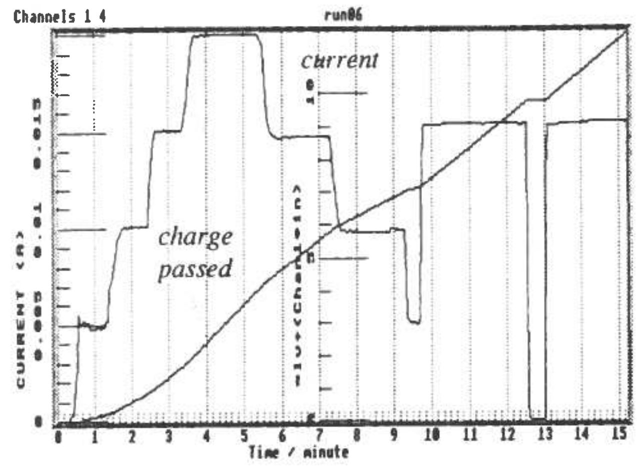


Fig.16 Current & charge vs. time

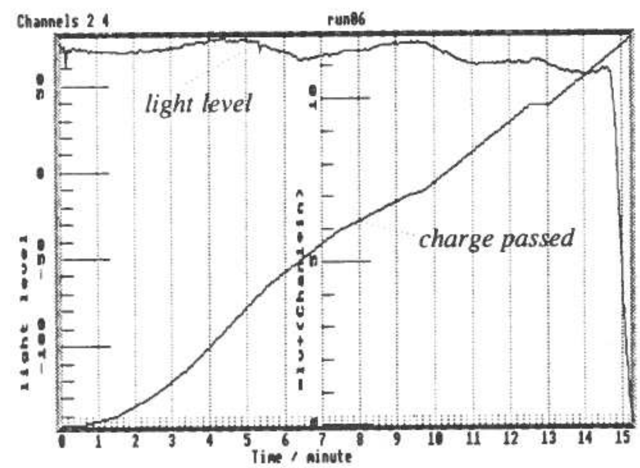


Fig.17 Charge & light vs. time

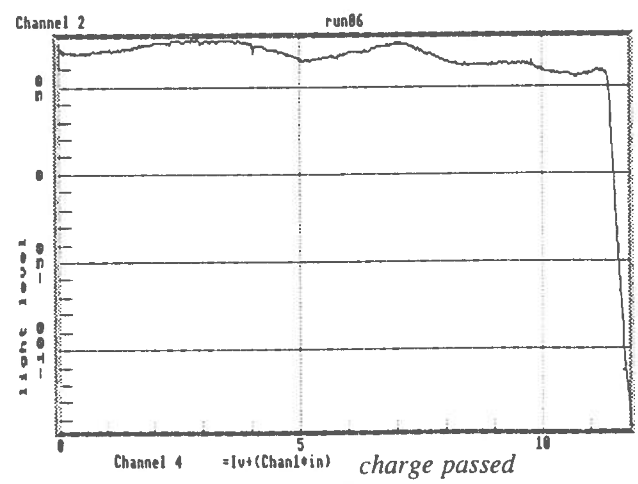


Fig.18 Charge vs. light level

The calculation of the concentration of thiosulphate originally present can proceed as follows:

coulombs of charge passed = 11 C

2 x 96500 coulombs release 1 mole of iodine

11 coulombs release 11/193000 moles of iodine = 5.7×10^{-5} moles

1 mole of iodine reacts with 2 moles of thiosulphate ions (from Equation 2)

5.7×10^{-5} moles of iodine react with 1.1×10^{-4} moles of thiosulphate ions

Since this was present in 1 cm^3 of the original thiosulphate solution, the concentration supplied was 0.11M.

Interfacing equipment and software

Datadisc Plus (from Philip Harris)

BBC Model B and Master

Software complete with Analogue Port Connecting Box (A29022/1):

Catalogue No. - A29024/5, £65 (80 track, 5$^1/_4$" disc)

Software only - A29025/7, £36 (" ")

Upgrade from *Datadisc* to *Datadisc Plus*
- A29027/0, £27

These machines already have an A-D converter fitted as standard.

Archimedes

Software complete with Analogue Port Connecting Box (A29022/1):

Catalogue No. - A29042/7, £66.50 (3$^1/_2$" disc)

Software only - A29040/3, £37.50 (")

An input/output board with A-D converter is available for the A300 and A400 Series from Acorn. A300 Series computers also require a backplane, which is also available from Acorn.

Two companies have just released input/output boards with analogue ports for the A3000 - Morley Electronics and HCCS Associates (see address list). We hope to test these in the near future.

References

1. SEB Arrangements in Standard Grade Chemistry
2. SEB Revised Arrangements in Higher Grade and CSYS Chemistry
3. Memorandum Number 16, "Practical Work in Sixth Year Studies Chemistry", SCDS (now SCCC), revised 1982.
4. Bulletin 163, "DIY transducers for distance and velocity v. time", p30-34, 1989.
5. Bulletin 166, "DIY coulometer cells", p26-27, 1990.

Technical Articles

DIY Computer Interfacing

(for the BBC Model B, Master, and Archimedes)

This is the first of a series of articles which will be of interest to anyone who wants to build their own interfaces for a BBC Model B, Master, or Archimedes, for datalogging or control.

Introduction

One of the beauties of the Model B or the Master, from the point of view of a science or technology teacher, is the inclusion of comprehensive interfacing facilities. These make it very easy to connect up the computer to record experimental results, or to control any kind of apparatus. Archimedeses and A3000s can have very similar interfaces fitted (internally) as optional extras.

Many third party suppliers offer various interfaces to connect the computer to your apparatus. But if the interfaces are already provided inside the computer, why do you need another interface?

For some purposes, the fact is that you don't - you can just connect your apparatus straight up to the computer. In almost every other case, the extra bits you need are so simple that it makes much better sense to do it yourself than to pay someone else a hundred pounds or more to do it for you. It may well be a valuable learning experience for you too!

The internal interface separates out information intended for external apparatus from all the complex communication going on within the computer, and outputs it as straightforward electrical signals; or receives information from external apparatus, and codes it into a form which can be interpreted by the computer. Either is quite a complex undertaking.

The main reason that a second interface is sometimes necessary is that the designers of the computer can't possibly know exactly what currents and voltages you need to operate your apparatus, or what signals your apparatus generates to go to the computer. Fortunately circuits to perform this kind of signal conditioning are quite simple, and require only reasonably cheap components.

Another reason for using an external interface is to protect the computer. This is much overplayed by the manufacturers of interfaces - Model Bs and Masters are quite well protected internally. Nonetheless, it is important not to connect the low voltage ports to the mains! Most interfaces on the market wouldn't give much protection against this anyway. There *are* circumstances where additional protection is necessary, but it's quite easy to provide given common sense and a little basic knowledge.

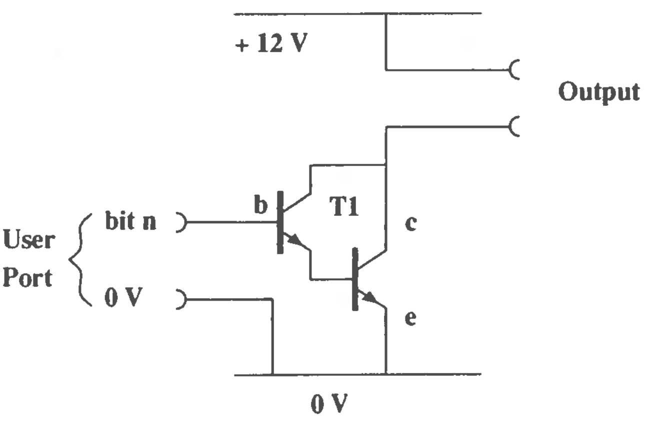


Fig. 1 - Simple Darlington User Port buffer

The internal working of the computer is digital. Each connection only has two states, 'on' or 'off'. These are not 5 V and 0 V, as is commonly stated: those are the voltages of the power supply, but the signals are generally in between. Any signal over about 2 V is 'on', and any below about 0.7 V is 'off'. Between these two levels is a forbidden zone of ambiguous and possibly damaging signals.

In your apparatus, you may require analogue control of voltages, currents or power; or you may have an analogue signal you want to input to the computer. Acorn provide an analogue input port, but no analogue output. This is thoughtfulness on their part: they've done the hard task. You can easily provide digital to analogue conversion - it's little more than an appendage on the circuit to produce whatever current and voltage levels you require.

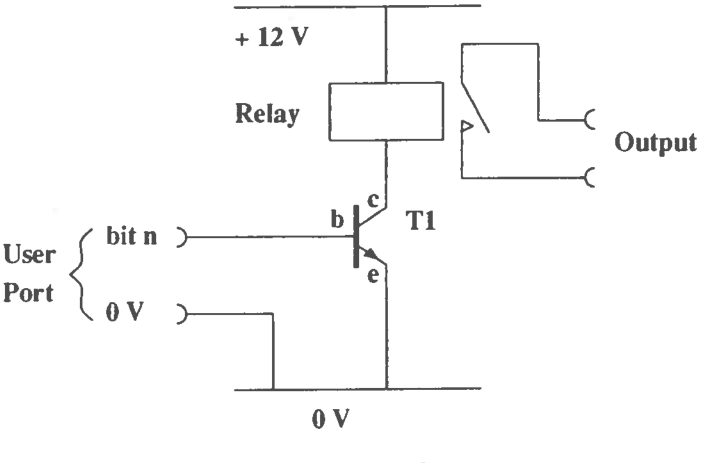


Fig. 2 - User Port operating a relay

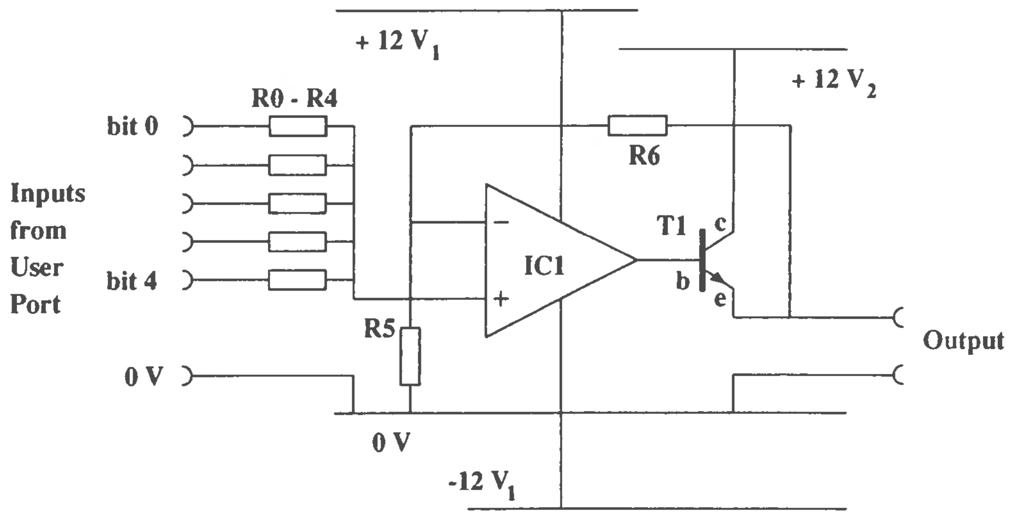


Fig. 3 - 5-bit DAC (digital to analogue converter)

R0	82K	5%	Resistor
R1	39K	5%	
R2	18K	5%	
R3,6	8K2	5%	
R4,5	3K9	5%	
IC1	741		Op-amp
T1	BD437		Transistor

Components for fig. 3

Boosting a digital output

The User Port outputs are only small signals: 1 mA max at at least 1.5 V_{DC} (on) and 1.6 mA max (inward current) at 0.4 V_{DC} max (off). This can easily be boosted to any chosen voltage and current with a suitable Darlington transistor circuit; or it can drive a relay via a small transistor (Figs. 1 & 2). Suggested components are TIP110 for the Darlington in Fig.1, and BC184 or BC108 for the transistor in Fig. 2.

If you want to use all 8 lines of the User Port for input, you can use the Printer Port for output. These are buffered outputs and provide larger currents and voltages; but the bare outputs would but rarely be sufficient even so. The same circuits work, and you wouldn't gain anything by changing.

Producing an analogue output

Fig. 3 shows a simple 5-bit digital to analogue converter circuit. Its output can be controlled in 32 more or less equal steps over the range from about 0 V to 10 V.

The circuit shown in Fig. 4 produces a voltage that's controllable in 256 steps. The range can be adjusted with VR2, from about 0 - 1 V, to about 0 - 10 V; and VR1 is used to set the zero point. With a BD437 for T1, the output will be able to deliver at least 800 mA; if you need more, you could use a TIP110 (Darlington) transistor. Almost any NPN transistor or Darlington will do. It's up to you to ensure that the load is not too great for the power supply, or the current carrying capabilities of the transistor. Look up I_c max in the specifications. This is 4 A for both BD437 and TIP110. Note that unless the load is very light, it is better to use separate power supplies for the IC and the load.

This D to A converter is simply an op amp summing circuit. The User Port (or Printer Port) outputs are added together, with bit 7 weighted 128 times the weighting of bit 0, bit 6, 64 times, and so on. If you don't need 8 bit precision, or you want to use a line or two as separate digital outputs or inputs, you can simply miss out the least significant bits.

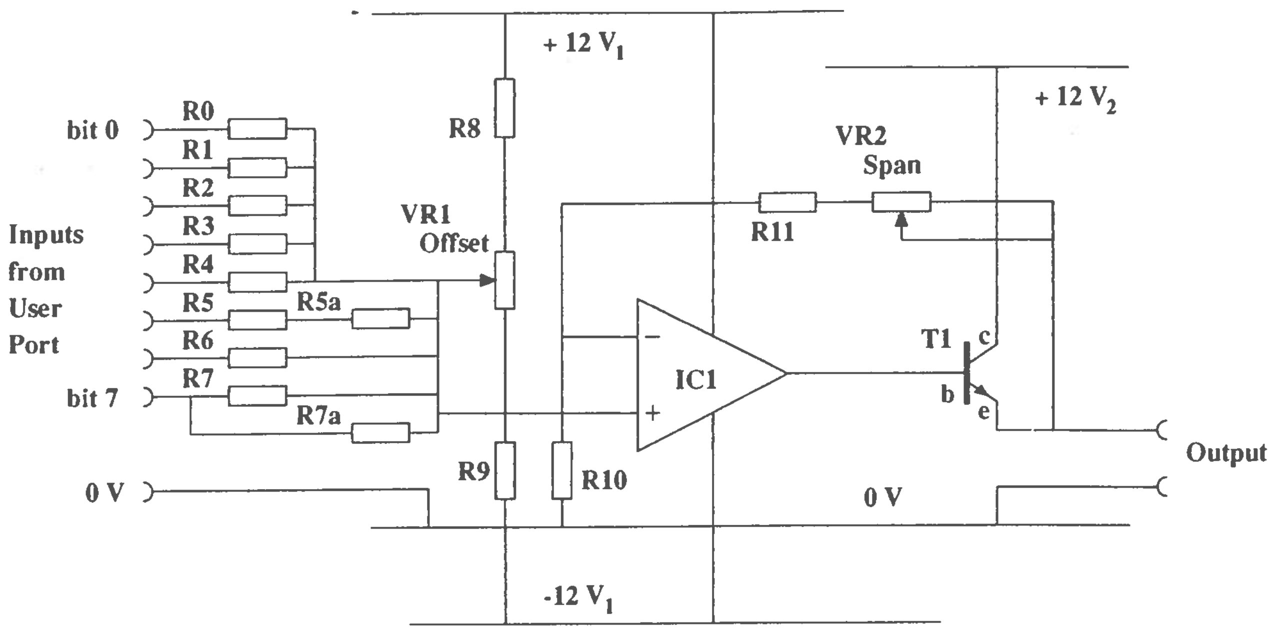


Fig. 4 - 8-bit DAC

R0	680K	5%	Resistor
R1	330K	5%	
R2	150K	5%	
R3	68K	5%	
R4	33K	5%	
R5,5a,6, R7,7a	8K2	1%	←←← !!!
R8,9,10	3K9	5%	
R11	820R	5%	
VR1	1K	20%	Potentiometer
VR2	10K	20%	
IC1	741		Op-amp
T1	BD437		Transistor

Components for fig. 4

Even if you use precision resistors, you can't expect to achieve 8 bit precision anyway, because the voltages on the User Port output lines are not guaranteed to be precisely the same. We suggest you stick to 5 or 6 bit precision! The extra bits can nonetheless be useful to give *smoother* control (see Fig. 5).

Figs. 5 and 6 shows possible effects of inaccuracies in the lower value resistors. The higher value resistors (less significant bits) don't need to be accurate.

We publish a leaflet 'A-D and D-A Conversion Notes' (£0-40p inc. p.& p.) if you want to look into this further.

Software

This will be covered more fully in a future article. For now, Listings 1 & 2 give procedures to use in your own basic programs to provide simple open loop control functions on Arcs and Masters respectively. Simply append the procedures to your program, call PROCUserSetUp before the first time you use the User Port, and call PROCUserOut(a%) to send a byte to the

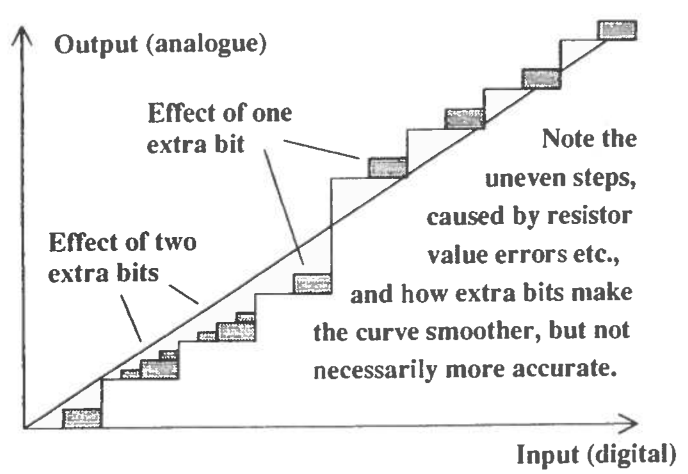


Fig. 5

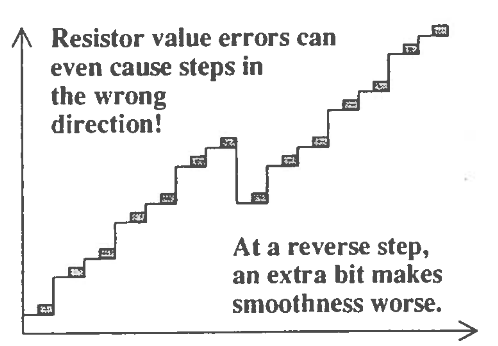


Fig. 6

```
10 REM Procedures to use the User Port - Master/Model B Version
20
30DEFPROCUserSetUp
40REM &FE62 is the location of the Data Direction Register
50REM This tells the User Port that all lines are Output
60?&FE62 = &FF
70REM &FE60 is the location of the User Output Register
80UserPort = &FE60
90ENDPROC
100
110DEFPROCUserOut(a%)
120?UserPort = a%
130ENDPROC
```

Listing 1

```
10 REM Procedures to use the User Port - Archimedes Version
20
30DEFPROCUserSetUp
40REM &62 is the location (in SHEILA) of the Data Direction Register
50REM This tells the User Port that all lines are Output
60*FX 151,&62,&FF
70REM &60 is the location (in SHEILA) of the User Output Register
80UserPort = &60
90ENDPROC
100
110DEFPROCUserOut(a%)
120*FX 151,UserPort,a%
130ENDPROC
```

Listing 2

```
10 REM D to A Sine Wave Generator
20PROCUserSetUp
30FOR T = 0 TO 100000
40X = 128 + 128 * SIN(T/256)
50PROCUserOut(X)
60NEXT
```

Listing 3

User Port. a% can either be an integer variable or a number; either way its value should be a number in the range 0 to 255. With the analogue output circuit, the output will be proportional to a%; if you are using the separate digital outputs each line will be on if the corresponding digit of the binary representation of a% is a 1. Listing 3 is a short example program which would produce a (slow) sine wave on the analogue output circuit, and Listing 4 would produce a traffic light sequence.

Archimedes Printer Port

Until you fit an I/O unit (podule) to your Arc, the only output available is the Printer Port. This can only be accessed by operating system routines. Once they have sent a byte of data to the port, they won't send another until they have received an acknowledgement from the printer, or whatever you have connected. This makes things slightly more complicated. This will be discussed in a future article.

```
10 REM Simple Traffic Light Sequencer
20PROCUserSetUp
30REPEAT
40REM RedEW = 1, GreenNS = 32
50PROCUserOut(33)
60PROCWait(10)
70REM RedEW = 1, AmberNS = 16
80PROCUserOut(17)
90PROCWait(2)
100REM RedAmberEW = 1 + 2, RedNS = 8
110PROCUserOut(11)
120PROCWait(2)
130REM GreenEW = 4, RedNS = 8
140PROCUserOut(12)
150PROCWait(10)
160REM AmberEW = 2, RedNS = 8
170PROCUserOut(10)
180PROCWait(2)
190REM RedEW = 1, RedAmberNS = 8 + 16 200PROCUserOut(25)
210PROCWait(2)
220UNTIL FALSE
230
240REM Insert appropriate procedures here
```

Listing 4

TECHNICAL ARTICLES

Fermenters - Part II

Practical tips are given on the implementation of a selection of published ideas for the d.i.y construction of fermenters.

Introduction

Part I of this article [1] delineated three broad categories of fermentation apparatus for use in schools. Distinctions were made on educational grounds. Three commercial fermenter systems were then reviewed against SSERC criteria for such devices.

Part I only touched on the potential for d.i.y. systems to bridge between biology and *design and make* technology activities. This second part explores more fully such possibilities in the context of simple models of batch fermenters. Emphasis is placed on practical, technical hints and tips useful in turning basic ideas into working educational models.

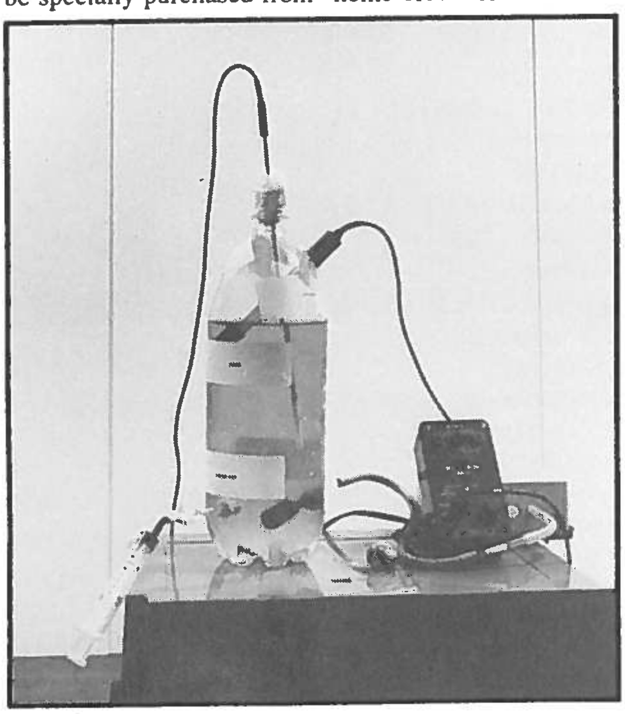
Developments in modelling continuous fermentation systems and in investigating some of the problems of *scale-up* are to be described in Part III, which will be published in Bulletin 168.

Simple bioreactors - batch process

Everyday containers as vessels

A number of published courses and teachers' resource books have illustrated and, or, described the use of everyday containers as bases for modelling fermentation systems. For example, see references [2], [3] and [4].

Such containers may be those to be found in laboratories, e.g. glass flasks and bottles, those which can be specially purchased from "home-brew" or other retail outlets and those recyclable after domestic use. One of the most useful of all of types lies in that last category - the used, plastic, fizzy drinks bottle.



These bottles are designed to contain dissolved gases as well as liquids. Unlike laboratory or other glassware they are unlikely to shatter dangerously on failure under pressure. They are cheap, and available with volumes which allow work at modelling scales. Again unlike glass, they tend to be of materials which prove reasonably convenient to work in order to provide the necessary openings in the finished vessel.

Such drinks containers come in a range of sizes and colours. The most useful tend to be of clear plastic with volumes between 1.5 and 2 litres. Dark, tinted plastic bottles such as those used to retail beers and ciders can also prove useful for certain applications. Many of the problems met in modifying such containers are of a relatively simple practical nature but these we found to have been neglected in some published accounts.

General tips

For anything other than the simplest batch fermenters for use in the lower school, ports which are reasonably leakproof for gases and liquids will be needed. Through these will be inserted instrument probes and air lines Possibly from others, samples of the culture under investigation will be withdrawn.

The provision of leak-free ports can be achieved fairly well using the methods outlined below. There are however limitations to such techniques and these, along with other constraints, bring a need to restrict the types of micro-organisms which may be used for such work (see the sub-section on "Microbiological Safety" below).

Ports

Figure 1 diagrammatically illustrates an example of a simple 1.5 to 2 litre bioreactor typical of the kinds used for work at S3 and upwards. (The system shown is a SSERC modified version of that suggested in published materials for use at Standard Grade.)

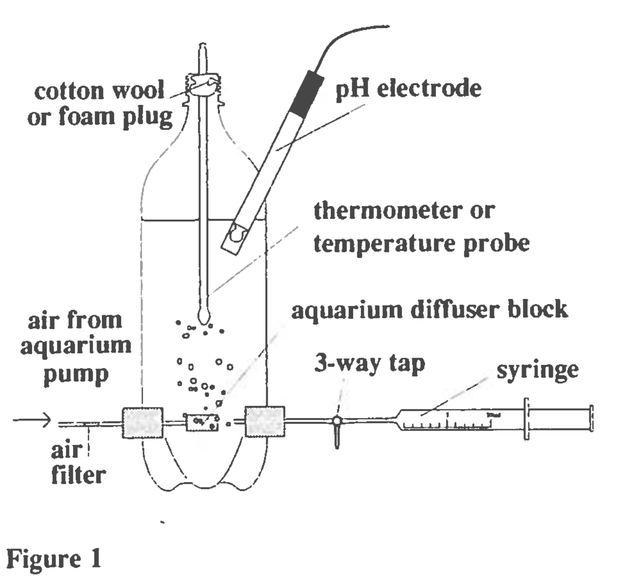


Figure 1

Making the holes

Convenient tools for making the necessary holes are metal cork-borers of the tubular type. Note though, that the end of a borer will first have to be heated before making the hole in the plastic. This heating may be done in a Bunsen flame. So heating a cork-borer will blunt its sharpened edge. The act of boring the hole may also deposit bits of melted plastic on and in the borer tube. A complete set of cork-borers does not come cheap. It is therefore wise to use an old set or to lay aside a few borers of the right sizes solely for this type of work with plastics.

It is also best not to overheat the borer since melting of the plastic may then be so rapid as to be difficult to control. More importantly, the plastic may not merely melt but may begin also to break down chemically and give off fumes of harmful monomers or of other toxic products. For this reason it is necessary to carry out the operation at least in a well-ventilated area or, more prudently, in a suitable fume cupboard.

Because the holes are formed by melting rather than drilling the plastic it is necessary to use a borer smaller than that normally intended for any bung of a given size. For example, a size 10 borer provides the correct aperture for a tight fit with a size 17 bung.

Sealing holes in the vessel

Although careful choice of borer and bung sizes will effect a reasonably tight fit in the vessel wall, we found that a secondary sealant was often necessary. In any case the sealant provides an additional insurance against even minor leaks.

We found that silicone-based aquarium sealants were effective in this regard. They also have the twin advantages of setting quickly and of being readily prised off with a knife, or other blade, to allow removal of bungs etc. before cleaning the vessel after use.

Representative samples

Some designs suggest the use of a single syringe for drawing off samples. Where the sample line has a long internal run in the vessel there will inevitably be trapped within it culture atypical of the general cell mass. This is termed a *dead* volume. There is then the possibility that samples will continually be being drawn from this area and that they will thus be unrepresentative of the body of the culture.

A simple way round this problem is to use a three-way syringe tap and two syringes. One syringe is used to first draw off the dead volume, the other then to take the actual sample. The first syringe is then emptied back into the vessel without detaching it from the tap. The second contains the *true* sample on which measurements are to be made.

Other considerations

Stability

The more ports and sample lines, the more likely it is that a fermenter vessel will get knocked over and the greater the chances of a gross spillage. Simple support, such as that given by retort stands and clamps, should be provided and the whole assembly stood within a large spillage tray. Given the types of organism likely to be grown in such simple bioreactors, this secondary containment is more a matter of convenience or of electrical safety than one of microbiological safety.

Siphoning and blockages

(i) Port positions

Any sampling ports should be carefully positioned so as to reduce the likelihood of siphoning, or of blockages from deposited sediment, or of taking unrepresentative samples because of inefficient mixing of cultures. Our experience shows that positions in the side wall of the vessel, at least one third of the way up from the bottom, are suitable. In some applications however other sampling lines may also be needed higher up the vessel.

(ii) Air lines and pumps

Several references describe the use of such simple bioreactors in the study of aerobic fermentations. Typically aeration is provided by means of an aquarium pump and air-stone diffuser (but see also "Specific Tips" below). Any such air pump must be positioned higher than the airline connection to the vessel. This is to prevent culture medium siphoning back into the pump mechanism - a messy and, in terms of electrical safety, potentially dangerous occurrence.

An alternative to an elevated pump position would be a one-way valve in the air-line. Inexpensive, commercial, one-way valves were once notoriously unreliable. Although they may have recently markedly improved in performance, many of them still suffer slight leaks and their use can lead to frustration. A carefully made SSERC pattern d.i.y. valve [5] is possibly a safer bet.

Depending on the organism in use, it may be prudent to fit such an air-line with a sterile filter. It should rarely, if ever, be necessary at elementary levels to use a commercial microbiological filter. One of sterile, non-absorbent cotton wool might be needed but care should be taken to see that it does not get contaminated by siphoned deposits and so block the air-line.

Microbiological safety

The need for leakproof ports, the possible use of sampling lines and the difficulty of completely sterilising the plastic vessels all mean that limits must be set on the kinds of micro-organisms which may be employed for this work.

Generally, ordinary yeast *(Saccharomyces cerevisae)* would be the preferred organism. For some of the work the use of a culinary bacterium such as *Lactobacillus* sp. and a lactose based medium could well be acceptable.

The material of the vessels suggested means that, except for media and ancilliary equipment, sterilisation by heat will be ruled out. Chemical disinfection of the vessel will be required. That in turn will prevent the use of such plastic vessels for organisms and in processes where sterile conditions are essential.

Given teacher expertise and facilities suitable for more demanding work, then use of other organisms such as *Vibrio (Beneckea) natriegens* or *Gluconobacter* sp. could be justified for senior pupils on CSYS courses or other project based activities. Consideration would have to be given however to the use of a heat-sterilisable glass container for at least the bioreactor part of the system.

A batch fermenter for Standard Grade

Topic 7 "Biotechnology" of Standard Grade Biology requires pupils to set up a simple fermenter. The biotechnology optional topic of Standard Grade Science involves similar pupil activities.

A d.i.y. vessel may well be used, in preference even to a simple commercial system, since the former allows for work at a pupil pair scale whereas the latter will mean at best a "stations approach" or even a teacher-centred demonstration activity. Indeed the Pupils' Workcard G2 in the National Examplar Materials [2] for the sub-topic "Living Factories" describes just such usage of plastic, lemonade bottles.

The system as illustrated therein (see Fig.1 - a *SSERC modified version*) is fairly easily constructed, but teachers and technicians may find the alternative list of parts given below, and the minor practical points which follow, useful:

Parts, consumables, tools list

Parts:

1.5 litre clear plastic, carbonated drinks bottle
Hoffman (screw) clips (2)
liquid-in-glass thermometer, 300 mm, 0 to 100°C max.
 range, preferably spirit filled
aquarium air stone or
 Pasteur pipette (air line entry restrictor)
glass tubing, 5mm o.d.
rubber tubing to fit 5 mm o.d. glass tube
rubber bungs, size 17 for ports, and
 size 3 to take pipette air line restrictor
non-return valve (optional)
aquarium pump (diaphragm type)
3-way syringe tap (optional)

Materials:

non-absorbent cotton wool
silicone based aquarium or bath sealant (clear)

Clinistix test strips
yeast (DCL "Active" dried is particularly recommended)
meta-bisulphite or chlorine based disinfectant

Tools & safety items:

cork-borers, sizes 2 & 10 for heating and boring holes
glass tubing cutter or glass knife
file
Bunsen burner
other sizes of cork borer for sleeving glass tubing
 prior to insertion into bungs etc.
eye protectors

Specific tips

The diagram in Workcard G2 shows the thermometer entering the vessel through a side port. This could result in breakage of the thermometer in the not unlikely event of the fermenter being knocked over. A better arrangement is for it to enter the top aperture with non-absorbent cotton wool as packing. This cotton wool plug should hold the thermometer reasonably firmly but be sufficiently loose as to allow proper venting (see Fig.1).

The same workcard also suggests the use of size 15 rubber bungs in apertures cut with a size 10 borer. Size 17 bungs should be substituted, since the smaller size originally recommended is too easily pushed out of a size 10 hole. Note that these combinations are only suggestions and that modifications can be made so as to suit others which may be equally effective (see General Constructional Hints above).

Where an aquarium air stone is used as a diffuser in the aerobic culturing of yeast and some other organisms, there is a tendency for the cells to invade the interstices of the stone. It then becomes less and less efficient and may even block entirely. Such contaminated air stones prove difficult to clean.

A Pasteur pipette used as an air flow restrictor gives a stream of smaller bubbles than a plain glass tube and more efficient aeration of the culture. It thus provides a useful alternative to the air-stone. Technicians or teachers should make such pipettes and should also be responsible for inserting glass tubing into holes in bungs. Note our recommendation on the use of the well known technique of employing a cork borer to both open up the bung aperture and sleeve such tubing on insertion, thus protecting the hands against serious cuts should the glass shatter.

In much of this work there is also a forseeable risk of injury to the eyes. The use of eye protection is therefore mandatory.

Using the batch fermenter

Readers are referred to the Exemplar Materials for Standard Grade Biology Topic 7 "Biotechnology" [2] for further detail.

Modelling biochemical engineering problems

Part III of this series of articles is to be published in Bulletin 168. It will give similar practical tips but be based on further development work by Centre staff on topics such as models of continuous fermentation systems and tower fermenters.

References

1. "Fermenters - Part I", SSERC, "Equipment Notes", Bulletin 166, June 1990.
2. "Biotechnology", SCCC in association with Strathclyde Regional Council, Standard Grade Biology Exemplar Materials, 1989.
3. "Practical Microbiology and Biotechnology for Schools", P.Wymer, Macdonald Educational, 1987, ISBN 0 356 11566 6.
4. "Biotechnology - A Resource Book for Teachers", J.Dunkerton and R.Lock, ASE Occasional Paper, 1989, ISBN 0 86357 1115.
   (Highly recommended in the context of this Bulletin article.)
5. "Biology Notes", SSERC, Bulletin 133, November 1982, page 8.

Further practical work to underpin Newton's Laws of Motion

Evidence of forces and of inertia can be found through studying, in photographs, the appearance of bodies undergoing a traumatic force.

The construction and use of a propeller driven trolley is described. This apparatus can be used to demonstrate the effects of Newton's three Laws of Motion.

Preamble

These two short articles continue the series begun in Bulletin 166 to modify the corpus of practical work associated with Higher Grade Physics.

Experiment 1: Evidence of forces and inertia using high speed flash photography

Purpose

The reinstatement of the third S (Frontcover) which used to adorn our name may be puzzling you. Have we flipped our lid again? Or will our next issue carry another grovelling admission of a mistake? (Undoubtably it will!) The purpose is oblique. It's there as an example of that useful pedagogical technique to arrest your pupils' attention - pretend to flip your lid - like smashing light bulbs.

There are many ways of trying to illustrate concepts.

How might it not be done? As evidence of the force of reaction between a body and the ground on which the body sits, you could press down on, say, a football and ask your pupils to observe the flattening which takes place at the parts in contact with the ground. The compression which causes this flattening is evidence that the ground exerts an upward force on the ball.

Far more dramatic is to take a high speed photograph of a light bulb resting on a bench while the bulb is being smashed with a hammer. The photograph is used as a stimulus to think about the forces which exist between the hammer and bulb, and bulb and bench top. It is also there as an aide memoire - something for pupils to return to, to recap, or reassess, their earlier concepts.

Procedure

In the series shown (Fig.1), five bulbs were bought and separately labelled with our initials, SSERC. Each in turn was placed on a bench and photographed being hit with a light hammer. The cardboard squares found round the necks of the bulbs when boxed were retained to prevent rolling.

The photographs were taken in a darkroom, but could probably also have been taken in a laboratory which has very good blackout. Black paper was placed on the bench top and over the back wall. Two persons were required, one to hit the bulb and the other to operate the camera.

A fast black and white film, Ilford HP5, which is 400 ASA, was used with the shutter on manual and the aperture at f16, This was the aperture setting specified by the flash unit, which depends on both the distance and film speed.

Before blacking out the room, the camera, supported on a tripod, was focused on the object. On switching off the lights and counting up to six the shutter was opened on five and the bulb struck on six. The shutter was then immediately released. The flash was triggered by a circuit similar to that which appeared in Volume One of the Standard Grade Physics Technical Guide [1] and discussed below. The microphone was sited about one metre from the bulb, being fastened by Blutac to a wall at that distance. The leads between the microphone and trigger circuit were found to be susceptible to mains pickup and needed to be protected. Either a twisted pair, or screened coaxial, would be suitable.

The presence of faint secondary images (Fig.1) indicates that multiple flashes can occur.

Trigger circuit

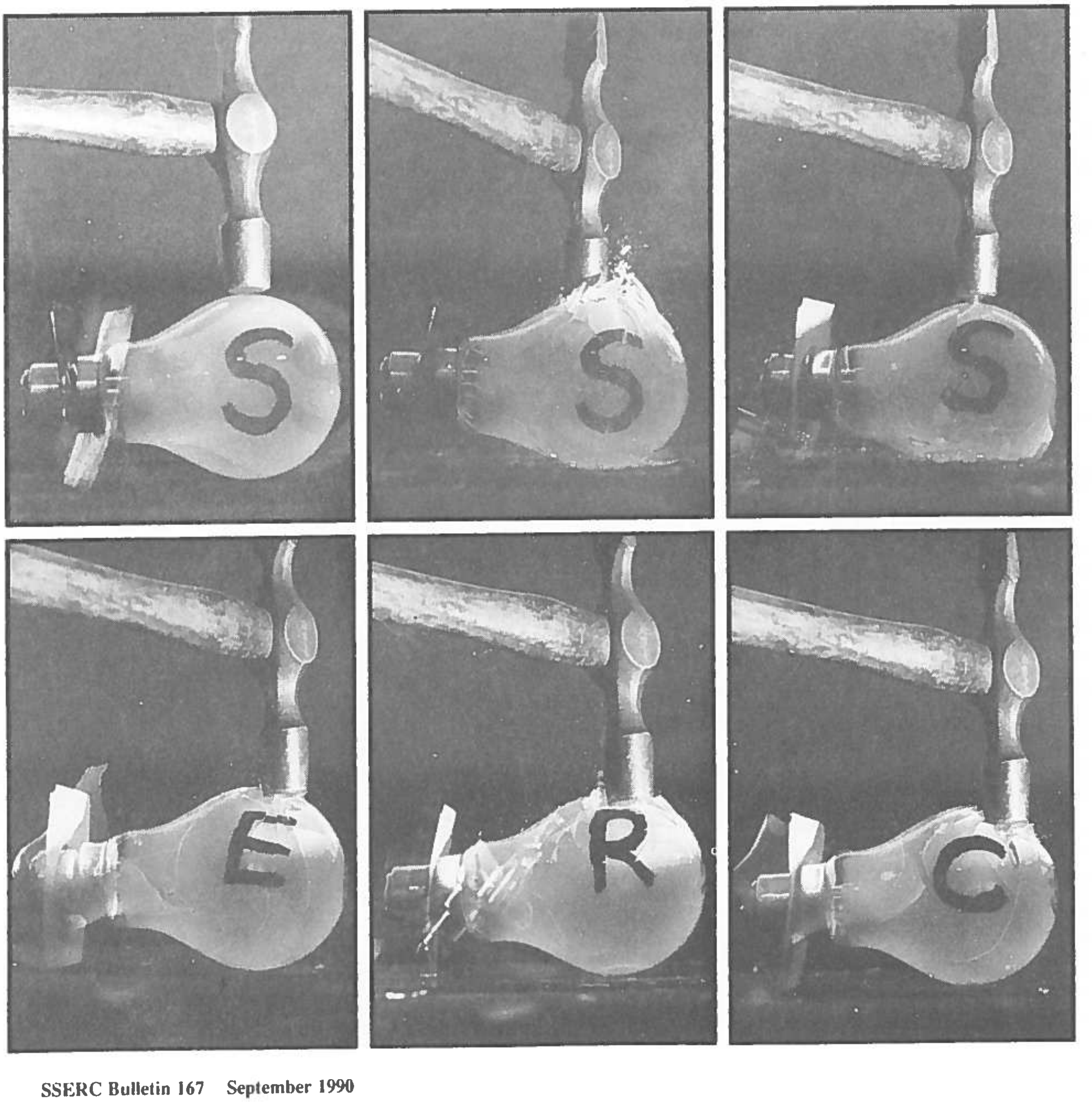
The sound-operated flash gun circuit described on pages 8 and 9 of the Technical Guide [1] should be quite sensitive enough to operate off retorts caused by the bursting of a balloon, or lightbulb. For retorts of lower volume, such as caused by the sound of a rubber ball hitting a benchtop, a more sensitive circuit is required. The one given here has been adapted from one published in The Physics Teacher [2] (Fig.2).

Discussion

There is evidence for several forces in Figure 1, namely a downward force exerted by the hammer on the bulb, an upward force exerted by the bench on the bulb, and, in the first photograph, an upward force exerted by the bulb on the hammer. Clearly, in this photograph, the hammer is rebounding.

Not all these forces are exhibited on every photograph. This suggests that there is a need to take several photographs to gather in the evidence you might be looking for.

Fig.1 - Evidence of forces



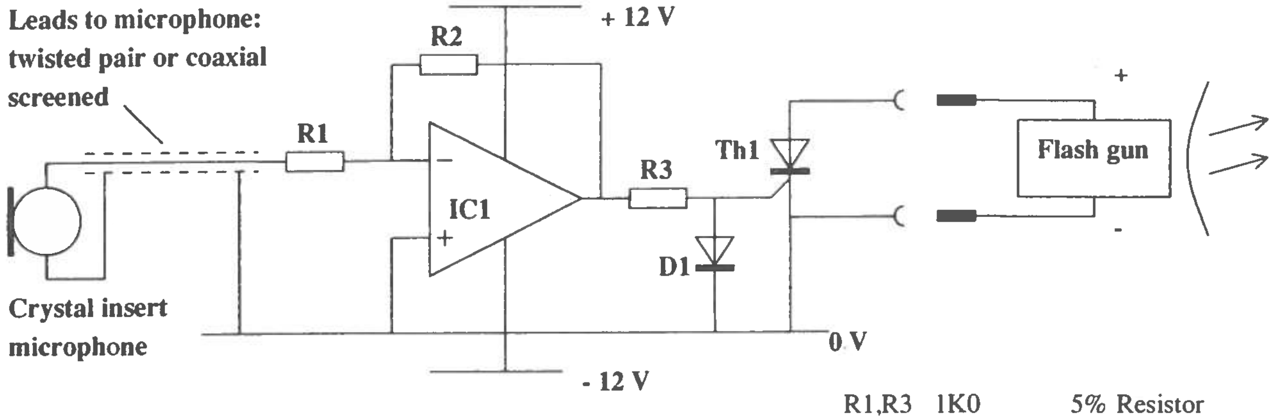


Fig.2 - Flash gun trigger circuit of high sensitivity

R1,R3	1K0	5% Resistor	
R2	1M0	5%	
IC1	741	Op-amp	RS 305-311
D1	1N4148	Diode	RS 271-606
Th1	TIC106M	Thyristor	RS 649-431

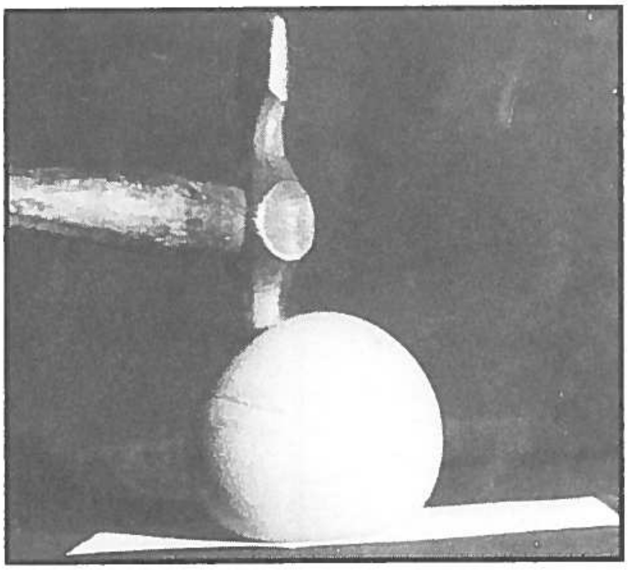


Fig.3 - Evidence of inertia

The property of inertia can be identified through the photography of bursting balloons. Whether air or water filled, the photograph usually reveals that most of the fluid within the ruptured balloon has retained its original shape for some period after the onset of rupturing.

The features observed when the hammer struck a rubber ball (Fig.3) were initially puzzling. Apart from the flattening of the base, readily explained by the upward force exerted on the ball by the bench, why does the head of the hammer tunnel into the ball leaving the general spherical profile on the ball's north pole unchanged? This again is presumably evidence of inertia.

And finally, why the treble S in our name? The failure of the first blow to break a bulb, and being the first bulb it bore an S, is the cause of our lapse to our bad old ways!

Experiment 2: Using a propeller driven trolley to illustrate Newton's three Laws of Motion

Construction

A motor with either a 2 mm or 3 mm diameter spindle should be mounted on a dynamics trolley (Fig.4). For the purpose of this demonstration, this end of the trolley will be called the front, the trolley being able to move one way only. The motor was supported by two plastic struts each 250 mm long. Many materials would suffice for struts. We used lengths of plastic chip carriers, finding that their complex, folded cross-section gave them considerable strength. The bottom ends of each strut were screwed to opposite sides of the trolley and the top ends drawn together with parcelling tape to form an apex. The motor was mounted within the embrace of the apex and secured with several turns of parcelling tape.

The propeller was constructed using parts from the Opitec aircraft propeller set made by the East German company, Durr Technik. Our trolley, a massive 1.4 kg, required a six bladed prop to drive it. This comprised two hubs (part 755) bolted together, and six blades (part 756). A three bladed prop ought to suffice with a less massive trolley. The central hole on the hub has a diameter of

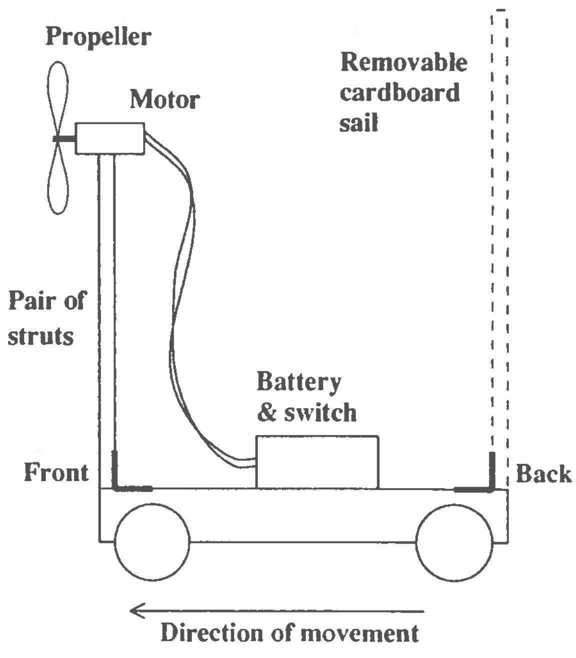


Fig.4 - Propeller driven trolley

1.9 mm at one side, and 2.9 mm at the other, and therefore fits the spindle of many types of small motor. Our choice of motor was surplus item 627. It was battery driven, two PP3s giving 18 V in our case, the batteries being mounted on the trolley. An s.p.s.t. toggle switch was added to switch current on and off.

At the time of printing, surplus item 627 is almost completely out of stock. Item 735 would be a suitable substitute. As its nominal maximum supply voltage is 6 V, don't put more than 9 V across it.

The sail measured 300 mm by 300 mm comprising two sheets of cardboard held together with parcelling tape. There was no tape over the bottom edge so that the sail could be quickly mounted on the trolley by slipping it over a bracket, the upright flange of which slotted between the double cardboard sheets. This sail-fastening bracket was mounted at the back of the trolley. The upright flange of the bracket measured about 60 mm high by 100 mm long.

The trolley is therefore driven from the front by its propeller, or fan. If placed on a horizontal surface it will be seen to accelerate. If the sail is raised while it is stationary, it will remain stationary. If the sail is raised while it is accelerating it will gradually decelerate because of frictional forces.

Classroom usage

It is suggested that the propeller driven trolley is demonstrated by the teacher. The demonstration might proceed as follows:

1. Let the trolley, minus its sail, accelerate from rest on a horizontal surface. The need to identify the external force causing the acceleration brings in the reaction to the thrust of the propeller on the air, namely, the thrust of the air on the propeller, and so Newton's Third Law. We therefore have both Newton 2 and 3.

2. Fit the sail on the trolley whilst it stands at rest and switch on the fan. The fact that it remains at rest brings in Newton's First Law. The sail can also be fitted on the trolley while it's moving, causing the forward acceleration to cease. (Unfortunately even if frictional forces on the bearings of the trolley's wheels are negligible, the large sail area will almost certainly retard its movement. The achievement of constant velocity is sadly unattainable, but the deceleration is really rather slight, and can be overlooked.)

There are two ways of analysing this. If we consider the trolley to be affected by two external forces - the thrust exerted in the forwards direction by the air on the propeller, and the thrust exerted in the backwards direction by the air on the sail - these forces are balanced and we have an acceleration of zero. If, however, we consider the trolley and its surrounding air to be one body, the motor in the trolley is thrusting against the sail with a force equal to that which it exerts on the thrust block it bears against, i.e. the struts on which it is mounted. The trolley doesn't accelerate because there's no external force. It's a similar problem to the man who pushes his motor car while sitting in the driving seat - he, too, can't get his car to move.

This second case, the trolley with its sail hoisted, therefore brings in Newton 1 and 3, and, indirectly, Newton 2.

Acknowledgements

The idea for using high speed flash photography to study forces and inertia came from a recent article in The Physics Teacher [2]. The idea of using a propeller driven trolley with sail came from Project Physics [3].

References

1. Technical Guides, Standard Grade Physics, Volume 1, SSERC 1988, pages 8-9.
2. Western A B and Archibald J H, 1988, An inexpensive acoustic trigger for dramatic flash photographs, The Physics Teacher, 26, pages 464-465.
3. Project Physics, Unit 1, 1982, Holt, Rinehart and Winston, D16-22, page 38.

Errata (Bulletin 166)

We are sorry for the confusion and nuisance these mistakes in Bulletin 166 may have caused.

A bi-directional motor driver

Figure 2 was wrongly repeated as Figure 5 (page 23) and the correct figure missed out. Figure 5 should have appeared as shown (right).

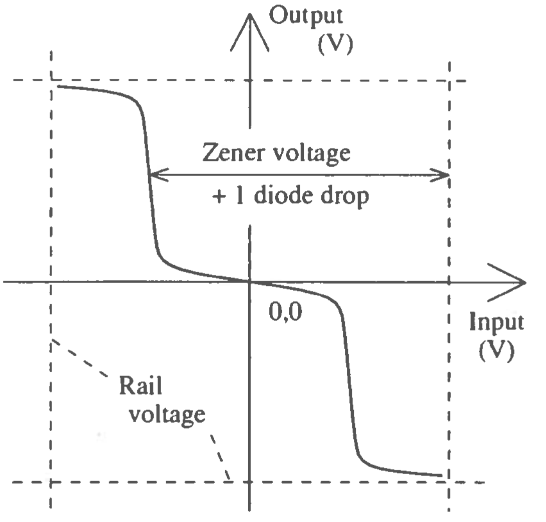


Fig. 5 - Pull-push amplifier characteristics

An op-amp power supply

Despite telling you to watch out for the difference in pin-outs of the positive and negative regulators (page 21), we ourselves managed to mis-label the negative regulator's pins! The correct labelling is shown (below right).

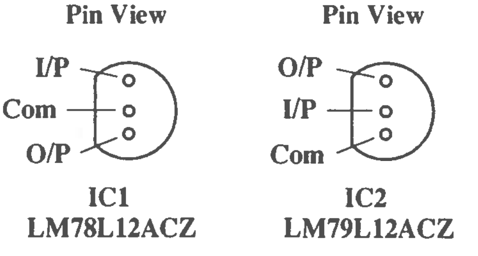


Fig. 2 Pin-outs of Regulators

MTS Fermenters

Equipment Notes carried a review of three fermenters including one from the Kilsyth company, Microprocessor Training Systems (MTS) (pages 29-35). Unfortunately we gave the wrong telephone number. Their correct number can be found in the address list of this issue of the bulletin.

Gas collection and d.i.y. electrodes revisited

Omitted from this article on gas collection (pages 28-29) were two methods of stoppering the tube which had just been filled with gas evolved from the electrode. These methods obviate the need to place a finger under the surface of the electrolyte - a good COSHH control. Both are self explanatory from the diagrams. In fig. 3, a one-holed bung is supported on a handle fashioned of either glass or plastic tubing. If slight contamination of the electrolyte is of no concern the aluminium cover shown in fig. 4 can be used.

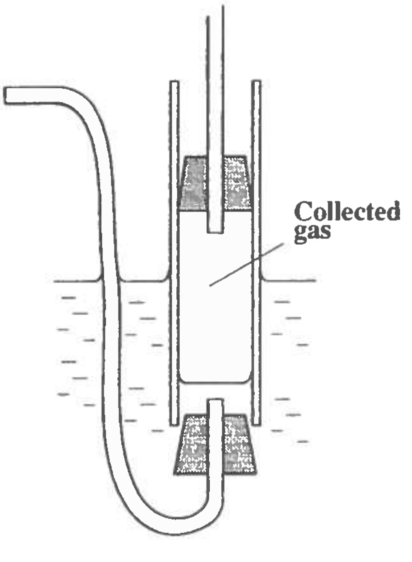


Fig. 3

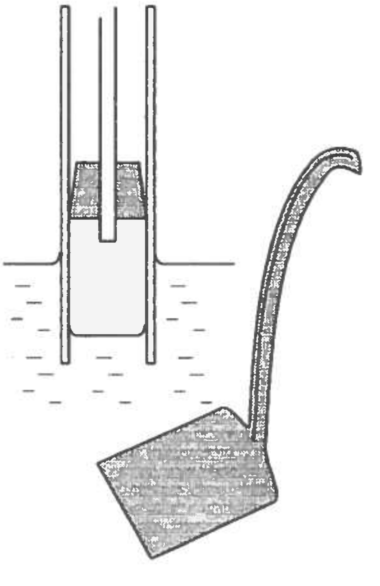


Fig. 4

EQUIPMENT NOTES

Digital multimeters

Scope of report

There has never been a better time to buy digital multimeters. Prices are tumbling, facilities are being enhanced, physical and electrical robustness are improving, they are staggeringly accurate, and through better design are becoming easier to work with.

In this survey, the first we have published in the Bulletin since 1986, the thirteen meters reported on are all considered to be good buys. Some were found to be less good than others, but none were found to have critical deficiencies.

There are very many multimeters on the market and which to choose for evaluation was quite a problem. We set three criteria. Firstly we only selected meters which we thought that schools were likely to buy. Secondly we only looked at the cheaper meters on offer, but included in the exercise a few costing more than £50 to assess whether it is worth spending this sort of sum. And thirdly, bar one exception, only meters with separate terminals for current and voltage were included. The reason for this third factor is explained below.

Nuisance fusing

There have been many reports to the Centre of nuisance fusing of the fuse which protects the milliamp current ranges on multimeters. Investigating these reports we have failed to find any technical defect in the meters about which the reports were made. We conclude that the cause can only be the short-circuiting of a power supply with meters that are switched to measure current. This might either be through attempting to measure voltage, but mis-switching the meter so that it actually measures current, or attempting to measure current, but mis-positioning the meter so that it short-circuits resistors.

We then noticed that all the meters about which we had received such complaints had a common terminal for voltage and milliamps. No one had complained about meters with separate current and voltage inputs. The reason could be that it can sometimes take a compound fault to fuse meters with separate inputs. Or it might be that when the meter is transferred from measuring current to measuring voltage, or vice versa, the necessary rewiring is a sufficient prompt to prevent too many instances of accidental abuse.

For these reasons, and until we get evidence to the contrary, we advise you not to purchase multimeters with a common input for voltage and current.

Test reports

The findings of the tests are shown in Table 1. The comments used in the table (good, poor, etc.), and the cryptic codes are defined in the following text.

Accuracy

Tests for accuracy against laboratory standards were made for the physical quantities of voltage (d.c. and a.c.), current (d.c. and a.c.), resistance, frequency and temperature that the multimeters were capable of measuring. Every range was tested. If the accuracy on a range was found to comply with the manufacturer's specification the *Accuracy* column is marked '∘'. If any ranges were found not to comply with specifications then the mark 'ε' is made.

Tests on other physical quantities, capacitance, inductance, h_{FE}, and the diode test, were also carried out, but less rigorously than on the quantities above. Any evidence that the meters are not complying with specified accuracies are signified by the out-of-specification symbol 'ε'.

Few instances were found where specifications were not met.

Over-current protection

All the meters surveyed had two separate electrical inputs for currents. The low current terminal leads to shunts for the lower ranges up to, in most models, 200 mA. These shunts are protected by a fuse: it is improbable that they could be damaged. But the high range shunt, usually it's on a 10 A range, is unprotected by a fuse. These high current shunts were tested by applying a 12 A current for a period of 60 s. All the meters were found to be capable of withstanding this treatment without adverse affect.

It is unlikely that a pupil might have access to a power source that could supply a current greater than 12 A. Both nickel-cadmium and lead-acid cells have that capability, but the resistance of leads and the contact resistance of connections will reduce the risk of damage. Damage to multimeters caused by over-current is therefore improbable.

Two meters included in the survey were designed to measure currents of up to 20 A.

Functions

The fundamental function on multimeters is the measurement of d.c. voltage, but most users would also probably regard current and resistance measurement as essential features. The facility to be able to measure a.c. as well as d.c. is vital in some curricular areas, but unimportant in others (Table 2).

Most meters provide diode tests, but there is no standardisation of such tests. Many meters include a facility to measure the h_{FE} transistor parameter.

Other physical quantities that some multimeters measure include frequency, capacitance, inductance and temperature. No meter we looked at could measure all of these quantities, so some mixing in purchase is probably necessary to get a reasonable spread of facilities.

Ranges

Most ranges increment by a decade geometric progression. Many multimeters suffer from gaps in this progression, e.g. 200 µA, 20 mA, 200 mA and 10 A. Watch out for these because such a multimeter will then be incapable of attaining the precision of coverage across the several orders of magnitude its specification might claim to reach. Table 1 shows where gaps in the standard progression occur.

Very few multimeters have a 2 A range on current.

If a meter had a range which did not match with the standard given at the edge of Table 1 then its upper limit appears in numerals in that table.

Range selection

The market has swung away from autoranging meters to models with manual switching. Autoranging does help young users avoid selecting an inappropriate range, but is confusing if the units are not also shown on the LCD display, or if the reading tracks through from one scale to another, say millivolts to volts, or from reading to a precision of 1 mV to 0.01 V.

For these reasons, and because of the excellently clear markings which appear on most range selection switches, manual, rotary type switching is recommended.

Two snags which can occur with rotary switches, and as far as we can gather are uncommon, are (1) loss of registration between the pointer and marking, and (2) contact resistance or switch breakage.

Input impedance

The meters tested were all found to have similar input impedances (measured at d.c.). On voltage, whatever the range, the input resistance is 10 MΩ. In many applications this is sufficiently large to have a negligible influence on the voltage being measured. But note that this is not always true.

When current is being measured, the input impedance is dependent on the shunt resistance, and therefore range:

Range	Input impedance
200 µA	1 kΩ (not exact)
2 mA	100 Ω
20 mA	10 Ω
200 mA	1 Ω
2 A	100 mΩ
10 A	20 mΩ

Shunt resistances of multimeters are not widely dissimilar to those found on analogue ammeters.

It is commonly asserted that multimeters are superior to analogue meters because they do not affect the quantity being measured. This, in general, is quite untrue. Only if the p.d. across a resistor of low resistance, or e.m.f. across a source of low internal resistance, is being measured does the meter have an insignificant effect on the measurand.

The impedance of multimeters does matter, and should always be borne in mind when using them.

Battery and battery current

One meter in our survey is powered off two AA size alkaline cells. We have found from experience that this type of source has an exceedingly long life. The other multimeters were powered from 9 V PP3 batteries. The capacity of a good quality, non-rechargeable, alkaline PP3, such as Duracell, or Ever Ready 'Gold Seal', or RS, is 500 mAh, whereas of a rechargeable nicad, 110 mAh. These capacities, and the operating currents shown in Table 1, should indicate the number of operating hours you might expect to get.

What size of current do multimeters draw? Most meters surveyed drew less than 3 mA, and we found one that operated off less than 1 mA. We also found that, in general, meters with a large number of functions had a higher than average battery current. One meter with lots of functions drew 13 mA. This was the largest battery current we found.

Meters marked 'auto power down' in Table 1 switch off power to their display when the quantity they are measuring does not vary for a certain period. This is a desirable facility because it helps to conserve battery life.

Display

All the meters looked at have $3^1/_2$ digit displays reading to 1999 maximum.

The height of the LCD numerical characters is shown in Table 1. The height most commonly found for some years has lain around 10 or 12 mm, but several new meters have display heights which are much greater - 20 mm even, and coupled with better contrast are therefore easier to read.

Those meters which show the physical unit of the measurand on the LCD display can be identified from Table 1 by the letter 'u' appearing after the display height.

Markings

A comparative assessment of the markings on the switches and terminals of multimeters has been made. Some meters were not so clearly marked as others. In general, those multimeters with lots of ancillary functions were less clearly marked than those with just the basic functions.

Mechanical robustness

All the meters looked at appeared to be suitably robust for classroom usage.

Best buys?

Curricular factors have a bearing on what constitutes the best buy. These factors are assessed in Table 2. This rates the usefulness to each subject of being able to measure each physical quantity.

Model		Beckman DM10	Beckman DM77	Cirkit TM5315B	Cirkit TM5365	Cirkit TM135	Goldstar DM6133	Goldstar DM7333	Rapid 210	Rapid 310
Supplier		Tait	Tait	Cirkit	Cirkit	Cirkit	Alpha	Alpha	Rapid	Rapid
Stock number		DM10	DM77	56-05315	56-05365	56-00135	DM6133	DM7333	85-0677	85-0710
Voltage d.c.	200 mV	∘	∘	∘	∘	∘	∘	∘	∘	∘
	2 V	∘	∘	∘	∘	∘	∘	∘	∘	∘
	20 V	∘	∘	∘	∘	∘	∘	∘	∘	∘
	200 V	∘	∘	∘	∘	∘	∘	∘	∘	∘
	1000 V	∘	∘	∘	∘	∘	∘	∘	∘	∘
Voltage a.c.	200 mV				∘	∘	∘	∘		∘
	2 V		∘		∘	∘	∘	∘		∘
	20 V		∘		∘	∘	∘	∘		∘
	200 V	∘	∘	∘	∘	∘	∘	∘	∘	∘
	750 V	500 V	600 V	∘	∘	∘	∘	∘	∘	∘
Current d.c.	200 µA	∘		∘	∘	∘			∘	∘
	2 mA	∘			∘	∘	∘	∘	∘	∘
	20 mA	∘		∘	∘	∘	∘	∘	∘	∘
	200 mA	∘	∘	∘	∘	∘	∘	∘	∘	∘
	2 A						∘	∘		
	10 A		∘	∘	∘	∘	∘	∘	∘	∘
Current a.c.	200 µA				∘	∘				∘
	2 mA				∘	∘	∘	∘		∘
	20 mA				∘	∘	∘	∘		∘
	200 mA		∘		∘	∘	∘	∘		∘
	2 A						∘	∘		
	10 A		∘		∘	∘	∘	∘		∘
Resistance	200 Ω	∘	∘	∘	∘	∘	∘	∘	∘	∘
	2 kΩ	∘	∘	∘	∘	∘	∘	∘	∘	∘
	20 kΩ	∘	∘	∘	∘	∘	∘	∘	∘	∘
	200 kΩ	∘	∘	∘	∘	∘	∘	∘	∘	∘
	2 MΩ	∘	∘	∘	∘	∘	∘	∘	∘	∘
	20 MΩ			∘	∘	∘	∘	∘	∘	∘
	2 GΩ				∘	∘				
Frequency	2 kHz				∘					
	20 kHz				ε			∘		
	200 kHz				ε			∘		
Capacitance	2 nF				∘	∘		∘		
	20 nF				∘	∘				
	200 nF				∘	∘		∘		
	2 µF				∘	∘				
	20 µF				∘	∘		ε		
	200 µF									
Inductance	2 mH									
	20 mH									
	200 mH									
	20 H									
Temperature						∘				
Common V & I terminals		no	no	no	no	no	no	no	yes	no
Battery type		PP3	2 x AA	PP3	PP3	PP3	PP3	PP3	PP3	PP3
Battery current (mA)		1.5	1.3	2.2	3.5	3.4	1.8	1.7	1.3	0.8
Auto power off										
Display height (mm)		12.5	10 u	12.5	12.5	12.5	12.5	17 u	11	16 u
Range selection		manual	auto	manual	manual	manual	manual	manual	manual	manual
Markings		good	excellent	confusing	confusing	good	good	good	good	excellent
Enclosure colour		cream	cream	yellow	yellow	yellow	dark grey	yellow	yellow	yellow
Price (£)	1+	32.50	39.10	17.38	32.96	39.96	36.95	64.70	15.90	21.80
	5+			16.95	32.13	38.96	34.95	61.20	15.30	20.60
	10+			16.52	31.33	37.98			14.70	19.50
	25+								13.80	17.20

Table 1 - Digital multimeter survey

	Rapid 320	Rapid 330	RS IDM91	RS IDM 93
	Rapid 85-0715	Rapid 85-0720	RS 253-585	RS 253-591
200 mV	∘	∘	∘	∘
2 V	∘	∘	∘	∘
20 V	∘	∘	∘	∘
200 V	∘	∘	∘	∘
1000 V	∘	∘	600 V	∘
200 mV	∘	∘	∘	∘
2 V	∘	∘	∘	∘
20 V	∘	∘	∘	∘
200 V	∘	∘	∘	∘
750 V	∘	∘	250 V	250 V
200 µA	∘	∘	∘	∘
2 mA	∘		∘	∘
20 mA	∘	∘	∘	∘
200 mA	∘	∘	∘	∘
2 A				
10 A	∘	∘	20 A	20 A
200 µA	∘	∘	∘	∘
2 mA	∘		∘	∘
20 mA	∘	∘	∘	∘
200 mA	∘	∘	∘	∘
2 A				
10 A	∘	∘	20 A	20 A
200 Ω	∘	∘	∘	∘
2 kΩ	∘	∘	∘	∘
20 kΩ	∘	∘	∘	∘
200 kΩ	∘	∘	∘	∘
2 MΩ	∘	∘	∘	∘
20 MΩ	∘	∘	∘	∘
2 GΩ				
2 kHz	∘	∘		∘
20 kHz	∘	∘		∘
200 kHz	∘	∘		∘
2 nF		∘		∘
20 nF	∘			∘
200 nF		∘		∘
2 µF	∘	∘		∘
20 µF		∘		∘
200 µF	∘			
2 mH		∘		
20 mH		∘		
200 mH		∘		
20 H		∘		
	∘	∘		
	no	no	no	no
	PP3	PP3	PP3	PP3
(mA)	3.2	13	2.3	3.4
	yes	yes	yes	yes
(mm)	16 u	16 u	20	20
	manual	manual	manual	manual
	good	good	good	good
	yellow	yellow	yellow	grey
1+	35.50	38.90	55.00	65.00
5+	33.80	36.80	53.63	63.38
10+	31.80	34.60	52.25	61.75
25+				

Technological Studies and Electronics

The main requirement is for a meter that measures d.c. voltage, d.c. current and resistance, for which the 210 from Rapid Electronics appears, at first sight, to be the best buy except that it has a common terminal for current and voltage. The TM5315B from Cirkit is quite a good substitute, but the unit markings of its range selection switch are placed so close to its terminals as to be confusing. The 310 from Rapid is therefore a better buy. We suggest that for every five of these meters, you purchase one model that also measures a.c., frequency and capacitance. A good choice for this supplementary meter is the 320, again from Rapid. The TM5365 from Cirkit also might suffice, but suffers from a crowded group of markings, some of which were found to be ambiguous, and is therefore not so highly thought of.

Chemistry

Measurement of a.c. and d.c. current and voltage is the main need. Here the best buy seems to be the 310 from Rapid Electronics.

If you are looking for a multimeter that also measures temperature, the 320 from Rapid, which, with a type K probe, claims to be able to measure up to 1370°C - a claim whose accuracy at high temperatures we have not substantiated - is worth considering. It is, we think, superior to the TM135 from Cirkit, which reads to 750°C, or the 330 from Rapid, which has a diode sensor, reads to 150°C with a resolution of 0.1°C, and guzzles batteries. However the complexity of functions on such meters is confusing. A single function electronic thermometer, or even a liquid-in-glass instrument, is preferable to a temperature reading multimeter for general work up to 110°C (see Bulletin 164 for buying advice). Only for high temperature readings, between say 100°C and 1000°C, is a temperature reading multimeter with type K probe recommended.

Physics

Measurement of a.c. and d.c. current and voltage, and also resistance, are the main needs, for which the 310 from Rapid Electronics offers excellent value. We suggest that for every ten basic meters purchased you buy a meter that additionally measures frequency and capacitance. For this, the 320 from Rapid seems to be your best bet. Measurement of temperature is probably best carried out by other means.

A specialised need in the revised H Grade Physics course is for the measurement of the resistance of semiconductor materials. Some materials have a resistance higher than 10^7 Ω, which can be measured on the 2 gigohm range that a few multimeters have. Of the two in our survey with this facility the Cirkit TM135 is our preference. Another meter with this facility - not included in Table 1, but which we have nonetheless evaluated and think highly of - is the Beckman DM25L, which is stocked by both Tait Components and RS (254-005, £69.00).

	Vdc	Vac	Idc	Iac	R	f	C	L	T
biology	1	3	2	3	2	3	3	3	2
chemistry	1	1	1	1	3	3	3	3	2
electronics	1	2	1	2	1	2	2	3	3
physics	1	1	1	1	1	2	2	3	2
science	1	1	1	1	2	3	3	3	2
technology	1	2	1	2	1	2	2	3	3
technician service	1	1	1	1	1	2	2	2	3

Key : 1 = essential; 2 = useful; 3 = unimportant

Table 2 - Measurement requirements across the curriculum

Biology

A meter with a small number of functions, but able to read d.c. voltage, is required. A good buy is the 310 from Rapid. Do not buy a multimeter with a temperature range especially to measure temperature as the markings and features of such meters are complex, and they are unlikely to be sufficiently accurate or precise across the chief range of interest, namely 0°C to 40°C.

Science

Measurement of a.c. and d.c. current and voltage, and probably also resistance, are the requirements. The 310 from Rapid would be an excellent choice of meter.

Technician

A basic meter, such as the 310, supplemented by one with lots of specialised functions, perhaps the 330, both from Rapid, would seem to be required for work at extra low voltages and on dead equipment. However the use of a multimeter on live[1] mains equipment is not recommended because it is too easy to mis-set a multifunction instrument. Both the detection and measurement of high voltage should only be carried out with specialised, single-function instruments which are simple to work with. These instruments should be used with specialised test leads having shrouded terminals, robust and flexible insulated leads, finger barriers, HBC fuses and current limitation. Recommendations on such equipment lie outside the scope of this article.

Extra robust

We have already written that all the meters examined seemed to be suitably robust, electrically as well as mechanically, for the rough and tumble of life in school. But two meters stood head and shoulder above the rest - IDM91 and IDM93, both from RS Components - as being extra robust. They are certainly worth considering.

Addendum

Since this article was written it has come to light that some digital multimeters do protect the 10 A range with inaccessible fuses. One such meter is the Beckman DM77.

[1] Your employer may not allow you to carry out tests and measurements on live mains equipment. Our discussion of competency on pages 5 and 6 of this issue of the bulletin is pertinent.

Trade news

Pipette fillers

At a recent interfacing workshop we found that some teachers were interested in the pipette fillers used for setting up a reaction kinetics experiment. The Bel-art Pipette Pumps which we were using are available from many of the standard suppliers at prices ranging from £5.04 to £9.92. The cheapest source found is Radleys, but they operate a minimum order charge of £30. To test the potential market we have purchased a few of two sizes and these are available from SSERC Surplus at the prices shown (item no. 728, please specify size).

These pumps are colour coded for size and give a very good control of the liquid level. The pipette fits snugly inside the tapered chuck, which is made of a flexible polymer. Radleys carry spares for individual components. The whole device can be dismantled easily for cleaning or maintenance.

It should be remembered that many pipettes are calibrated to deliver the specified volume only if allowed to drain with the top open. For such accurate work the pipette pump should be removed after the pipette is filled to the reference mark.

Another version of this pump is fitted with a *quick release lever* for air entry. The prices from Radleys for pumps with quick release levers are £5.60 (2 cm^3 size), £5.90 (10 cm^3 size) and £7.50 (25 cm^3 size). This 25 cm^3 pump is also now stocked in Surplus (item no. 733, £7.00).

The best of the *rubber bulb* type of fillers we have found are those from Saffron, who charge £51.00 for ten. Pipettes are easily fitted into the tapered holder without fear of breaking the glass. We have used several of these for years without any problems of leaks. They too are now stocked in Surplus (item no. 734, £5.00).

Supplier		**capacity** 2 cm^3 (blue)	10 cm^3 (green)	25 cm^3 (red)
BDH	Cat. No. 241/3963	/02	/03	/04
		£6.15	£6.15	£6.70
Radleys	Cat. No.	37897	37898	37899
		£5.04	£4.82	£6.00
	each, 10 ordered	£4.03	£3.86	£4.80
SSERC	item no. 728	£5.00	£5.00	

Bel-art Pipette Pumps: Suppliers and prices

New Alpha boards for H Grade Physics

You may be interested to know that the Standard Grade Physics Alpha Kit was devised jointly by SSERC and Unilab. Very recently, the Centre has been working with Unilab to specify some additional boards for this kit so that it will also cover the recommended practical work in the revised Higher (Unit 2.5, and part of Unit 2.2).

Not many new boards are required, and several Standard Grade boards are re-utilized for the Higher.

The main additional board has an op-amp, with spaces for removable component panels. The two op-amp circuits specified in the revised Higher - the inverting and differential amplifier circuits - can both be constructed on this board.

Input signals to the new op-amp board are taken from a Potential Divider board (223.070), thus reinforcing the concept of potential division. Two Potential Divider boards can be interconnected to construct a bridge circuit for out-of-balance bridge analysis. The out-of-balance signal can be applied to the op-amp wired as a differential amplifier. Strain gauges, or a platinum film resistor, may be connected to arms of the bridge circuit to build up instruments that measure force or temperature respectively.

Output signals can be boosted by some of the driver circuits already in the Alpha range. Appropriate boards are the Power Amplifier (223.221), the Transistor Switch/Indicator (223.041), and two new boards, the High Power Driver and the Bi-directional Analogue Driver.

The op-amp is powered off the dual ±3 V supply already in the Alpha range (either 223.001 or 223.002).

It is envisaged that the new boards required for H Grade Physics will be marketed by Unilab as a unified kit, with some items being optional extras. These should be available before the end of the year. On-going compatibility into the CSYS Optional Topic 2, Analogue Electronics, and the Electronics Short Course, Analogue Systems, have also been provided for in this development.

Omega boards for H Grade Physics

The Centre has also had discussions with Omega Electronics on equipment for Unit 2.5 in the revised Higher. If you already have the Omega Standard Grade Physics Kit the essential additional boards are C43, the Op-Amp board, two off C14, a resistor board, both of which Omega already retail, and a new 1 kΩ potentiometer board. A dual rail power supply, say ±12 V, would also be required, but for safety reasons we advise you not to buy the one that Omega currently offer (P4).

Several other boards, nearly all of which are included in the Omega Standard Grade Physics Kit, would be useful additional items to have. As we go to press, Omega are preparing a list for publication giving details of their Higher Grade Kit. We understand that this entirely corresponds with the recommendations made to them by SSERC.

BDH branch closure

We have notification that the chemical suppliers, BDH Limited, have closed their Aberdeen Sales Office and transferred their North of Scotland business to their Glasgow Sales Office, whose address can be found on the inside front cover.

Solex - old and new

The instrument distribution company Solex International went into liquidation earlier this year. Their business has been taken over by another company, which confusingly is using two names: Analog and Numeric Devices Limited, and The New Solex. Either name will access the same range of goods.

We understand that the new company is using the 1990 Product Catalogue issued by Solex International and is operating Solex prices. With the exception mainly of a number of oscilloscopes, most of the product range has been kept up. The address differs from the one used by Solex, but the telephone number is the same.

Submersible water pumps

Low voltage, submersible water pumps, which we have stocked in Surplus for several years, have now become unobtainable on the surplus buying market. If you are looking for such a device we suggest you contact a local caravan shop, looking up, if necessary, under *Caravan Agents* in Yellow Pages. One such company that we understand is prepared to sell these pumps to schools by mail order is Jim Fraser Caravans Limited (see address list). Pumps are priced at around £12 - twice what we charged in Surplus.

Model hooses

Watch out Barratts and Millers! Wee model hooses - not for dolls, not for gerbils, not the sort for gawn hame tae, but ones that you insulate and stick thermometers into - are now being constructed by, and are available from, an Edinburgh company called School Science Service. They make two types of model house - one at £28 for investigating the effect of loft insulation on heat loss; the other at £30 for comparing the insulating properties of different wall types. We have not yet had any to inspect, but from the maker's description they would seem to be a substitute for the Ross and Lamont model house, which now appears to be off the market. First signs of a West of Scotland property slump?

Materials for TAPS Tests

The original product range of the School Science Service consisted of materials for TAPS Tests for Standard Grade Science. To this they have added the bits and pieces for the joint Biology and Physics Test series. These include those exotic substances, aluminium and zinc wire, which, as with other exotica, may be purchased as single items as well as in kit form.

Lensman - a pocket microscope

Measuring just 105 mm in diameter and 27 mm thick, and by means of what its makers call folded optics, this strange disk-like object is a pocket microscope. Its objective lens is on the top centre of the disk, above which the object is placed. Its eyepiece juts out from the side. In normal usage it would be held to an eye by both hands using the left hand thumb to focus and either the second or third finger of the right hand to clamp or move the microscope slide. Illumination can either be natural or artificial from its own lamp and battery, and can be reflected, dark ground or transmission.

The Lensman seems ideally suited for fieldwork. It is stocked by C.E.Offord (Microscopes) at £99. We intend to carry out a technical evaluation of it.

Regulated power supplies

Several new regulated power supplies have appeared on the market recently including triple rail supplies from E & L Instruments, Farnell Instruments Limited and RS Components. A new company called Linnaeus manufactures a range of such supplies. Economatics have introduced models recently.

We hope shortly to produce an evaluation report on regulated power supplies, including not just the newcomers, but also some equipment that was introduced several years back by Griffin, Harris, Irwin and Unilab.

Locktronics

The educational business of A M Lock, the originators of the electronics kit, Locktronics, has been transferred to the Beverley Group of Bristol, whose whereabouts are shown in the address list. We understand that the well established Locktronics product range is being maintained.

Radford

The power supply manufacturers, Radford, have closed down because of the retirement due to old age of their owner and engineer, Mr Radford.

The educational product's side of Radfords has been transferred to Alner Hamblyn Electronics Limited (see address list). We understand that this company supplies spare parts for, and carries out repairs on, Radford products. Although they do not at present manufacture Radford items, it is their intention to start doing so.

SURPLUS EQUIPMENT OFFERS

Please note that items are not arranged according to the item number sequence. They have been grouped by similarity of application, or for other reasons. Often the item number serves only for stock identification by us in making up orders. Please also note that you will be charged for postage.

Since most of our stock is bought on the surplus market it is subject to an uncertainty of supply. Some items regrettably become unobtainable. Items recently dropped from our stock list include motors (627, 651, 652 and 654) (all the lemon cell ones), the submersible pump (348), infrared sensors and emitters, and Sensifoam (505). We are sorry for the disappointment this may cause.

Acknowledgements

The Centre is grateful to the companies Griffin and George, and Racal-Guardall, who have donated goods for distribution to schools through our surplus sales.

Motors

590	Stepper motor, single phase, 5 V manufactured for clock or other timing device. Delicate gearing with 40 tooth plastic wheel as output. Suitable for demonstration, or as a method of digital input for control or timing. Uni-directional. Dimens. 30 x 25 x 10 mm.	£1.20
591	Stepper motor, 4 phase, 12-14 V d.c., 400 mA, 27.5 Ω coil, step angle 7.5°, powerful motor with 15 mm x 6 mm dia. output shaft. Dimensions 40 mm x 70 mm dia. on 70 mm square mounting plate with fixing holes at 56 mm centres. Circuit diagram supplied.	£4.50
653	Precision motor, 0.2 - 12 V d.c., no load current and speed 20 mA, 7800 r.p.m., stall torque 14.9 mNm, 9 segments, dimensions 34.1 mm x 23 mm dia., output shaft 8 mm x 7 mm dia. steel spline.	£5.00
655	Precision motor, 0.3 - 24 V d.c., no load current and speed 9 mA, 7000 r.p.m., stall torque 22 mNm, 9 segments, dimensions 39.5 mm x 26 mm dia., output shaft 8 mm x 7 mm dia. steel spline	£5.00
628	Precision motor, 0.05 - 6 V d.c., no load current and speed 35 mA, 5200 r.p.m., stall torque 46 mNm, 9 segments, dimensions 39.5 mm x 28 mm dia., output shaft 8 mm x 7 mm dia. steel spline.	£3.50
735	Precision motor, 0.05 - 6 V d.c., no load current and speed 35 mA, 5200 r.p.m., stall torque 46 mNm, 9 segments, dimensions 39.5 mm x 28 mm dia., output shaft 11 mm x 3 mm dia.	£6.00
736	Precision motor, 0.15 - 24 V d.c., no load current and speed 9 mA, 5300 r.p.m., stall torque 55 mNm, 9 segments, dimensions 39.5 mm x 28 mm dia., output shaft 8 mm x 7 mm dia. steel spline.	£6.00
592	Miniature motor, 2.5 - 9 V d.c., smooth running, speed governor, no load current 30 mA, dimensions 35 x 40 mm dia., shaft 8 mm x 2 mm dia.	£1.00
593	Miniature motor, 1.5 - 3 V d.c., no load current 350 mA at 14800 r.p.m. and 3 V, stall torque 50 mNm, dimensions 25 mm x 21 mm dia., shaft 8 mm x 2 mm dia.	30p
614	Miniature motor, 3 - 6 V d.c., no load current 220 mA at 9600 r.p.m. and 3 V, stall torque 110 mNm, dimensions 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia.	40p
621	Miniature motor, 1.5 - 3 V d.c., open construction, ideal for demonstration, dimensions 19 x 9 x 18 mm, double-ended output shaft 5 mm x 1.5 mm dia.	20p
732	Motor with gear box, high torque, 1.5 - 12 V d.c., 125 r.p.m. at 12 V, dimensions 40 x 40 x 28 mm, shaft 10 mm x 3 mm dia. with key. Suitable for driving buggies, conveyor belt, etc.	£5.00
625	Worm and gear for use with miniature motors, nylon worm and plastic gear wheel.	35p
378	Encoder disk, 15 slots, stainless steel, 30 mm dia. with 4 mm fixing hole.	75p
642	Encoder disk, 30 slots, stainless steel, 30 mm dia. with 4 mm fixing hole.	£1.30

Miscellaneous items

629	Dual-tone buzzer with flashing light, mounted on small p.c.b. The unit has a PP3 battery clip and two flying leads for switch applications.	40p
710	Sonic switch and motor assembly. 1st sound starts the motor, 2nd sound reverses the direction of rotation and a 3rd sound stops the motor. Driven by 4 AA cells (not supplied).	45p
715	Pressure gauge, ca. 40 mm o.d. case, 25 mm deep and 33 mm dia. dial reading 0 - 4 bar (i.e. above atmospheric). With rear fitting for 1/8" BSP. Suitable for use as indicator for pneumatics circuits in Technological Studies.	75p
313	Thermostat, open construction, adjustable, range of operation covers normal room temperatures. Rated at 10 A, 250 V, but low voltage switching also possible.	60p
165	Bimetallic strip, high expansivity metal: Ni/Cr/Fe - 22/3/75, and low expansivity metal: Ni/Fe - 36/64 (invar) length: 10 cm	15p
	30 cm	40p
385	Pressure switch, operable by water or air pressure. Rated 15 A, 250 V (low voltage operation therefore possible). Dimensions 2" x 3" dia.	65p
419	Humidity switch, operates by contraction or expansion of membrane. Suitable for greenhouse or similar control project. Rated 3.75 A, 240 V.	75p
371	Ferrite rod aerial, two coils MW and LW, dimensions 140 mm x 10 mm dia.	85p
511	Loudspeaker, 8 Ω, 2 W, 75 mm dia., resonant frequency 250 Hz.	50p

333	Microphone inserts, high impedance, 23 mm dia., 12 mm depth.	40p
700	Microswitch, miniature, SPST, push to make.	25p
723	Microswitch, miniature, SPDT, lever operated	40p
354	Reed switch, SPST, 46 mm long.	10p
645	Ceramic magnets, assorted shapes and sizes.	7p
688	Croc clip, miniature, insulated, colours - red and black.	5p
690	MES lamp, 6 V, 150 mA.	9p
691	MES battenholder.	20p
692	Battery holder, C-type cell, holds 4 cells, PP3 type outlet.	20p
730	Battery holder, AA-type cell, holds 4 cells, PP3 type outlet.	20p
729	Battery connector, PP3 type, snap-on press-stud, also suitable for items 692 and 730.	5p
724	Dual in line (DIL) sockets - 8 way	5p
	14 way	7p
693	Power supply, switched mode, input: LT d.c., output: 5 V regulated.	£2.00
716	3-core cable with heat-resisting silicone rubber insulation, 0.75 mm^2 conductors, can be used to re-wire soldering irons as per Safety Notes, Bulletin 166. per metre	£1.35
714	Sign "Radioactive substance" to BSI spec., ca. 145 x 105 mm, semi-rigid plastic material. Suitable for labelling a radioactive materials store. With pictogram and legend.	£2.10
727	Hose clamp, clamping diameter from 8 mm to 90 mm, 101 uses - securing hose to metal pipe, tree to stake, joining wooden battens for glueing, etc.	30p
731	Re-usable cable ties, length 90 mm, width 2 mm, 50 per pack.	12p
612	Beaker tongs, metal, not crucible type, but kind which grasps the beaker edge with formed jaws.	£1.20
659	Assorted rubber bungs, one or two hole, per pack.	50p
728	Pipette pump, should be less messy and more controlable than rubber bulb types, one handed operation, easily disassembled for cleaning. Available in two sizes: 2 ml and 10 ml.	£5.00
733	Fast release pipette pump, 25 ml.	£7.00
734	Pipette pump, rubber bulb type, capacity of roughly 30 cm^3 a squeeze.	£5.00

Components - resistors

328	Potentiometer, wire wound, 15 Ω, linear, 36 mm dia.	30p
737	Potentiometer, wire wound, 22 Ω, linear, 36 mm dia.	30p
329	Potentiometer, wire wound, 33 Ω, linear, 36 mm dia.	30p
330	Potentiometer, wire wound, 50 Ω, linear, 40 mm dia.	30p
331	Potentiometer, wire wound, 100 Ω, linear, 36 mm dia.	30p
421	DIL resistor networks, following values available: 62R, 100R, 1K0, 1K2, 6K8, 10K, 20K, 150K, 125R/139R and 1M0/6K0. Price per 10:	30p
420	5% carbon film, $^1/_4$ W resistor values as follows: 1R5, 10R, 15R, 22R, 33R, 47R, 68R, 82R, 100R, 120R, 150R, 180R, 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R, 1K0, 1K2, 1K5, 1K8, 2K2, 2K7, 3K3, 3K9, 4K7, 5K6, 6K8, 8K2, 10K, 12K, 15K, 18K, 22K, 27K, 33K, 39K, 47K, 56K, 68K, 82K, 100K, 150K, 220K, 330K, 390K, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M. Price per 10:	6p

NB If schools are interested in purchasing values in the E12 range between 1R0 and 10M which are not listed above please let us know so that we can consider extending our stock list.

BP100	Precision Helipots, Beckman, mainly 10 turn, many values available. Please send for a complete stock list.	10p to 50p
BP2017	Precision Helipot, Beckman, 10 kΩ, 10 turn, 6 mm dia. shaft.	50p

Components - capacitors

695	Capacitors, tantalum, 4.7 μF 35 V, 15 μF 10 V, 47 μF 6.3 V.	1p
696	Capacitors, polycarbonate, 10 nF, 47 nF, 220 nF, 470 nF, 1 μF, 2.2 μF.	2p
697	Capacitor, polyester, 15 nF 63 V.	1p
698	Capacitors, electrolytic, 1 μF 25 V, 2.2 μF 63 V, 10 μF 35 V, 33 μF 10 V.	1p

Components - semiconductors

322	Germanium diodes	8p
701	Transistor, BC184, NPN Si, low power.	4p
702	Transistor, BC214, PNP Si, low power.	4p
717	Triac, Z0105DT, 0.8 A, low power.	5p
726	MC74HC02N quad 2-input NOR gates.	5p
725	MC74HC139N dual 2 to 4 line decoders/ multiplexers.	5p
699	MC14015BCP dual 4-stage shift register.	5p
711	Voltage regulator, 6.2 V, 100 mA, pre-cut leads.	10p

Sensors

615	Thermocouple wire, type K, 0.5 mm dia., 1 m of each type supplied: Chromel (Ni Cr) and Alumel (Ni Al); makes d.i.y. thermocouple, described in Bulletins 158 and 165.	£2.00
640	Disk thermistor, resistance of 15 kΩ at 25°C, β = 4200 K. Means of accurate usage described in Bulletin 162.	30p
641	Precision R-T curve matched thermistor, resistance of 3000 Ω at 25°C, tolerance ±0.2°C, R-T characteristics supplied. Means of accurate usage described in Bulletin 162.	£2.60

718 Pyroelectric infrared sensor, single element, Philips RPY101, spectral response 6.5 μm to >14 μm, recommended blanking frequency range of 0.1 Hz to 20 Hz. The sensor is sealed in a low profile TO39 can with a window optically coated to filter out wavelengths below 6.5 μm. Data sheet supplied. 50p

722 Mercury tilt switch, welded steel body. 30p

Kynar film items

See Bulletin 155 for details of applications such as force/time plots and detection of long wave infrared radiation.

502 Kynar film, screened, 28 μm thick, surface area 18 x 100 mm, with co-axial lead and either BNC or 4 mm connectors (please specify type). £20

503 Kynar film, unscreened, 28 μm thick, surface area 12 x 30 mm, no connecting leads. 55p

504 Copper foil with conductive adhesive backing, makes pads for unscreened Kynar film to which connecting leads may be soldered. Priced per inch. 10p

506 Resistor, 1 gigohm, $^1/_4$ W. £1.25

Opto-electronics devices

507 Optical fibre, plastic, single strand, 1 mm dia. Applications described in Bulletin 140 and SG Physics Technical Guide Vol.1. Price per metre 40p

713 Solar cell and motor assembly. £3.50

508 LEDs, 3 mm, red, yellow and green. Price per 10 50p

719 LED, HMLP 3850, 5 mm, yellow. Package untinted and non-diffused. 5p

720 LED, HMLP 3401, 5 mm, yellow. Package coloured and diffused. 5p

721 LED, red, rectangular 5 x 3 mm. 5p

Other components

We also hold in stock a quantity of other electronic components. If you require items not listed above please let us know and we will do our best to meet your needs, or to direct you to other sources of supply.

Items not for posting

The following items, numbered 657 to 686 inclusive, and 712, are only available to callers. You will appreciate our difficulties in packing and posting glassware and chemicals. We will of course hold items for a reasonable period of time to enable you to arrange an uplift.

Glassware

657 Screw cap storage jar, plastic cap, 4 oz, wide neck. 10p

660 Test-tubes, 75 x 12 mm, rimmed, 144 per box. £1.00

661 Pyrex side arm flask, 1 litre. £1.00

662 Dessicator. £2.00

663 Flat bottom flask, 250 ml. 50p

664 Flat bottom flask, 500 ml. 50p

665 Flat bottom flask, 800 ml. 50p

Chemicals

NB: chemicals are named here as described on the supplier's labels.

667 250 ml N.H carbamide (Urea). 25p

668 500 ml dodecan-1-ol. 50p

669 1 kg glucose lump, technical. 40p

670 500 g Keiselguhr acid, washed. 25p

671 25 g L-Leucine. 25p

672 500 g Magnesite native lump. 25p

673 250 g manganese metal flake, 99.9%. 50p

675 250 g nickel (II) sulphate AR. 25p

676 500 g quartz, native lump. 25p

677 100 g sodium butanoate. 25p

679 500 g strontium nitrate AR. 25p

680 500 g tin metal foil alloy, wrapping quality, 50% lead. 50p

681 zinc acetate AR. 25p

682 2.25 litre ammonia solution. 50p

683 500 g carborundum powder, 180 - 620 mesh. 25p

684 100 g cobalt sulphate AR. 25p

685 500 ml N-decanoic Acid. 25p

686 250 g iron (III) nitrate AR, (ferric nitrate). 25p

712 Smoke pellets by Brocks. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans, etc.

Large (each) 50p

Small (each) 50p

SSERC BULLETIN 167

CONTENTS

September 1990