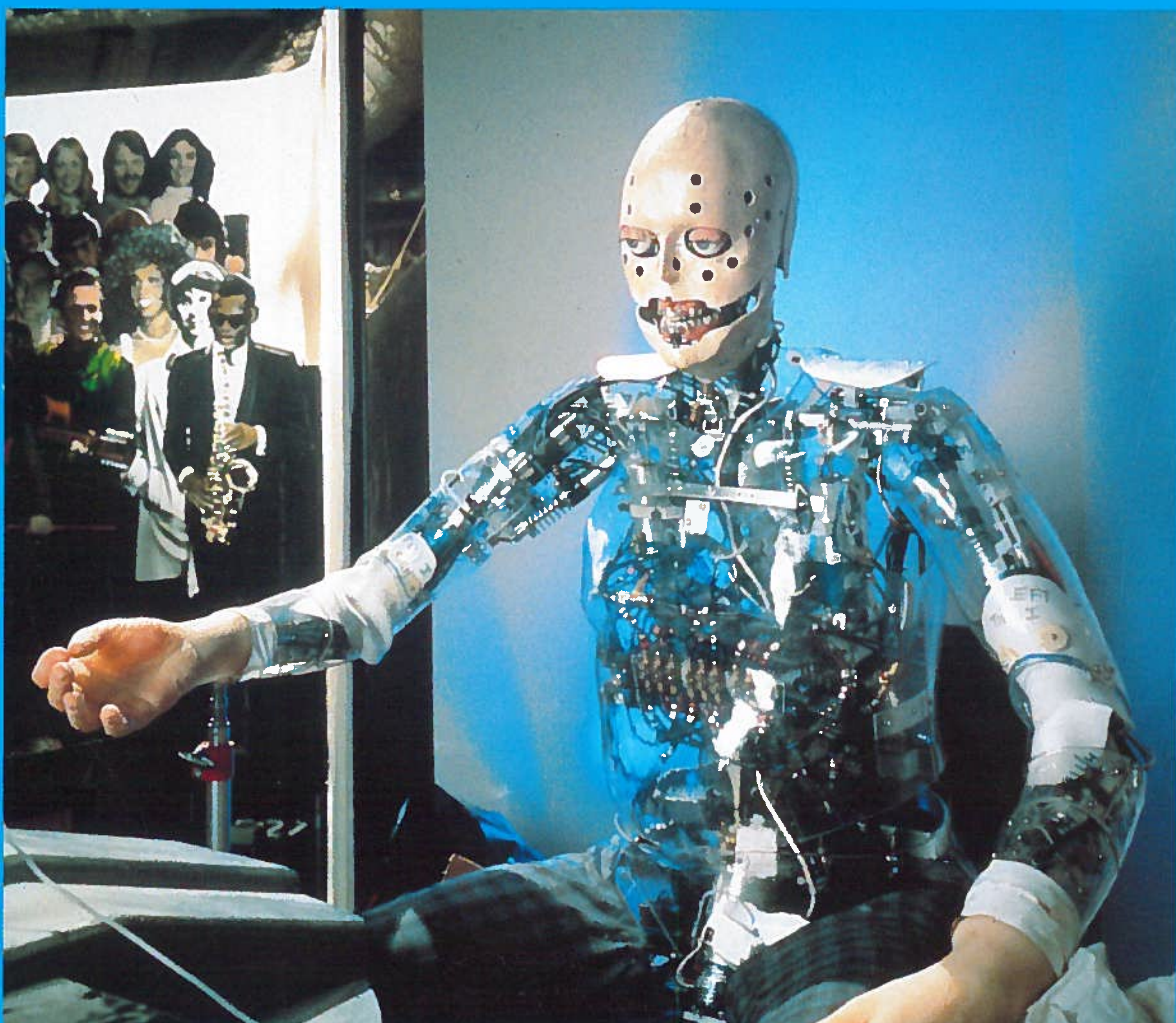
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences

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Foreword

Sponsorship

This issue has received in-kind sponsorship from the British Educational Suppliers' Association. We are most grateful to the staff of BESA for their interest in and support for the work of the Centre. Even though this sponsorship has come indirectly from educational suppliers it was collective rather than from any individual company. We are receiving exhibition space in return for publicising "Education Scotland 1994" which is to be staged at the Scottish Exhibition and Conference Centre, (SECC) Glasgow in February.

Such sponsorship thus still meets our criteria for the acceptance of commercial support for our activities. Readers and clients of SSERC should note that we only ever accept such sponsorship from individual firms which have no commercial or other direct interests in the educational equipment market. This is in order to maintain the independence of our testing, evaluation and equipment information service.

We are pleased however to accept this support from BESA not least because the association voices the agreed views of suppliers in much the same way as SSERC represents their Scottish customers. Despite the fact that collective approaches, of whatever kind, seem unfashionable at present they may still have their uses. They can effect solutions to shared problems and bring economies of scale and - believe it or not - they may be very efficient.

Dominic Savage, Director of the BESA has kindly provided us with an account of the aims of the exhibition and of the Association itself.

Education Scotland 1994 - Exhibition and Seminars

This second Education Scotland event will mark the culmination of two year's work which began immediately after the first combination exhibition and seminar event closed its doors in February 1992. Again it will combine a comprehensive exhibition of educational equipment, materials, books, furniture, information technology and services with a major series of staff development and training seminars. Even at this stage over 100 companies and organisations have agreed to exhibit.

Education Scotland 1994 is a joint initiative. It brings together the British Educational Suppliers' Assocation (BESA) and the Educational Publishers' Council (EPC) as co-organisers. It has directly involved Strathclyde in the initiation of the seminar programme and in the encouragement of the use of in-service days to visit the event. Other Scottish EAs have also lent their support. This link with staff development is particularly important. As in 1992 it should ensure that the event provides an excellent focus for education in Scotland. It is also an important opportunity for contact with a wide range of professionals in Scottish education.

The exhibition is also of specific relevance to the delegated management of schools. In Scottish EAs responsibility is already shifting to individual schools for a range of their activities. It is vital that before spending monies on resources or services, schools and their staff are aware of what is on the market.

Schools need access to information, sound advice, to see and compare across a wide a selection as possible of the products on offer. A high proportion of the hundred-plus exhibitors at Education Scotland '94 are members either of BESA or of the EPC. All members of the BESA have agreed to abide by its Code of Practice. This offers specific safeguards to schools and colleges who buy from BESA members. The code provides assurances on choice, quality, and safety of products as well as on service levels provided by member companies.

The intended audience for the event includes teachers, lecturers, play group leaders, librarians, school board members and others involved in education or training. It is thus intended as a professional event and for this and safety reasons no one under the age of eighteen will be admitted. Otherwise entry to the whole event is open to all educationalists and is free. Free parking will also be available at SECC when visitors exchange a completed registration card for a free car park ticket. Registration cards and publicity material, including a list of exhibitors and seminar details will be sent to most educational establishments in Scotland. Registration cards will also be available on the day.

More than 6,000 teachers and others attended the event in 1992. This caused some difficulties such as queues for registration with crowded aisles making it hard to see some stands properly. The event has thus been moved to a larger hall (Hall 5) and will have more space and wider aisles. Because of the size of this event it is well worth planning out your visit. To that end an exhibition plan and list of exhibitors is to be sent to schools in January.

We look forward to seeing you at this important event in the Scottish educational calendar.

Opinion

Inexpert systems

Should you, reading this, experience a degree of *déja vu* then - you'll not be alone - so too do we having scratched this itch before. It seems that recent curricular developments have thrown up a new and virulent strain of educational shingles. It's as though we've just been fitted with stookies to treat a curricular limp. This is most irritating and needs getting at with a bit of needle.

'Expert' is a term not much liked at SSERC. Ask anyone who has dared to so introduce someone from here to an audience or group on a course. This anathema comes from a firm belief in an established definition of "an expert" as "someone who is, invariably, wrong". Another definition, much liked by a CLEAPSS colleague, takes a small liberty with spelling and defines "exspurt" as "a drip under pressure".

'Consultant' is another tag with which we can well do without. Yet frequently we get introduced thus to participants in our health and safety management courses. Maybe it's just the temptation of the available alliteration that makes for : "Mr Y from SSERC is here as our consultant on COSHH". [Meanwhile, stage left, Mr Y cringes - consultant like].

The cringing is also a matter of definitions since there are many for 'consultant' and most are far from complimentary. One of the less vicious runs something like :

"Anybody with a smart suit and a flashy brief case who is more than fifty miles from home".

But less kind are those such as :

"Somebody who wastes your time with a lot of damn fool questions so that they can then charge you a fortune for telling you what you already knew".

The thrust of much of this blackish humour is rooted in a suspicion that experts and consultants oft may know and understand much less than they pretend. In particular this criticism extends to their grasp of the day-to-day practicalities of running a specific undertaking. This, of course, is countered with the argument that "the observer sees more of the game" and that the outside consultant can take a broader, more objective, view of a business or indeed of a service such as education.

What fascinates me is the amazing presumption in some educational circles that those with the most detailed and practical knowledge cannot themselves be trusted, trained and given the time to review and influence policy and practice. Why is it that those who in practical terms may well know least seem to talk and write most? This is again a phenomenon in science and technology education. Strange it is to mark what and who may emerge once a problem at last begins to attract a proper degree of official, political and - most importantly - media attention.

This may of course be but a symptom of that British disease which spawned the Churchillian generalist and classical aphorism - a war cry almost - "Scientists and engineers on tap - never on top!".

And that, I suppose, is the nub of the problem. I well recall the deep suspicions in TVEI circles when it became obvious that we knew a bit about the sciences. Once it became clear that we could also talk semi-cogently on mechanisms, structures, electronics, IT, biotechnology and control engineering we were sunk without trace. From then on any criticisms of ours that technology support schemes were waffly[1] were dismissed with a derisory : "Ooh - aren't they technical!".

So there you have it - in a woody integument of a single seeded fruit[2]. If you want to get on in science and technology education then, whatever else you do, don't repeat that mistake. Take our advice. Look non-plussed if ever you're asked if you know what a NOR gate might be, or to what application you might put a 555 timer chip. Never, ever, mention DNA or disk drives except in the most general, TV series type terms. Remember that to you pneumatics are some kind of marital aid and pulleys are positively pornographic[3]. Should you let it slip that you have any technical expertise or useful practical knowledge whatsoever, then your cover's blown. Kiss farewell to any chance of serious influence on educational developments.

It may be an ill-kept secret but be warned nonetheless that in Britain science and technology are managed on an inverted need-to-know basis. In this strange and topsy-turvy world, ignorance - feigned or otherwise - is power.

[1] "Waffly" - technical term meaning "shallow, lacking rigour".

[2] Techno-speak for "nutshell". Likely to be confused, but only by the non-technical, with "sour grape".

[3] We have also found that too frequent insertion of the lingual organ into the lateral extremities of the buccal cavity is best avoided.

Introduction

Dates for your diary

Education Scotland '94

The Education Scotland Exhibition 1994 will be held at the Scottish Exhibition and Conference Centre in Glasgow on Thursday 10th February 9 am to 6 pm and Friday 11th February 9 am to 5 pm. See the Foreword to this issue and the outside back cover for further details of this important exhibition of equipment and publications.

Science festival

The sixth Edinburgh International Science Festival 1994 will run from the 7th to the 23rd of April 1994. The schools programme will however start on the 28th of January and run through to 23rd April. Contact the Festival Office for details (see inside back cover).

ASE Scottish Region Annual Meeting

The Organising Committee for the above event have announced that the Annual Meeting will take place at Culloden Academy, Inverness from Wednesday 6th to Friday 8th April 1994.

SSERC Courses

We already have a number of bookings for next financial year (1st April '94 onwards) for courses arranged with Regional Education departments or through neighbourhood groups.

We would also be pleased to receive enquiries on our course programmes from individual schools, teachers or technicians. We shall be offering some courses on an open, first-come, first-served basis with set dates and venues. These will include some health and safety management courses as well as technical training on topics such as the Schools Chip, electronics, interfacing and datalogging for measurement and control. Anyone interested in obtaining further detail on any of these proposed courses or who has other questions on the availability of SSERC training in any practical aspects of science or technology should contact the Director of SSERC in the first instance.

DNA review postponed

The National Centre for Biotechnology Education has intimated that it will be launching its own DNA Technology Kit for schools around the turn of the year. We have thus decided to postpone the review of the Science and Plants for Schools (SAPS) kit and intend carrying a comparative review of both items in Bulletin 180.

SSERC publications

Hazardous Chemicals Manual

Longman Group, publishers of the SSERC Manual, have informed us of their decision to declare this book out of print. We are already working on an improved and extended version which we intend publishing ourselves and marketing directly. This new edition should be available sometime in 1994.

Health and Safety Bibliography

As part of our development of training materials for courses in COSHH and the Management of Health and Safety at Work Regulations 1992 we have drawn up a new bibliography for schools and colleges. This has been prepared on a spreadsheet/database package and has a tabular landscape A4 format. It is organised by hazard category and in a succession of three further columns provides details of :

- relevant statutory instruments, Acts, Regulations etc.;
- non statutory documents, Guidance Notes, Codes of practice etc.
- references to health and safety documents or articles for that hazard type and which are specifically relevant to school and college science.

The bibliography is available to member schools and colleges at £1.60 per copy (including postage).

"Interfacing in ..." series revised

Our popular "Interfacing in Biology (Chemistry; Physics) " series of three volumes which we use on our own tutor-led courses has recently been revised and updated to provide amongst other things a fuller coverage of stand-alone dataloggers. The sections "Background Information", "Technique Sheets" and "Task Sheets" have all been bound within a robust, A4 ring-binder.

As well as supporting our own taught courses these materials should also be extremely useful for in-school, in-service courses. We are thus making them available to those who for one reason or another cannot attend a one or two day SSERC practical course but nonetheless want to learn something practical on this topic for themselves.

"Interfacing in . . . . " files can be obtained at £8 per subject volume (incl. post & packing). Please state clearly which science subject version(s) you want. Cash sales or cheque with your order are strongly preferred unless you buy more than one volume.

Safety Notes

Labelling regulations

In a reply to a reader's letter in Bulletin 176 [1] we gave early warning of new chemical labelling requirements. These regulations - *The Chemicals (Hazard Information and Packaging) Regulations 1993* [2] came into force on the 1st September 1993. They replace and extend the earlier Classification, Packaging and Labelling Regulations (CPL) and are intended to operate much along the same lines. As before, they place the primary duties on the supplier.

New Risk Phrases

The major difference between the new and old regulations is the addition of a number of new Risk and Safety Phrases. There is also a new hazard warning pictogram (see Figure 1) for substances which are deemed harmful to the environment i.e. ecotoxic substances. A number of the new phrases are relevant also to this category of ecotoxins. For example indications are given that a substance may harm aquatic organisms and the safety phrase may then warn against disposal into watercourses, etc. :

R53 - "May cause long-term adverse effects in the aquatic environment"

Dangerous to the Environment

Fig. 1 New pictogram - symbol N

Which may be accompanied by a Safety Phrase like :

S56 - "Dispose of this material and its container to hazardous or special waste disposal point"

Indications also have to be given where a substance may harm the ozone layer e.g. :

R59 - "Dangerous for the ozone layer"

Irreversible effects

The other major addition is a more sophisticated system for indicating risks from substances which may be mutagenic, teratogenic (harming the unborn child) or carcinogenic. A number of new risk phrases are available now for the better description of the type of hazard presented by such substances through different routes into the body, e.g.

R49 - "May cause cancer by inhalation"

The risks are indicated by assignation to a category. For example carcinogens are divided into Categories 1, 2 and 3. The criteria used to decide the category to which any particular suspected carcinogen might be assigned, include any epidemiological evidence and the strength of any indications from animal tests etc. Note that these categories are not the same as a ranking. It is likely that SSERC may be asked to update official educational guidance on such matters in which case we shall be publishing a paper sometime next year.

Material Safety Data Sheets (MSDS)

Regulation 6 of the CHIP regulations describes the safety data sheets that (with certain exceptions) are required to be provided when substances or preparations deemed to be "dangerous for supply" are supplied.

In effect Regulation 6 broadly specifies the content of MSDS in terms of health, safety and environmental effects and lays down certain requirements as to the need to update sheets if significant new information becomes available. Suppliers are required to provide a MSDS free of charge not later than the date of first supply. Any such updates are to be provided free of charge to any recipient of the substance or preparation who was supplied within the preceding twelve months. Updates are to be clearly marked - "revision".

Labelling by the user

Despite the changes brought about by the CHIP Regulations the advice we gave in Bulletin 176 as to the labelling of secondary containers by users still stands.

References

1. *Readers' letters*, Bulletin 176, SSERC, March 1993.

2. *The Chemicals (Hazard Information and Packaging) Regulations 1993*, SI No.1746, HMSO, ISBN 0 -11-034746 (See also the HSC *Guidance on Regulations*, HMSO, ISBN 0-11-882155-5).

Management (de-?) regulations

It had been our intention for this issue to provide more detailed guidance on the Management of Health and Safety at Work Regulations 1992. These were made as a result of an EC Framework Directive. This in turn was issued under arrangements which are part of the Single European Act. We had also hoped to give further advice and guidance on the other Regulations which arose from the so-called daughter directives.

As we began drafting this section of the Bulletin, leaks to the press were suggesting that there is soon to be a major (no pun intended!) UK programme of deregulation in the field of health and safety. At the time of writing we understand that the Government's intentions on these matters will form an important part of the Queen's Speech at the opening of the next session of Parliament.

Whilst we find it hard to credit that the government's intentions are as extreme as has been suggested in the press, there seems little point at this stage in attempting to second guess the detailed content of any legislative programme. Any firm advice we might offer in this issue may well be in error. That we might discover even before we receive the finished copies of this issue from the printer.

The case for de-regulation

Anyone who has had to study, interpret and work with the existing UK legislation would agree that there may well be a strong case for a general tidy-up and clear-out. There is now much overlap. With the advent of the EC measures many of the earlier and highly specific requirements are better covered by the widely applicable principles of hazard recognition, risk assessment and preventive or protective measures. The detail then can be dealt with by referral out to specific technical standards or codes.

We have before described such increasing reliance on recognised European technical standards (or *Normes*) or codes of practice - for example in connection with the Electricity at Work Regulations, 1989.

It is also fairly easy to see how many of the earlier statutory measures appended as a schedule to the Health and Safety at Work etc. Act 1974 might usefully be repealed. For example both the Offices, Shops and Railway Premises Act 1963 and the Factories Act 1961 are by now well past their sell by date. Many of their provisions are effectively superseded by the more general principles in the Management Regulations and in others which flow from the EC Directives. Examples are the Workplace Health Safety and Welfare Regulations and the Provision and Use of Work Equipment Regulations (both 1992).

Kitemarks or kite flying?

The intention may well be to rationalise and consolidate legislation and also increasingly to rely both on non-statutory, technical, safety standards as well as on the principles enshrined in the directives. This would allow for the integration of health and safety with more general issues of effective management. We certainly hope so.

We can see also a rationale for removing a highly specific piece of consumer protection legislation so long as the general public continues to be safeguarded by wider principles and general duties which are in turn backed up by a detailed technical standard.

One example of this approach could be that of which some sections of the press seem to have made most - the flammability of nightwear. A specific regulation may not be needed here but only so long as manufacturers and importers are still effectively required to meet the relevant British Standard (or European Norme).

Some of the press reports we have seen suggest that deregulation may be intended to go far beyond the cogent measures with which those reasonably knowledgeable in health and safety might concur. If that is the case then it is much harder to see how the government can avoid another European stooshie.

Whilst only the intention or desired outcome of EC Directives are binding on member states, they must be implemented. Individual governments are left to decide for themselves the details of that implementation. But the mere existence of a directive limits any member state's room for manoeuvre. Where a member's provisions are seen to fall short of, or to conflict with, EC measures then the latter usually take precedence. The UK Parliament may often like to pretend otherwise but the real 'Supreme Court'[1], which decides many such matters, now lies o'er the watter.

Should deregulation go so far that it brings with it a string of actions in the European Court of Justice, or consumer group financed civil actions at home, it then becomes more difficult to appreciate just how the longer term interests of British businesses are better served. This is especially so, given what would then be a direct clash with a renewed espousal by sectors of British business of some other aspects of Europeanism[2].

Time will tell - watch this space!

[1] See Article 177 of the Treaty of Rome and the Single European Act.

[2] As witnessed at the CBI conference (which just happened to coincide with the leaks on deregulation).

Technical Articles

More on enzymes

This is the second in a series of articles on minor technical difficulties with practical work for Biology and Human Biology at the Standard and Higher Grades.

Introduction

In the first article of this series [1] some problems associated with investigating the inhibitory effects of lead ions on enzymically mediated reactions were discussed. In this account some other snags which have arisen in investigations using urease and diastase are dealt with.

Urease

This has the distinction of being the first enzyme ever to be isolated in a pure form. It was extracted from Jack beans, purified and then crystallised by Sumner in 1926.

It is also an unusual enzyme in a number of respects. It is largely found in plant tissues. Particularly rich sources are seeds such as those of soya or Jack bean plants although the seeds of some melon varieties also yield significant quantities. It is also found in a smallish number of invertebrate species but is apparently unknown in vertebrate animals. This is not so surprising when one considers that it catalyses the hydrolysis :

$$\underset{\text{urea}}{CO(NH_2)_2} + \underset{\text{water}}{H_2O} = \underset{\text{carbon dioxide}}{CO_2} + \underset{\text{ammonia}}{2NH_3}$$

Other unusual features of urease are its inhibition by high concentrations of its own substrate and an optimum pH which shifts with changes in the concentration of that substrate. Studies on such an enzyme clearly need careful experimental design!

Curricular applications

This somewhat atypical enzyme is the basis both of studies in SEB biology courses and of a TAPS 3 investigation. This article concentrates on problems in a suggested biology practical wherein urea concentrations are assayed using urease to hydrolyse the urea into ammonia and carbon dioxide and thereafter titrating against acid.

The potential snags in the TAPS 3 investigation, and possible ways to avoid them, are still under study. In any event we wish to avoid mixing up the two procedures else we too get confused!

Soya flour

For now teachers are warned against the use of soya bean flour as a source of the enzyme. In their natural state soya beans are indeed a rich source of urease. Unfortunately commercially available soya flour almost always is not. This is because most of it has been heat treated (so Spillers, the biggest miller, tells us). Small amounts of untreated soya meal are produced, but these are sold directly to bakers for mixing with wheat and other flours as an *improver* and bleach enhancer.

Jack bean meal is thus a more reliable source although whole, viable soya beans can be cut up or ground and will yield variable amounts of urease.

We hope to have completed our studies of other minor snags with the TAPS 3 investigation in time to publish a fuller account in the next issue of the Bulletin.

Assaying urea in artificial urine

The Higher Grade syllabus for human biology has a compulsory practical on the estimation of urea (carbamide) in an artificial urine sample. Unfortunately the method given in the SCCC published exemplar materials [2] (itself an adaptation of a method of Freeland's [3]) uses excessive volumes of the acid for the titration (bucket-loads!). Even when scaled down for our own trials it proved unreliable and gave results grossly at variance with those expected from theoretical calculations (Figure 1).

An alternative procedure is thus recommended. The one used came from literature provided by BDH (Merck) with their urease tablets.

Procedure

The BDH method is itself based on a procedure first published in nineteen oatcake [4]. The urease tablets contain :

- 2-hydroxybenzaldehyde oxime ((salicylaldoxime)
- urease from seeds
- lactose (starch free)
- acacia gum powder
- magnesium octadecanoate (stearate)

In the batch we used the activity of each tablet was such that it was capable of converting at least 400 mg of urea into ammonium carbonate in three hours at 37°C (or 80 mg of urea in three hours at 15°C).

Calibration

The "artificial urine" samples used for calibration are made up by dissolving different weighed amounts of urea in distilled or deionised water so as to produce w:v concentrations of :

0.5, 1, 2, 4 and 8 g/100 cm³

One tablet, previously crushed, is placed in each of five glass-stoppered bottles (we used 125 cm³ reagent bottles) and 50 cm³ distilled or deionised water is added to each sample together with two drops of methylbenzene (toluene) as a preservative. Exactly 2 cm³ of each known urea concentration is then added - one of each per bottle. Each bottle is then stoppered securely and allowed to stand for three hours being shaken periodically.

If results are wanted in a shorter time then use two tablets of this type and incubate for half the time (ninety minutes). The use of a water bath at 37°C , although optional, would also assist the process (see the sample results).

Titrations

At the end of the incubation period the ammonia produced in each sample is titrated against 0.1 M hydrochloric acid with methyl orange as indicator.

Untreated 2 cm³ samples of the original concentrations diluted with 50 cm³ of deionised water may also be so titrated if wished to express results as % urea. This is because the difference between the titre for an untreated sample and that for the incubated equivalent is the basis of a factor to convert the volume of acid used to an estimate for the percentage of urea in the sample (see note to Table 1).

Conc. of urea (g/100 cm³)	Vol. of HCl (cm³ 0.1 M for neutralisation)	Calculated titre (cm³)	Estimated % urea*
0.5	5.8	3.3	0.86
1.0	8.8	6.6	1.31
2.0	16.4	13.2	2.45
4.0˙	32.1	26.4	4.80
8.0	51.7	52.8	7.74

*Using BDH method where (Y cm³ x 0.15) = % urea in sample. Y cm³ = difference in titre between original and incubated samples.

Table 1 Results for samples of known concentration of urea each incubated with two crushed urease tablets for one and half hours at 37°C.

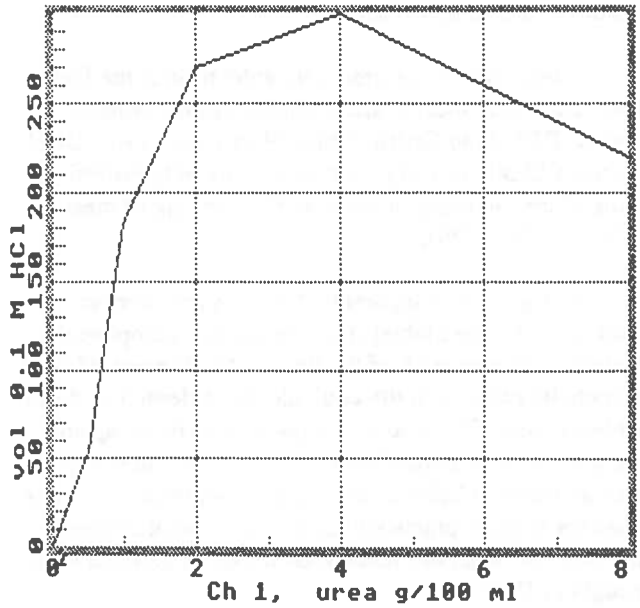


Fig. 1 Typical calibration graph using 'SCCC method'

(Note large volumes of HCl needed and non-linear results)

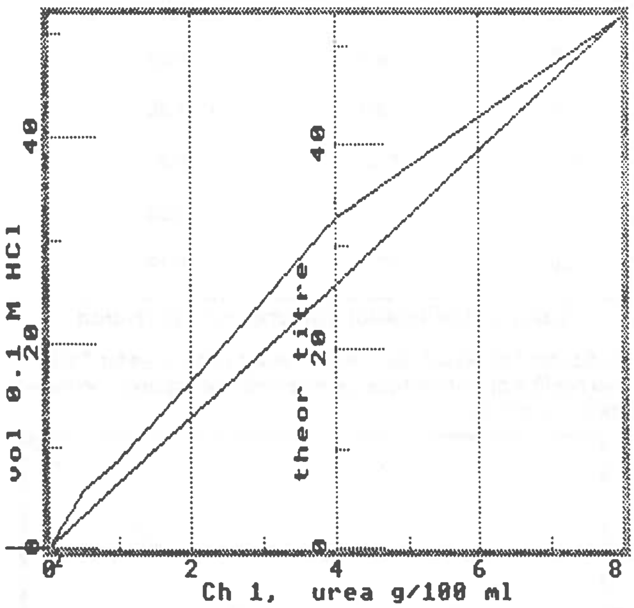


Fig. 2 Calibration graph using 'BDH method'

(Actual volumes compared with theoretical titres [straight line]. Plotting the calculated % urea against sample concentrations in g/100 cm³ yields an almost identical graph).

Costs

Urease tablets are relatively expensive at £10.60 for 60 (BDH, Cat. No. 39047 A). Using the two tablets per sample method means that one pack will only do for six complete calibration procedures. New batches of BDH tablets now however possess greater activity than those of the sample we used. The 1993 catalogue quotes an activity per tablet of 1000 mg of urea hydrolysed in three hours at 37°C against the 400 mg per tablet quoted in the earlier literature. That means that one tablet per sample would now suffice.

Another source of urease

The usual source for urease in tablet form is the Jack bean. Jack bean meal is also available from companies such as BDH (and Griffin, Philip Harris etc.). From BDH it costs £12.50 per 100 g with an activity of hydrolysis of 3 mg of urea in thirty minutes at 37°C per mg of meal (Cat. No. 39045 2S).

Thus 1 g of meal apparently has the same nominal activity as 3 urease tablets (but should also complete the hydrolysis in one-sixth of the time). £12.50 worth of meal potentially has an activity equivalent to at least 5 packs of tablets costing £53. These savings have to be set against the possibility of unused meal losing activity in storage. As the results in Table 2 and Figure 3 below indicate, this does not seem in practice to be a serious problem since the batch of Jack bean meal used in our studies had been bought in 1987.

Conc. of urea (g/100 cm^3)	Vol. of HCl (cm^3 0.1 M for neutralisation)	Estimated % urea*
0.5	6.7	0.99
1.0	9.3	1.38
2.0	17.2	2.56
4.0`	35.0	5.23
8.0	61.0	9.13

Table 2 Calibration for urea concentration

(*Estimates calculated using BDH method formula as for Table 1. 400 mg [0.4 g] of Jack bean powder used per sample, incubated for 3 h at 37° C).

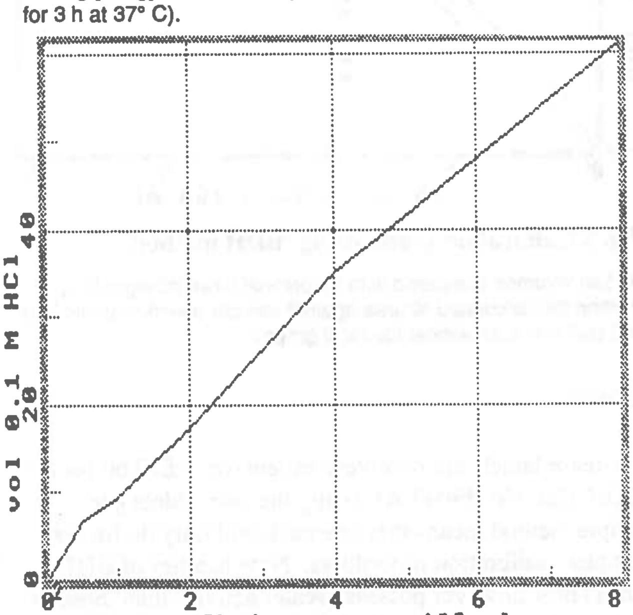


Fig. 3 Typical calibration graph using 'BDH method' and Jack bean powder as the urease source.

Diastase

Background

Like urease, diastase is a somewhat unusual enzymatic system. Firstly it is not one enzyme but a mixture of two different forms - α-amylase and β-amylase. Both act on and hydrolyse starch of which coincidentally there are two forms. These are the unbranched chain form known as amylose and the highly branched form known as amylopectin.

Diastase seems to have come into fashion again after a number of EAs banned, or teachers abandoned, the use of human saliva as a source of amylase.

In humans, ingested amylose and amylopectin are rapidly hydrolysed by α-amylase secreted in saliva and by the pancreas. This form of amylase hydrolyses internal α-1,4 linkages to yield the disaccharide maltose, a tri-saccharide maltotriose and an oligosaccharide α-dextrin. The first two contain glucose residues α-1,4 linked and the dextrin has several units but with one α-1,6 linkage in addition to the α-1,4 links. Subsequent digestion is by maltase which hydrolyses maltose and maltotriose to glucose, and by α-dextrinase which similarly breaks down the α-dextrin into glucose units.

Diastase also contains β-amylase which is active in sprouting, malting barley. This form of amylase hydro-lyses starch into maltose by sequentially snipping off disaccharide units from the polymer's non-reducing ends.

Practical and other snags

There are two basic problems in the substitution of human salivary amylase by diastase for school practical work.

Reducing sugars

Firstly, it is not uncommon for commercial diastase preparations to be contaminated with traces of reducing sugars. Sometimes such sugars are even deliberately added to act as stabilisers. BDH diastase prepared from malt contains such sugars. This means that the hydrolysis reaction cannot really be followed by monitoring the rate of appearance of reducing sugars since these are present at the outset.

There are other preparations of diastase, some of which are reducing sugar-free. These are however much more expensive than the normal grades. For example BDH malt-derived diastase (Cat. No. 39013 2F) is £11.70 for 100 g whereas that from pig pancreas (Cat. No. 39123 3N) costs £19.80 for only 25 g.

Heat resistance

Diastase is unlike many other enzymes which, along with other proteins, are thermolabile and become quickly ineffective above the mid fifties Celsius. Diastase is remarkably resistant to heat damage and will go on working well up to and beyond 80°C. It is not unique in this respect however - despite the simple versions of the enzyme story we tend to relate to pupils[1].

For example a microbial amylase called *Termamyl*^{R} and made by Novo Nordisk is available from the National Centre for Biotechnology Education (NCBE). This is remarkably heat-stable and will operate up to and beyond 100°C. This ability to function at high temperatures can be advantageous when it is used in industry where it has a wide range of applications from de-sizing fabrics to the production of dextrins from corn starch as a preliminary to high fructose syrup production.

Effects in experimental work

Because less expensive kinds of diastase contain reducing sugars there is a tendency to try and follow the progress of the hydrolysis reactions using the rate of disappearance of the substrate (starch) rather than the rate of appearance of products (reducing sugars). One obvious way to do that is to treat the starch with iodine in potassium iodide solution so as to obtain the distinctive blue-black coloured complex. The rate of decolorisation of that complex should then in theory be proportional to the rate of hydrolysis.

Temperature

This is the method trialled by Jim Shields whose work on catalase we published in Bulletin 178 [1]. One of the investigations he trialled was to look at the effects of temperature on rates of diastase mediated hydrolysis. His real problems began when he found that he needed to heat the diastase to over 80°C in order to have a control with 'heat-killed' enzyme. He found that at the higher temperatures the blue-black starch/iodide decolorised anyway, with or without enzyme! Try it for yourself if you don't believe it.

pH

The fun continued when he tried to investigate the effects of pH on diastase by acidifying starch suspension and iodine in KI mixtures. When several drops of a strong mineral acid such as hydrochloric, or a strong base such as sodium hydroxide are added to the complex the blue-black colour again disappears!

[1] The same may be true of the effects of low temperatures. For example, try investigating the rates of reactions mediated by catalase at temperatures approaching the freezing point of water.

As before, the clearing of the colour is unrelated to the presence or absence of the enzyme.

The obvious explanation is that of an acid or alkali mediated hydrolysis. This won't wash and for a couple of reasons. Firstly tests for reducing sugars reveal that at the most only small quantities are present so that very little of the starch, if any, can have hydrolysed. Secondly, and even more convincingly, the process is reversible. The blue-black colour may be restored if the sample is returned to approximately pH7 by the addition of acid or alkali whichever is applicable.

Buffering

The pH of a starch/iodide complex can be adjusted away from neutral, with maintenance of the colour, by the addition of buffers. We found that we could obtain blue-black starch mixtures at pH4, 7 and 9 by the use of buffer solutions prepared from proprietary tablets.

The appearance of the starch suspensions was altered slightly by such treatment in that there was what looked like slight flocculation. Nonetheless the starch remained in suspension and it was possible to compare rates of hydrolysis in different pH regimes by monitoring the rate of clearing of the blue-black suspensions.

It was found necessary to do this with an iodine limited system in a fairly dilute starch suspension with an excess of enzyme. To that end iodine in potassium iodide solutions was diluted much more than is usual. The investigations were done in test tubes or 25 cm^3 beakers. Typical reagent concentrations were as set out below :

diastase - 1% w:v
starch in buffer - 0.2% w:v
I_2 in KI - 2.5% in 5% w:v as stock
dilute iodine stock reagent before use 1:20 v:v

5 cm^3 of each of the starch suspension and diastase solution are used with 3 drops of the iodine reagent. The effect of pH may be investigated by making up different suspensions of starch in buffers of, say, pH 4, 7, and 9.

Some investigations were carried out at room temperature (ca. 22°C) when, even at pH7, the complete decolorisation could take several minutes to become apparent by direct observation. Using a beaker of warm water as a simple water bath does help to speed things up a bit.

Alternatively, the process may be followed by datalogging using transmitted light and a sensor.(p.10)

A simple set up to do this uses the internal photocell of a Philip Harris *Blue box* light sensor. If a small beaker (25 cm^3, say) with the starch in buffer, iodine and enzyme is placed over the sensor then the rate of increase in transmission will be proportional to the disappearance of the blue black complex and in turn to the rate of the reaction. The different rates of clearing of the blue-black colour then become obvious even in the first few minutes (Fig.4).

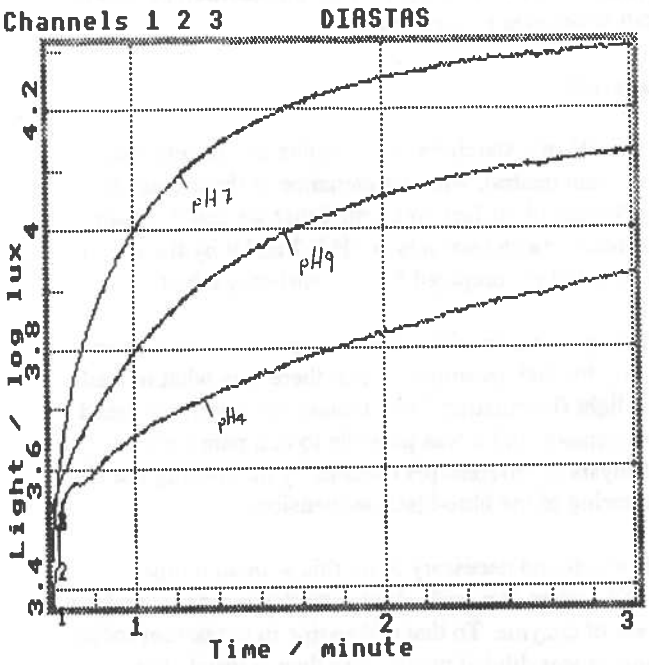


Fig. 4 Rates of decolorisation at different pH values

Summary

This article, like the first in the series, is intended to assist with technical problems and as a reminder of the importance in experimentation of identifying and isolating each variable which may have an effect.

Urease

Trustfully the two methods outlined for urea assay will prove more reliable and less profligate in the use of reagents than those first provided in the curricular support materials.

Once suitable calibration graphs have been obtained with either source of urease then it should be a relatively straightforward matter to estimate urea concentrations in made-up 'unknowns'.

Should urease be used for investigations into factors affecting rates of enzymically mediated reactions then SSERC would counsel caution and remind teachers of the need to ensure that all variables, except that being measured, are under control. For example if the effects of temperature are to be looked at, then students must be made aware of the inverse relationship of the solubility of the ammonia with temperature. Similarly, investigators of the optimal pH of urease or of the effects of substrate concentration, need to be aware of other peculiarities of this enzyme (see page 6).

Diastase - rules and exceptions

In conventional teaching we try to keep things simple and so - in the jargon - control the "noise to signal ratio" We stress that between strict limits enzyme mediated reactions (as do other chemical reactions) double their rate for each 10°C rise in temperature. But we also indicate to pupils that enzymes are proteins and that at the same temperatures at which proteins denature then enzymes cease to be effective.

There are however exceptions. Diastase and a number of microbial enzymes are not rendered ineffective above 50°C and catalase controlled reactions can still be rapid at just above freezing. A moment's reflection would show that these observations are not really so surprising. Forms of life are found in all sorts of extreme conditions on the Earth, from bacteria in hot sulphur springs to algae in Antarctica. Unconventional enzyme systems must therefore in certain circumstances confer selective advantage. It should come as no surprise that rules are broken. How the teacher tackles these exceptions in their teaching is another matter - it's over to you!

Risk assessment

Enzymes - sensitisation etc. Technicians or teachers handling enzymes in powder forms should take care not to raise dust. Toluene as preservative - volume required means the risk once two drops dispensed is insignificant but care is needed to avoid inhaling vapour when dispensing.

References

1. *Accentuate the experiment*, Technical Articles, SSERC, Bulletin 178, SSERC, September 1993.

2. *Life Support Mechanisms*, Appendix 7, Compulsory Practical, Exemplar Materials, SCCC, 1992.

3. *Problems in Advanced Level Biology*, Freeland, P.W., Hodder & Stoughton, ISBN 0-340-35168-3.

4. *Determination of urea in urine*, Marshall, J. Biol. Chem. 14, 283, 1913.

Pneumatics - a neglected technology?

In school technology devices which are driven by controlled flows of compressed air - pneumatic devices - seem but poor cousins of electrically powered and electronically controlled systems. This short article attempts to give the lie to such a view of pneumatics. It describes a number of modern, industrial and commercial applications of compressed air devices. They are intended to assist teachers provide pupils with a more balanced view of pneumatics technology applications.

Introduction

In school technology pneumatics has never enjoyed as high a profile as have electronics and computing. This seems to be especially true of schools presenting pupils for Technological Studies at the Standard or Higher grades.

It is almost as though some teachers believed that it is an outdated subject and that pneumatic devices no longer are needed or used in modern industries. It is also a technology too often seen as less exciting and not so high-tech as, say, microelectronics.

Nothing could be further from the truth. Pneumatics and hydraulics, related groups of technologies, have long been - and will continue to be - the sources of controllable force or power for mass production methods. This applies even to the most modern production plant particularly that controlled by microprocessor based devices.

In an attempt to correct some of the misimpressions which may be formed at school level here are some vignettes of some unusual, modern applications of pneumatics. Because of cost and knowledge demands they are not easily or directly transferrable to the classroom. They do show however what can be, and is being, achieved in industry. We hope also that they may stimulate further interest in schools and possibly even provide the inspiration for projects which use analogous ideas and techniques.

Off road but still on air

Recent models of the Range Rover are fitted with an electronically controlled air-filled suspension system. This uses direct acting, solenoid operated, pneumatic valves to effect continual balance of the bodywork whatever the underlying road (or off-road) conditions.

The hybrid electronic and pneumatic control circuitry for this system was developed jointly by Dunlop and Norgren Martonair in cooperation with Weber Solenoids who designed the valves.

Flying - seat of the pants style

Manned flight simulation provides an even more exotic background for an application of pneumatics. Here the physical condition of the pilot is one parameter which has continually to be monitored.

For a pilot flying a modern combat aircraft the gravitational (G) forces exerted on his body are in constant flux. They will change, for example, as the aircraft accelerates in level flight, dives and pulls up out of that dive, climbs or executes a turn. Without any protective measures these sudden gravitational shifts will play havoc with the physiology of the pilot.

In particular there will be large and rapid changes in relative blood pressure. Blood flow into certain parts of the body may then be increased at the expense of other cherished bits of the anatomy (wait for it!).

For example blood may suddenly be shifted into the blood vessels in the pilot's legs at the expense of maintaining circulation in the brain. The pilot will then lose consciousness. He will 'black-out'. This is not generally a good thing to happen in the middle of a manoeuvre at well over 700 mph.

In actual flying these problems are tackled with special over-trousers which inflate or deflate as required. Should G-forces increase then the trousers inflate. That in turn increases the pressure exerted externally on the pilot's legs thereby automatically preventing excessive blood flow into them.

For example, when a pilot is being subjected to a force of nine times the Earth's normal gravitational field (pulling 9G, as some would say) then the trousers become fully inflated and exert a pressure on the legs of about 2 psi (two pounds per square inch). Although he is now less likely to black out he will have noticeable discomfort in his legs. It is this discomfit which has to be reproduced in a flight simulator.

It is actually fairly simple to design such a system for real flight conditions with rapidly changing, but relatively high, G-forces. Designing a system for use in a simulator is a lot trickier. Here the actual G-forces may change but always remain relatively low compared with real flight. The simulator will provide the appearance and experience of rapid acceleration and deceleration etc. but to simulate, on the ground, the equally rapid inflation and deflation of a flying suit is by no means easy. Why should this be so?

The major cause of difficulty is a relatively large volume of air trapped in an inelastic medium (the trousers) at low pressure. Some means has to be found to rapidly and actively deflate the trousers and to link that process accurately to the simulated gravitational change.

The design engineers met this brief with a system whereby analogue voltages between 0 and 10 V were produced which were linked with and proportional to the applied gravitational force. These voltages are in turn used as input signals to a software controller which generates outputs which can rapidly switch special pneumatic valves.

Such valves are produced by the company Joucomatic and are known as "Sentronic Proportional Valves". They have matched inlet and exhaust ports which facilitate both rapid and linear responses with a minimum of hysteresis. Who said pneumatics isn't high tech?

(But, be careful - see "Opinion" on page 2).

Could the use of such a hybrid microprocessor and pneumatics technology make an interesting final year project?

Spare the rod!

In the food industry and others, the control of conveyor belts is almost as serious a consideration as it is in projects and case studies for Technological Studies at the Standard Grade. In industry however the concern is now much less with simply controlling the speed of the belt and the flow of objects upon it etc. Technologists are now also addressing fine-tuning issues such as conveyor belt tracking and the control of maintenance costs, and of production losses through stoppages because of plant failures.

Keep on tracking!

Pile-ups and stoppages can be minimised by ensuring that the conveyor belt always runs centrally regardless of the mass of individual loads passing any point. One way of doing this is for the rollers to be inclined at a slight angle (Fig.1).

This works quite well but one by-product of this technique may be excessive wear on the belt. The way around that snag is to continually re-align the rollers so adjusting for different loads. Initially this was done with conventional pneumatic cylinders. This was still a less than optimal solution to the problem since the response times of these rodded cylinders were too long and two cylinders were required per roller (Fig.1 top).

Rodless cylinders

The subsequent design of rodless acting cylinders has brought the twin advantages of a one cylinder per roller system (Fig.1 bottom) and swifter control through shorter response times.

Figure 2, opposite, provides a simplified diagram of a rodless cylinder.

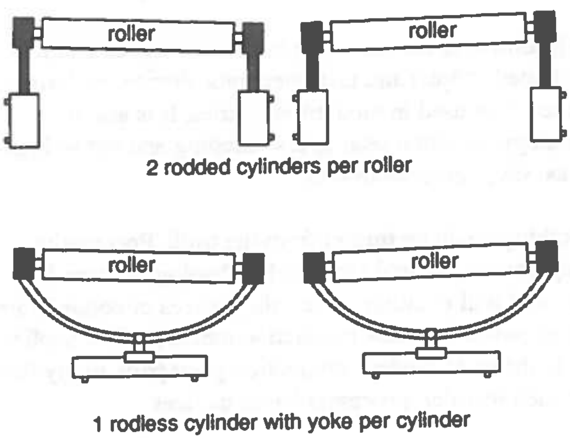


Fig. 1 Simplified diagrams showing the use of rodded cylinders (top) and rodless cylinders in angling the rollers of a conveyor belt.

The carriage on a rodless cylinder is moved by means of a flexible metal band which runs over a pair of ball race rollers - one at each end of the cylinder. Both carriage and piston are connected centrally to this band which helps to limit any bending. Since both carriage and piston are coupled to the metal band, their lateral movements are mirrored. As the piston moves to the left the carriage is pulled to the right and vice-versa (Fig. 2).

Rodless cylinders are designed with a closed, non-slotted profile which permits excellent sealing over the entire circumference of the piston. A further design innovation has been the introduction of an oval piston. This reduces the overall height of the cylinder without decreasing the piston area and retains the same cylinder power.

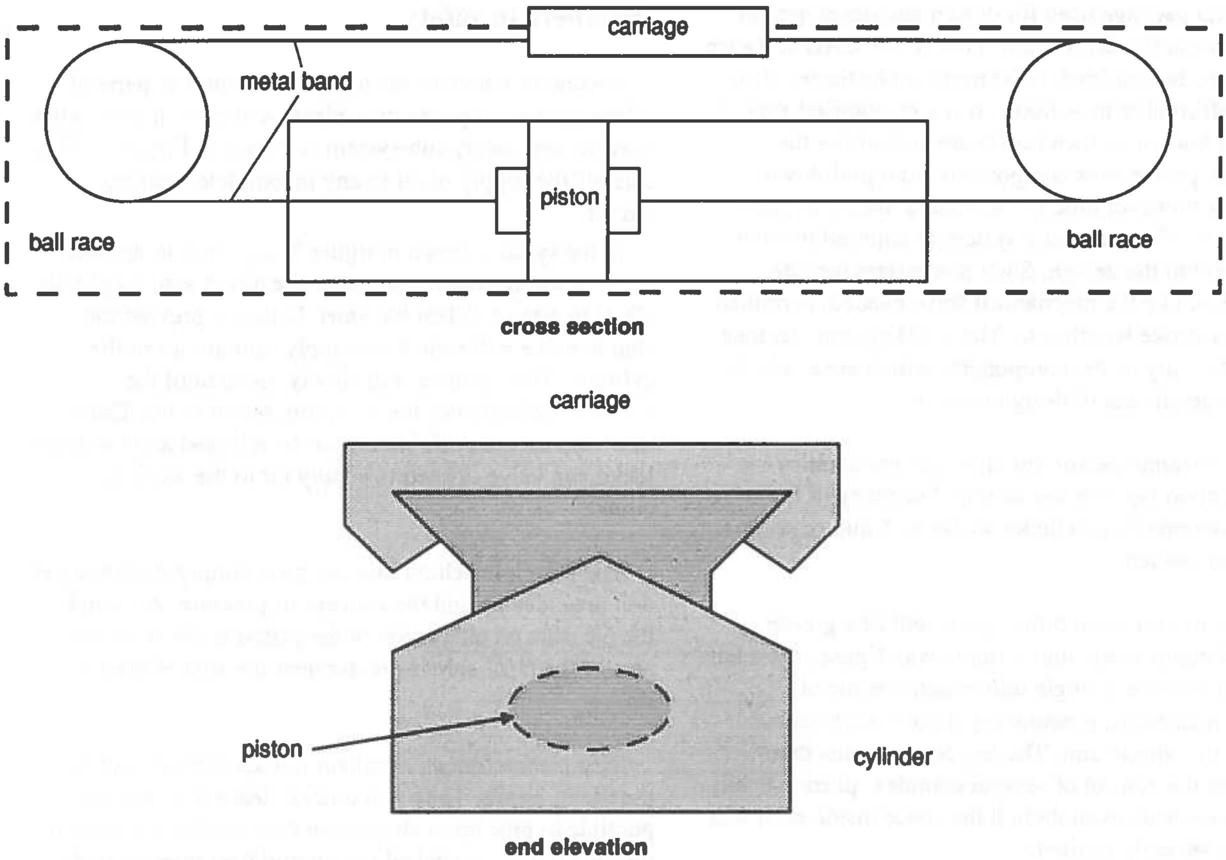


Fig. 2 Basic design features of a rodless pneumatic cylinder

Multi-core - blimey!

An even more sophisticated and complex application of these rodless cylinders is now to be seen in electrical manufacturing. They form part of a machine which has been designed for the semi-automatic wiring of multi-core cables to connectors with up to sixty-four separate terminations.

The machine cycle involves the moving of the connector through thirty-two steps. This accurate movement is effected by a rodless cylinder. At each of these steps a pair of wires may be connected to the termination as follows: the termination connector stops; the operator places two wires in their approximate final positions; the position of each wire is continually monitored by sensors; when the operator's manual adjustments find the exact positions pneumatic probes automatically insert the wires into the terminals and any excess on the far side of the connector is trimmed off.

Waxing lyrical

In May of this year, Madame Tussaud's in London opened a new development at the famous waxworks. This is a dark ride through four centuries of city history. The new visitor attraction is called *The Spirit of London* and it uses many of the latest techniques in creating special effects which recreate the sounds, smells and sights of landmarks in the history of the English capital.

The major innovation in this exhibition has been to give the wax figures movement and synchronised speech. This is the technology known as *animatronics*. As the name suggests it is the technology of animation and is a melding of the art of the sculptor with electronics, pneumatics and computer science.

The work of the Tussaud's design team provides a superb example of a multi-disciplinary approach (cross-curricularists, take note!). They co-operated closely with an outside agency made up of a second team from a specialist pneumatics supplier. Computer assisted design (CAD) techniques were used to design and evaluate prototype and final versions of the pneumatic circuitry.

The CAD package used for design and development was the Kosma Expert System. This is true CAD software and, it has to be admitted, is far more sophisticated than anything affordable by schools. It is a customised version of the well known Autocad software and allows the selection of pneumatics components from pull-down menus. It is however much more than a library of parts. The designer of a pneumatic system is required to enter data relevant to the design. Such parameters include requirements like the mechanical force needed, permitted or required stroke lengths etc. The CAD system can then display all or any of the components which are available to meet a specific set of design criteria.

One over-riding reason for choosing pneumatics for this application lay in space saving. For many of the figures' movements a cylinder stroke of 5 mm or so was all that was needed.

In order to save even more space, and fit a greater number of components into a single wax figure, the team went on to develop a single unit which combined miniature manifolds, pressure regulators and solenoid valves all in a single unit. The use of such units then allowed for the control of several complex, pneumatically driven movements even though the space inside each wax figure was severely limited.

An example of one of these figures is shown on the front cover of this bulletin issue. This is in skeletal form and many of its mechanical and pneumatics parts can thus be seen. Those of you who have read Isaac Asimov's *Foundation* series of novels may be reminded of Daneel Olivaw. All we need now is the "psiotronic" brain.

Numbers in safety

Pneumatics devices are often to be found as parts of safety systems in production plant. A simple, if somewhat over the top, safety sub-system is shown in Figure 3. This cuts off the supply of air to any incomplete working circuit.

In the system shown in figure 3, any drop in pressure in the working circuit will cause the direct acting cylinder *(D/A)* to retract. When the *Start* button is pressed the shuttle valve will switch and apply primary air to the cylinder. This cylinder will slowly move until the cylinder rod activates the $^3/_2$ spring return valve. Once that happens the push button can be released and the lever lockdown valve opened to supply air to the working circuit.

The principle behind this design is simply the force per unit area idea behind the concept of pressure. Although the pressure on either side of the piston is the same, the area of the *OUT* side is greater than the area of the *IN* side.

This is therefore an excellent introductory circuit for the use of pupils. They will quickly learn that it is not possible to pipe up or strip down their working system if the air supply is switched on. Should they attempt to do so the safety circuit will sense the resultant pressure drop and switch off the air supply. In any explanation of its action a simple mathematical treatment of pressure as force per unit area is unavoidable.

Another example is provided by the circuit shown in Figure 4 (opposite). This is but one means of providing a slow start up system. Further explanation would be superfluous. Build it and try it for yourself.

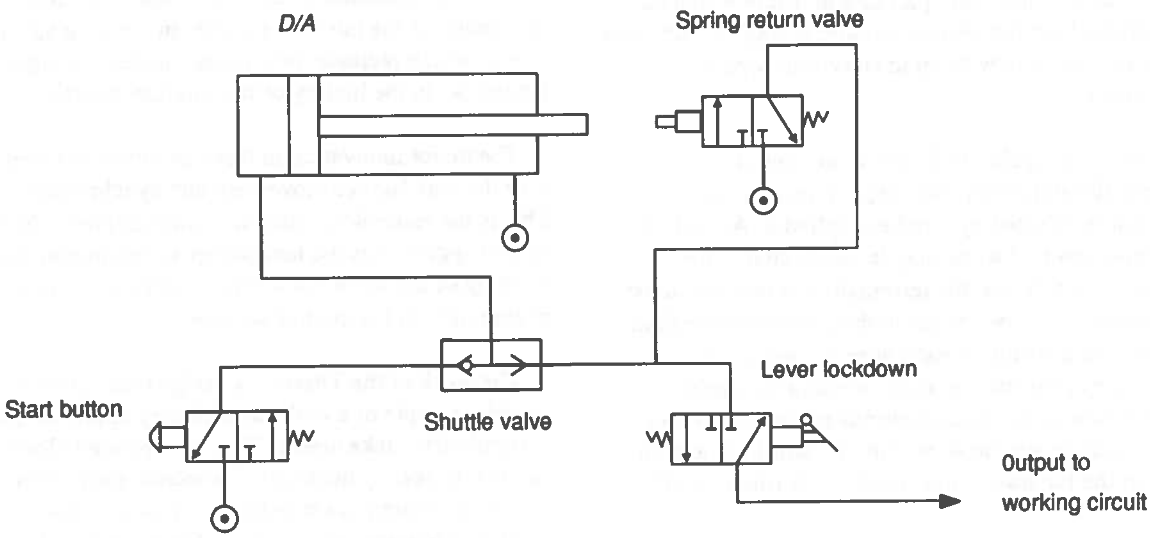


Fig. 3 Pneumatic safety cut-out

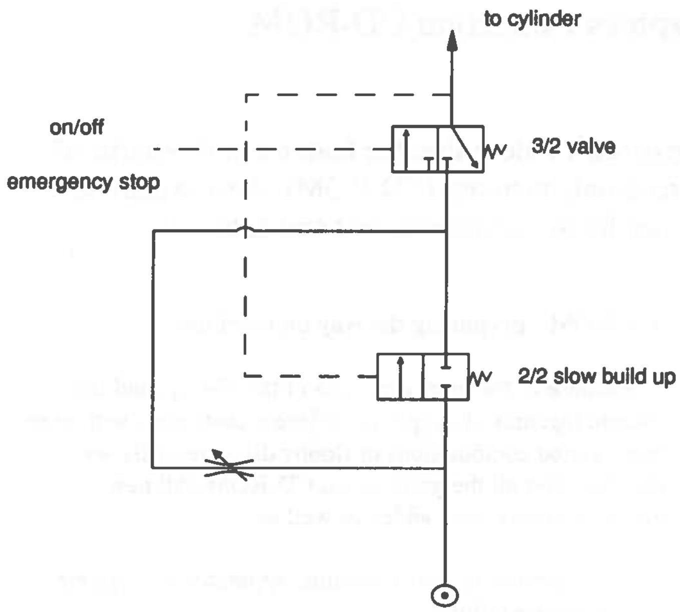


Fig. 4 Slow start arrangement

Summary and conclusion

In many industrial applications pneumatic components are preferred to electro-mechanical devices. This is for a number of reasons. In general they suffer fewer break-downs. They are safer as well as more reliable in operation and are often to cheaper to make. No less important is the fact that the same result may be often be achieved with a smaller number of parts than an electro-mechanical solution might demand.

That school technology departments seem less keen on using pneumatics may be attributed to the expense of equipping a course with industrial standard components. So the excitement and realism of the industrial situation does not translate to the classroom for financial reasons. What seems a 'cheap' alternative in industry may look anything but to a school. This is a factor rarely acknow-ledged by those well up the educational hierarchy when they urge on us industrial links and seek to advance the cause of mimicking industrial techniques of control and instrumentation.

That cause need not be the sole *raison d'être* of school pneumatics. It also provides opportunities to introduce some practical and meaningful mathematics.

How do we choose a particular type or size of cylinder for a specific application? How about introducing ideas on kinetic energy, pressure, cross-sectional areas?

Numeracy is undoubtedly a so-called *core* skill and a collection of ideas on and techniques in handling number is useful for every pupil. For anyone contemplating any kind of technological vocation - rocket engineer, motor mechanic, production manager or carpenter - it is an absolute, inescapable, requirement.

Competition and prizes

A £10 book token is on offer (or the equivalent in items from our sales list of motors, components etc. No and second prize isn't £20 worth of surplus!) to the best and most amusing suggestion as to the identity of the *being* on the front cover of this issue.

An identical prize to whoever comes up with the best caption and another prize, equivalent or better, for an **innovative** pneumatic circuit which could be incorporated in a robotic design.

This competition is open to pupils as well as teachers and technicians. Winners and runners-up will be announced in Bulletin 180.

Acknowledgements

We are grateful to the following organisations and individuals for their assistance in the preparation of this article :

Design Products and Applications Ltd.
MECMAN,
Diane Robertson Education Officer
Madame Tussaud's

Graphics

The pneumatics symbols shown in the diagrams for this article are to BS 2917 : 1977 (ISO 1219). They are available as part of SSERC Graphics Libraries on the SSERCSoft Technology Disc. They also form a tiny part of our CD ROM for Archimedes and other Acorn A-Series computers (for more detail see the next article).

Technical Articles

Computer assisted drawing : SSERC Graphics Collection CD-ROM

This article has been set in what some may see as *hypetext*[1]. It describes the features and benefits of our graphics and data collections on compact disc, read-only memory (CD-ROM). Also explained are some of our own, in-house, applications of this vast library of objects, text and data.

Introduction

As the inside cover proclaims, this issue of the Bulletin, like most in the last decade or so, was typeset in-house. Similarly much of the artwork including the line drawings was prepared in SSERC.

Fewer and fewer drawings these days are drafted from scratch. Increasingly they use elements from previously drawn objects which form part of a huge collection built up over the last five years or so. New objects are continually being added to the library when they arise from figures drawn to illustrate either this publication or our training materials.

Graphics Libraries on floppy discs

It was realised early on that other Archimedes[2] users might find many of these science and technology graphics useful in their own work. Such was the time saved by using standard, scaled elements from a library of objects that teachers and others were prepared to pay money for such a collection of high quality line drawings. Approaches were made by other Arc users offering to swap Drawfiles for some of our graphics. When the quality of these outside contributions was sufficiently good they also were added to the library.

Before long this collection occupied fifteen 3½" floppy discs and demand from users of other machines meant that many of these were also available in other formats e.g. for the PC in DXF, TIFF and EPS. We have been earnestly trying to get suitable Mac versions but have had a number of setbacks. Watch this space for developments. As might be imagined, the logistics of managing the sales of this lot became somewhat unwieldy - especially for an activity which had begun as a spin-off from our own mainstream work. We had to look for a more space-effective format.

[1] "*Hypetext*" - modern typeface reserved for the production of unashamed self publicising reviews. Developed specially by, and for the use of, software authors and Information Technology Advisory Centres.

[2] Trade names are acknowledged as the properties of Acorn Computers, 4Mation, Computer Concepts or Oak Solutions as may be appropriate.

CD-ROM - preparing the way on hard disc

Because of the increasing size of the library, and the fraught logistics of supplying different customers with even more varied combinations of floppy discs, recently we decided offer all the graphics on CD-ROM. All new graphics to date were added as well as:

- composites of useful circuits, apparatus set- ups etc.
- software utilities
- sample data gathered using data-logging techniques
- collections of molecular models produced by the *SSERC Chemical Modeller* software.

The operation required a 540 megabyte hard disc to hold all of the data. We commissioned Roger Spooner of *Design Concept*, (an Edinburgh-based software house) to design a front-end indexing program for the CD. This was an absolute necessity if users were to make best use of all the graphics and data on offer.

This operation proved extremely useful for in-house purposes. For example, because of the multi-tasking capability of the Acorn A-Series, it is possible to use a DTP package to prepare or revise training materials whilst at the same time running the library indexing program. Previously drawn diagrams or graphic objects could be quickly found and either dropped directly into a page frame or tweaked in a suitable drawing package such as Draw, Vector or Snippet[2] and then placed directly onto a page.

Compact disc

Once the hard disc stage was working satisfactorily it was detached and sent away to be used to make a master for a compact disc, read only memory or CD-ROM. To be doubly sure that all was OK we had write-once-only *gold discs* made. Forty of these versions have been sold or reviewed and have been well received. The latest stage has been reached where a glass master is made and the first big batch of *silver* discs pressed before Christmas. The first 100 customers will also receive a complimentary copy of the highly acclaimed *!Draw Practical Guides* 100-page book.

What can the CD-ROM offer? See Table 1 opposite.

Platform *- all Acorn A-Series with CD-ROM drive*

One price *- £150 for a full School Site Licence*

Data *- 9000 files (average cost per file 1.7 p!)*
- more than 4 years of graphics work
- 330 Mb
- 880 interfacing files from real experiments
- 28 Vector Libraries
- !Draw Practical Guides included

File types *- Drawfiles, Text-to-Path, DXF & sprites*
- 1045 files compatible with Worracad

Molecules *- 127 molecules each in up to 18 different model representations*

Help *- interactive help available on search operations. 38 multiple page help and information files available for multi-tasking display with graphics or applications*

Programs *- to generate Drawfiles of waveforms, mathematical functions, gears (isometric & orthogonal), sprockets, ratchets, bevels, tapped threads, washers, cylinders, nuts, bolts tesselations, perspective, tunnel, sheared views, serial communication, colour mixing, refraction, convex lens operation etc. etc*

Front-end *- upwards of 50000 key words*
- indexing data alone is almost 1Mb
- multiple key-word entry accepted
- selective search by file type possible
- fast access to any file on the CD-ROM

Table 1 Information and statistics on the SSERC Graphics Collections CD-ROM

Decreasing drive costs

Both Morley and Cumana have recently launched some new CD-ROM drives which are less expensive than earlier models. These are also easier to connect to the computer. The advent of these devices means that the twin barriers of cost and convenience have been considerably lowered and are now much less of a hindrance to the fuller application of CD-ROM as an educational tool.

Applications

In order to show how the graphics collections may be used Figure 1 below shows the raw ingredients of the diagrams used to illustrate the safety cut-out device shown as part of the article on pneumatics in this issue. These can be searched out using keywords and then quickly compiled into a circuit simply by adding lines of appropriate thicknesses and any labels which may be needed. In similar manner electronics circuits may be drawn up, or stripboard layouts produced from other collections of suitable, consistently scaled graphics.

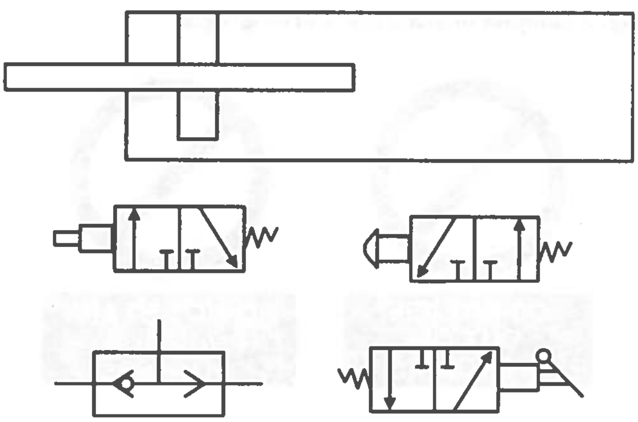


Fig. 1 Components drawn to BS 2917 (ISO 1219) used in drawing of the safety circuit on page 14.

The wet sciences are also well catered for. Figure 2 should serve as an example and shows the elements of a set of apparatus used to illustrate our training materials on interfacing in chemistry. These collections of standard apparatus are particularly useful because they were prepared to a consistent scale. Thus bungs fit the appropriate flasks and test tubes and tubing fits the bungs. The diagram is completed by arranging these elements and adding lines and labels as shown overleaf as Figure 3.

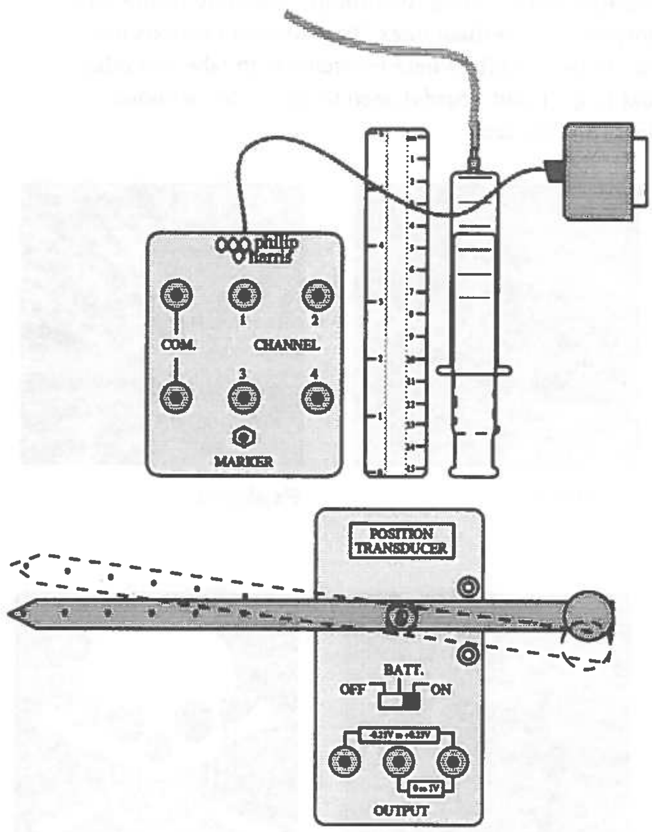


Fig. 2 Elements used in a diagram of a system for monitoring rates of reaction by logging rates of gas production.

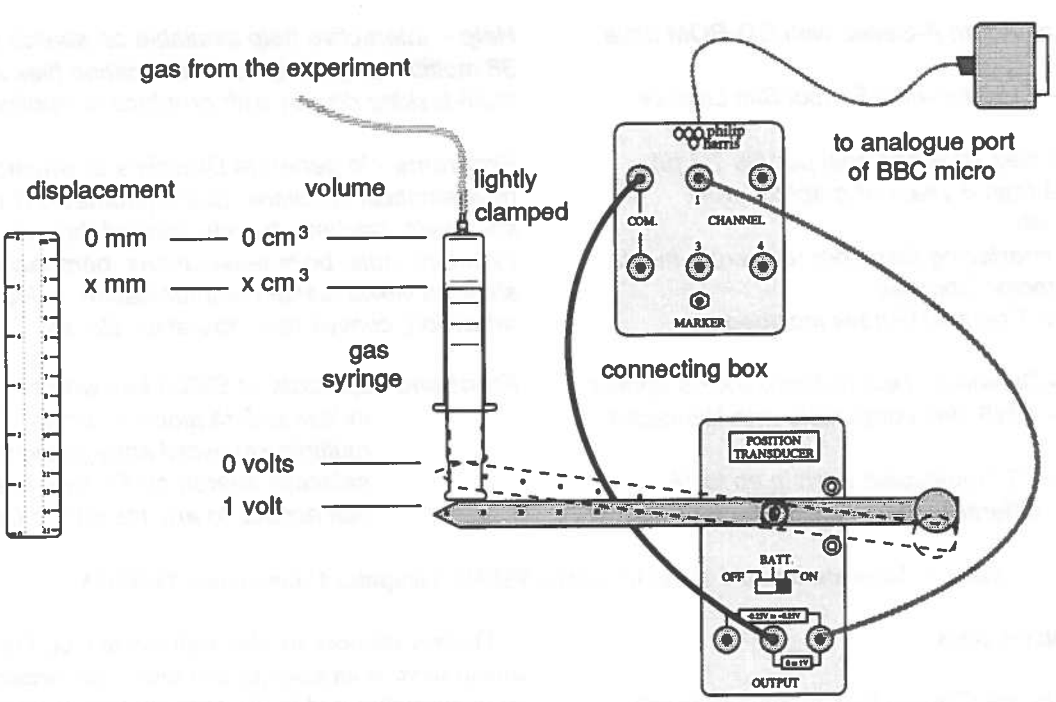
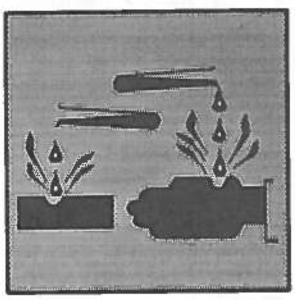


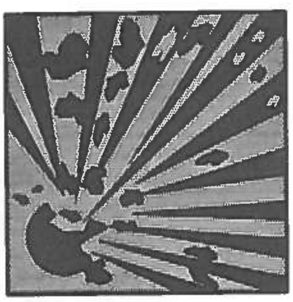
Fig. 3 Composite drawing using graphics elements shown in Figure 2.

Set grid patterns

This is one of the keys to successful preparation of composite drawings. Because all of our elements were drawn to set grid patterns they may be edited and manipulated avoiding distortions caused by losing vital horizontal or vertical lines. Text-to-path versions are particularly useful where elements with labels or other text (e.g. circuit boards) need to be rotated without distorting the text.



Corrosive



Explosive

Oxidising

Toxic

Fig. 4 A selection of hazard warning signs from the library

Safety signs

Nor is health and safety neglected. The hazard warning pictogram in the Safety Notes section of this issue is too new to have been included on the CD but all the major pictograms required by the older CPL Regulations are there as are a number of other standard signs. Figures 4, 5 and 6 provide examples.

Fig. 5 Samples of electrical warning signs

Fig. 6 Samples of more general warning signs

Indexing

This is literally the key to the SSERC CD. With so much data there has to be some means to find a file easily and quickly. When the library was organised by topic or subject this could be partially achieved by means of a sensible directory structure. With a collection the size of the CD-ROM library an index and keyword search facility is a must.

The front-end to our CD is intended to provide such means of access as well as cross-referencing and display of any file from a total of about nine thousand in total. Provided that you know part or all of the subject word for which you are looking, access times typically are less than ten seconds.

The text and graphics box shown below is made up of facsimiles of the screen displays associated with this indexing and searching facility and provides a summary of many of its features. The front-end index makes the task of putting together multi-media presentations much easier as disparate graphics, applications, data and programs are drawn together. e.g. a keyword search for *ECG* will bring up not only drawings and sprites of the heart, but also an explanation of the PQRST waveform, a biological amplifier, a microcomputer screen ECG display colour-corrected for black and white printing, an ECG interfacing apparatus set-up and, finally, real interfacing data derived from that apparatus. Any or all of these elements may be quickly incorporated into a document via a DTP package or into other media for presentations.

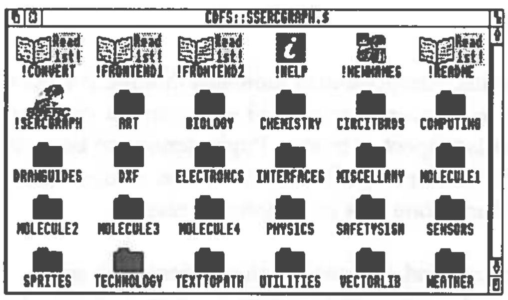
Further information on the 15 *Graphics Libraries* (we still sell these incidentally, £10.50 + VAT per disc), or the *SSERC Graphics Collections CD ROM* please write to us here at the Centre. The libraries are the brainchild of Ian Birrell, SSERC Development Officer. He is the first point of contact for other than routine enquiries.

Acknowledgements

To all of those teachers, technicians and others who have contributed in some way or other to the library we are extremely grateful. In particular, thanks go to John Hammell for his technical assistance and encouragement throughout.

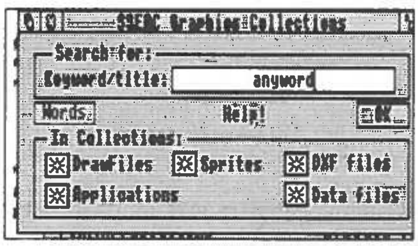
The SSERC Graphics Collections CD-ROM

Getting started *- Load the SSERC CD-ROM into your CD drive and click SELECT once when the mouse arrow is over the CD drive icon on the icon bar at the bottom of the screen. The drive light will flicker and the root directory (highest level) appears as below :*

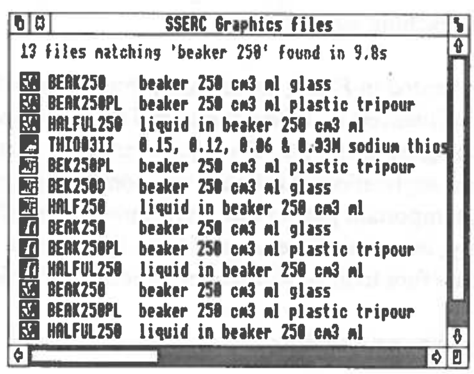


The root directory of the CD-ROM

Double click SELECT on the !SERCgraph application to install the !SERCGRAPH CD application on the icon bar. Click SELECT on the SSERC CD icon to run the front-end application. The index application also supports interactive help. Double click SELECT over the !HELP application and SELECT over the icon on the icon bar. Now move the mouse pointer over anything that takes your interest and all is explained.



Front-end application *- helps you find a file you want, based on reference keywords. Each file has several keywords, so you just need to find one or more of them. You can also restrict the search criteria by selecting/deselecting file types. You can even enter parts of the word if you are not quite sure and it will present you with a number of possibilities and how often they occur. Once a file has been found, you may view it in an appropriate application e.g Draw, Vector, Artworks, DTP.*



The Search Match window

Feature Article

Robotics systems - A survey of users Part II

The pupils' views

Bill Lindsay

This article follows on from an earlier account [1] on teachers' perceptions of robotics systems used for teaching purposes.

Introduction

To recap from Part I the curricular context for this survey was Scottish Technological Studies courses. These seek to develop :

"- an understanding of technology as it is applied in industry and commerce;

- an awareness of applications of technology in the community;

- a recognition of the responsibility to humanity and the environment and

- an appreciation of the need for flexibility by the individual with regard to work practices" [2].

In an attempt to meet the above requirements pupils are meant not only to be exposed to a wide range of technological equipment but are to use it to solve specific problems. This range of hardware is intended to include computing and control equipment including robotics systems.

This emphasis on hands-on experience means that there may be at least two, distinct user groups for any classroom robotics system - teachers and pupils. This article seeks to compare, and if need be to contrast, the views and attitudes of these two groups to a range of robotics teaching equipment.

As indicated in Part I, attitudinal outcomes may be heavily influenced by both general and specific aspects of the teaching environment. The equipment used in the study and application of robotics and computing systems forms an important part of that environment. Its safety, reliability, user friendliness and fitness for purpose are likely therefore to have significant effects on learning.

Survey aims and method

Phase 2 of the research study [3] set out to gather data on pupils' impressions of a range of educational robotics equipment. These were then compared with the teachers' opinions.

School and pupil samples

From within each of three Scottish secondary schools, one class group was selected for involvement in the exercise. The usual, maximum, class size for this subject is twenty pupils but actual class sizes used in this study were sometimes less and samples thus varied somewhat.

Pupil evaluation exercise

Arrangements were made with each of the three participant schools for robotics equipment to be set up and for an evaluation exercise to be carried out with the class group. Pupils were issued with a task sheet. In small groups, they programmed one of the systems to carry out a specified task. On completion the pupils filled in a questionnaire before repeating the same task with a different system.

Thus, for each task every pupil had used a number of different systems and had completed a questionnaire. The resulting data was consolidated, analysed and presented in tabular and graphical forms.

Analyses

Comparing questionnaires indicates that the teachers generally were more restrained in expressing a view on any particular aspect or model. Pupils tended to be more extreme in their opinions but were, on the whole, more positive. That alone was an interesting result.

The same broad approach to the presentation and discussion of results will be followed as was adopted for Part I. The broad classification of features into hardware and software and the use of sets of evaluation criteria under headings such as reliability, ease of use etc. will again be used.

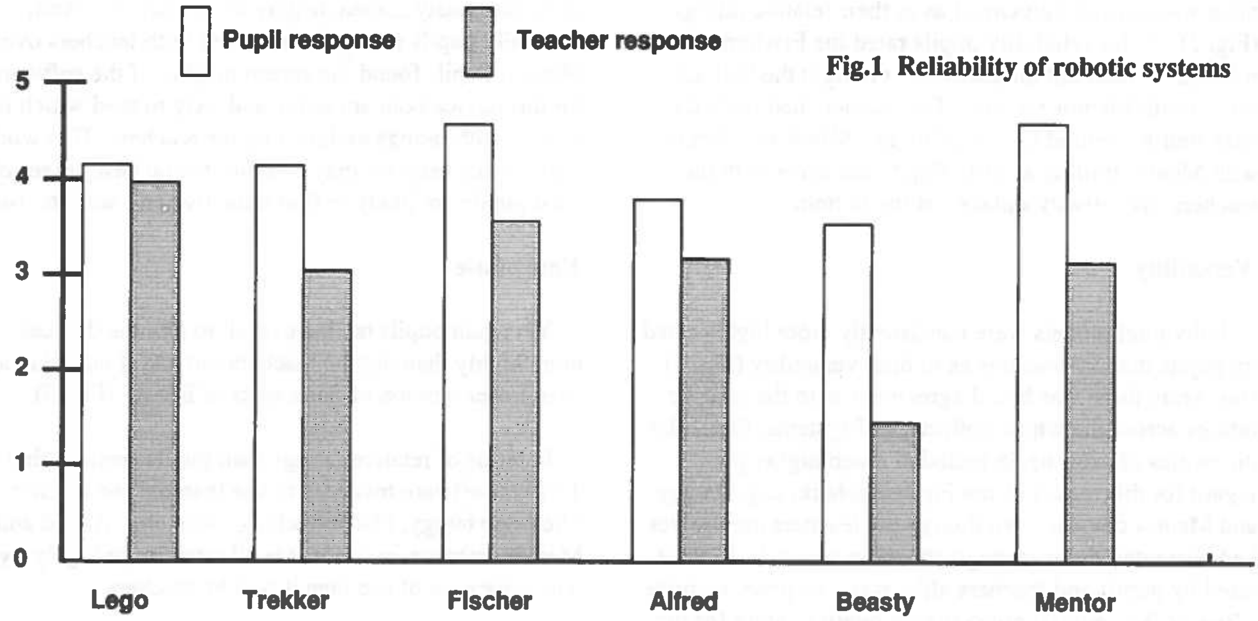
Hardware

Reliability

A somewhat different vocabulary was adopted for the evaluation exercises with pupils than that used with teachers. For example, to make it more meaningful to pupils "reliability" was broken down into three direct questions about the robotic device:

1. Did it do what you wanted it to?
2. Did it go where you wanted it to?
3. Did all the bits of it stay together while it was working?

Fig.1 Reliability of robotic systems



As earlier indicated, pupils appeared more optimistic than teachers when assigning ratings to various aspects of robotics teaching systems. Even when that overall tendency is allowed for, there is still some agreement between the two groups. This can be seen in their relative ratings of systems (Fig. 1). Where there are significant differences these lie in pupils rating three of the devices - Fischertechnik robot, Beasty and Mentor - as more reliable than did the teachers.

These results raise questions as to teachers' own interpretations of "reliability" which may suggest earlier unsuccessful experiences with robotic systems. If that is the case then the experience of such teachers in the field does not equate with that of the majority of pupils in this particular exercise. It may highlight a need for further training in the setting up and use of robotics equipment in a classroom environment.

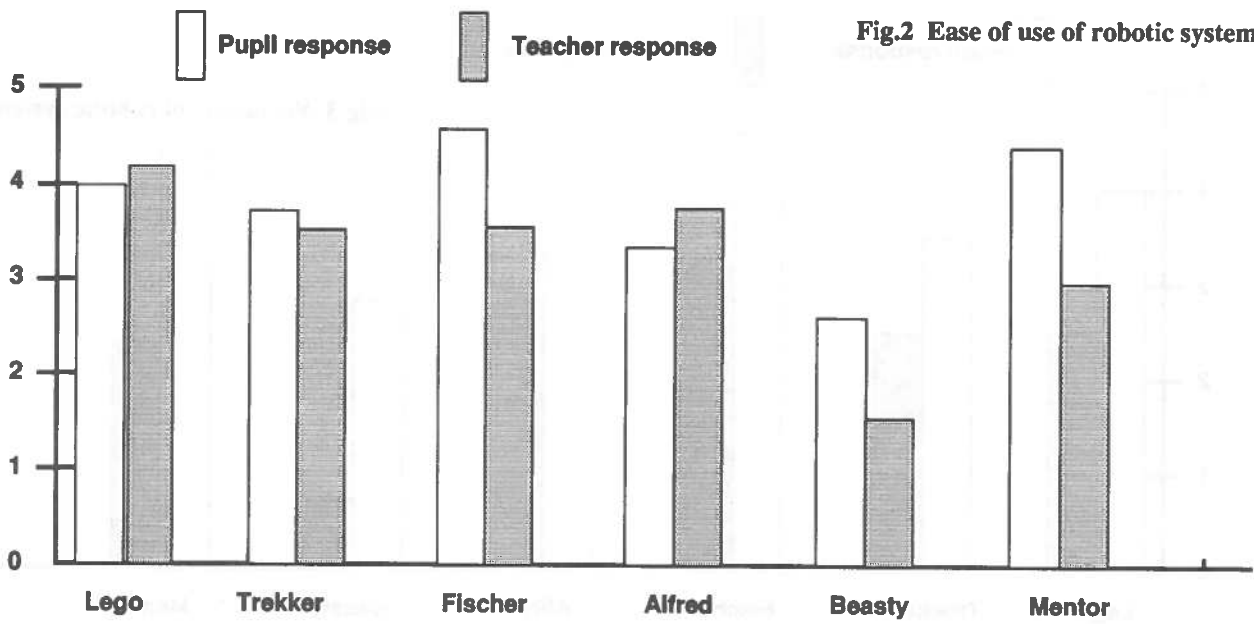
It is notable that both groups agree in rating Beasty as the least reliable device. Separate analysis of scores for pupil responses to the three questions pertaining to reliability reveals some other interesting differences.

The first two questions relate to reliability of operation whereas the third question relates to reliability in terms of robustness of construction. When the pupils' responses to that third question are ignored their overall rating for the reliability of Beasty falls significantly. It then approaches more closely the score assigned by teachers. This suggests that whilst the pupils judged it, in their short experience, to be reasonably robust they did not find it reliable in the sense of operating well.

Ease of use

Again there were variations in the scores of teachers and pupils related to aspects of ease of use. For most systems

Fig.2 Ease of use of robotic systems



there was general agreement as to their relative ratings (Fig. 2). As for reliability pupils rated the Fischertechnik robot more than did the teachers, giving it the highest score (with Mentor second). The teachers had ranked it only fourth, behind the Lego buggy, Alfred and Trekker with Mentor trailing at fifth. Pupils did agree with the teachers over Beasty's place - at the bottom.

Versatility

Individual models were consistently more highly rated by pupils than by teachers as to their versatility (Fig. 3). But, again there was broad agreement as to the relative ratings across the whole collection of systems. Particular disparities of view again included much higher pupil regard for this aspect of the Fischertechnik, Lego buggy and Mentor devices even though the teachers themselves had also rated these amongst the more versatile. Lowest rated by pupils and teachers alike was - surprise, surprise - Beasty. The pupils' much higher relative rating for the Lego buggy was of particular interest. It may suggest that pupils come to study and use this kind of control system with fewer preconceptions than do teachers of what constitutes a "robot".

Software

User interface

Much the same questions, on attractiveness to the user and ease of use, as were put to the teachers were asked of pupils. The wording was simplified however to :

1. Was the screen display attractive?
2. Was the screen display easy to read?

The results of this part of the survey are shown in figures 4 and 5. Pupils rated Trekker and Beasty software screen displays as "not easy to read" but paradoxically rated the Beasty screen display as "attractive". And, ironically pupils yet again disagreed with teachers over Mentor. Pupils found the screen display of the software for this device both attractive and easy to read which is it at odds with ratings assigned by the teachers. This would suggest that teachers may well not be the best judges of what pupils are likely to find attractive and want to use.

Ease of use

Yet again pupils tended overall to rate the devices more highly than did the teachers but had if anything an even lower opinion of this aspect of Beasty (Fig. 5).

In terms of relative ratings then pupils seem to find Trekker software less easy to use than did the teachers. The Lego buggy, Fischertechnik robot arm, Alfred and Mentor software in contrast is all rated more highly by pupils for ease of use than it was by teachers.

What should a robot do?

Like teachers the pupils were also asked to place a rank order on a list of tasks or attributes of which a robot should be capable or possess. They agreed with teachers in putting "pick and place" at the top of their lists. "Being able to follow instructions" they also saw, again like teachers, as very important. They differ however in ranking "an ability to sense the environment" as third in importance. Teachers placed this attribute at fifth equal alongside mobility and ability to simulate industrial robotics applications.

Summary

Pupils and teachers are clearly agreed on many points covered in these surveys. For example, except in only one regard, nobody likes poor old Beasty. They are also

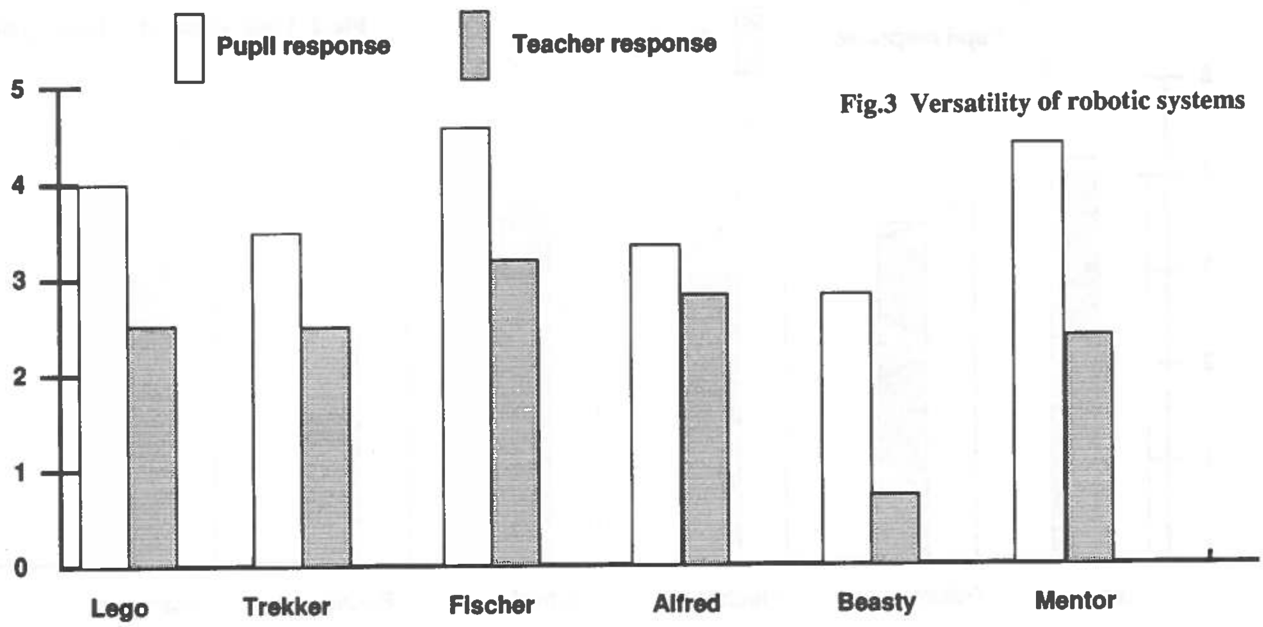


Fig.3 Versatility of robotic systems

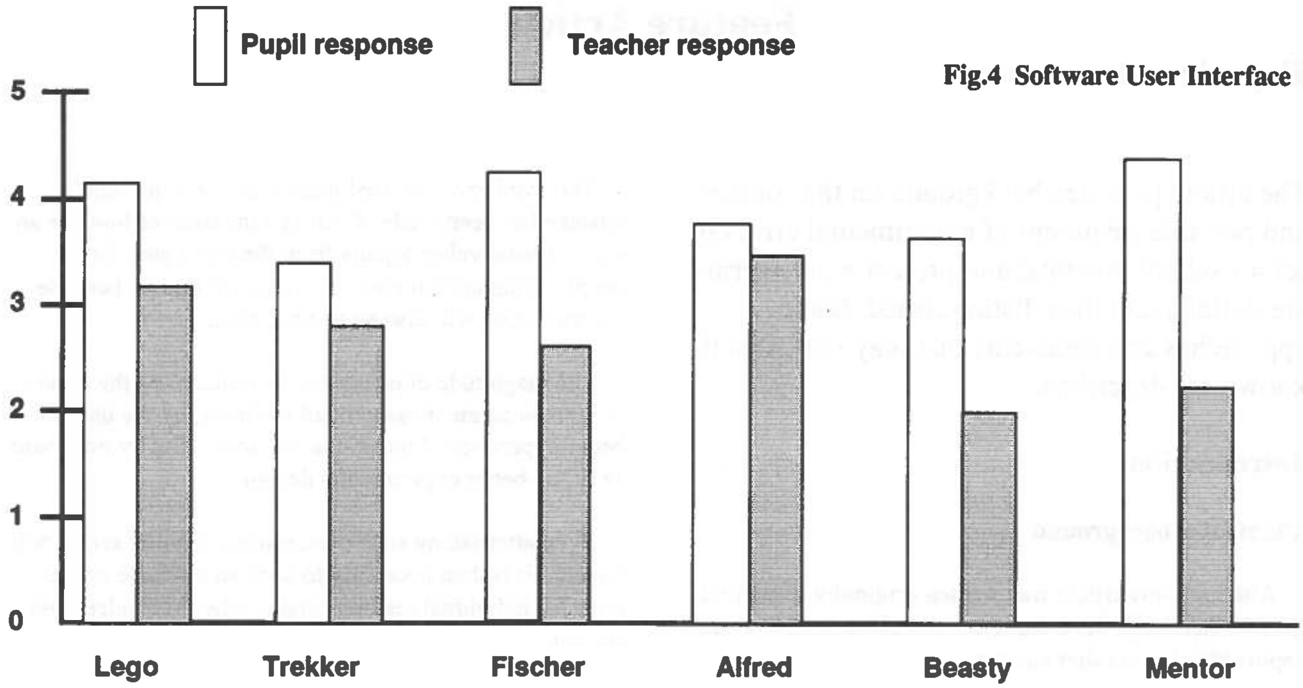


Fig.4 Software User Interface

agreed that whatever else they can do robots should be able to pick and place objects. Yet, two of the fairly well liked devices are incapable, in themselves, of carrying out that type of task (Lego buggy and Trekker).

Alfred, Mentor and Fischertechnik robots are reasonably well regarded by teacher and pupil alike but Alfred was seen by teachers as the least versatile of these three. Significant disagreement emerged between pupil and teacher users over the attractiveness of user-interfaces for the control software. These specific differences arose over Mentor, Fischertechnik, Alfred and Beasty. The pupils found all of these to be more attractive than the teachers had judged and (except for Beasty) found them all easier to use than the teachers had suggested they might be.

Conclusion : in evaluating and choosing equipment the class teacher sometimes may not be as reliable a judge of certain aspects of pupil needs as might often be assumed.

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2. *Technological Studies at the Standard Grade*, Conditions and Arrangements, Scottish Examination Board, 1988.

3. *Robots in Technological Studies*, W.G.Lindsay, 1991, M.Sc. Dissertation.

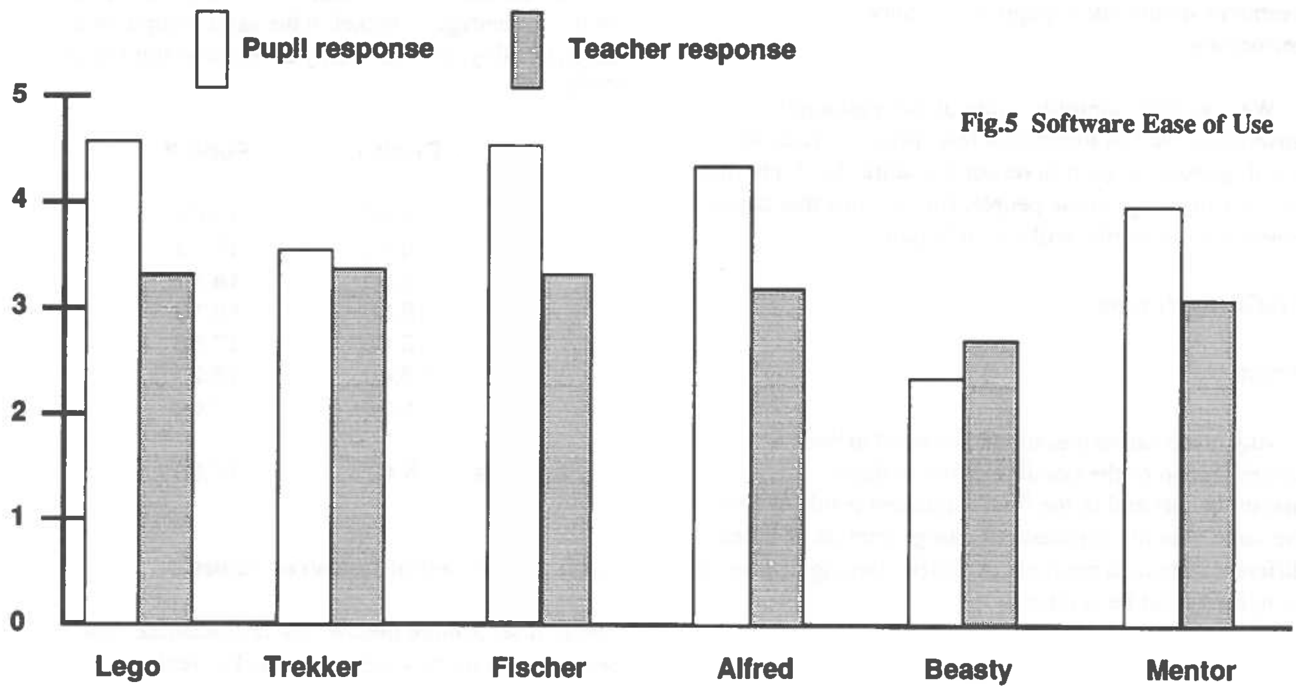

Fig.5 Software Ease of Use

Feature Article

Experimental errors

The article provides background on the sources and possible treatment of experimental errors in senior school practical and project work. Terms are defined and thus distinguished. Some approaches and short-cuts that may not be well known are described.

Introduction

Curricular background

Although this article was written originally to support CSYS Chemistry, the techniques and ideas described are applicable also in other subjects.

Purpose and scope

The purpose of this document is not that of replacing the relevant chapter in Memorandum 16 on CSYS Chemistry, but to provide additional background which pupils might find useful in their treatment of data in project work.

The level of treatment recommended in the introduction of Memorandum 16, the use of significant figures to express uncertainty - both in experimental readings and in the final calculated answer - is fine for the set experiments. Where quantitative measurements are made in projects however, for example in physical chemistry, then the use of a slightly more sophisticated treatment should allow pupils to enhance their performance.

We also try to simplify some of the traditional methods as well as illustrate a few short cuts and other novel approaches seen in recent literature. No doubt this article will enrage some people. But we trust that others, especially the pupils, will find it helpful.

Defining terms

Error

Any quantitative measurements must include a determination of the possible errors in those measurements and in the final calculated result. Where the same quantity is measured a large number of times, different statistical methods of widely varying degrees of complexity can be applied.

The word *error* as used here does not imply that a mistake has been made. *Error* is a measure of how far an experimental value departs from the true value. Some people maintain that error can never be known because the true value will always be uncertain.

The magnitude of errors can be reduced by the choice of more accurate measurement methods, by the use of better experimental technique and lastly, but by no means least, by better experimental design.

Even after taking such precautions, smaller errors will remain. It is then necessary to state an estimate of the error for individual readings and for the final calculated answer.

Precision and accuracy

These two terms are often used in everyday language as though they had the same meaning. In fact they are quite different.

True error is an indication of the *accuracy*. It is the closeness of the observed or experimentally determined value to the *true* result or *commonly accepted* value.

Precision on the other hand gives an indication of the reproducibility or consistency of a set of results.

Example

Consider the results obtained by two different students for the percentage of nickel in the same sample of a magnetic alloy, the commonly accepted result being 17.99 :

	Pupil 1	Pupil 2
	18.35	18.02
	18.42	17.73
	18.50	18.41
	18.50	18.13
	18.45	17.86
	18.40	18.20
	18.38	17.60
average	18.43	17.99

Table 1 Two sets of measured values

The first set is more precise, but less accurate. The second set is more accurate, but lacks precision.

Random errors

Many errors are random in nature in that the readings or the results are just as likely to fall on either side of the mean answer. Trustfully the mean will come out close to the true answer. If many results are taken and the number of times each answer is found (or frequency) is plotted against the magnitude of each value, a symmetrical bell-shaped curve or Gaussian distribution results.

In the absence of other sources of error most of the results will lie close to the true value and a smaller proportion far away from it (Fig. 1).

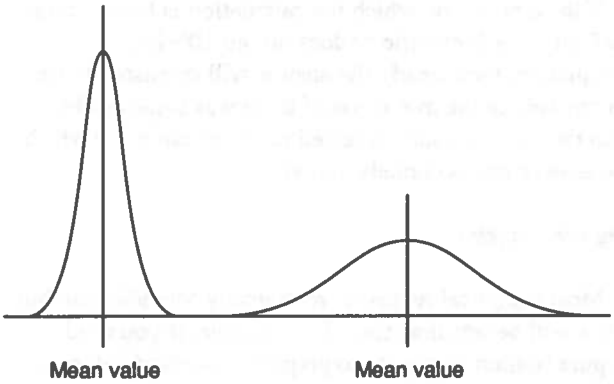

Fig. 1 Distributions showing random error

A more precise set of results with the same accuracy produces a tighter curve, which might also have a narrower mouth to the bell. This has a larger proportion of the results close to the mean value. One way of expressing the size of the spread about the mean is to calculate the standard deviation (SD). The left hand distribution (Fig. 1) has a smaller SD than the right hand one.

Reading errors

Some errors connected with reading scales and divisions are of a random nature. The use of instruments with a finer scale helps to minimise such errors. Conversely, a titration carried out with a measuring cylinder instead of a burette would produce larger random errors!

Analogue and digital readouts

With an analogue readout you are aware of the need to interpolate and estimate the position of the needle between two scale divisions, or of a liquid level in a burette between two 0.1 divisions. You cannot escape realising that there is some degree of uncertainty. On the other hand the human error in reading a digital instrument will be zero or close to it. Because of this many people wrongly assume that that such instruments are always more accurate than analogue instruments, forgetting that these devices have their own internal errors. This aspect is discussed in more detail later.

Systematic errors

In practice many errors are biassed or systematic as well as random (Fig. 2). If there is a systematic error, then a set of measurements will largely, or entirely, lie to one side of the true value. Such errors are insidious in that they are not easily recognised, unless of course you know the answer or true value from another source. In Table 1 the results obtained by the first student were almost certainly due to some systematic error. Possibly he or she had a bad pipetting technique, but had employed it consistently; alternatively one of the instruments may have been poorly calibrated.

Figure 2 illustrates some of the ways in which systematic errors, or a bias, can effect the accuracy of

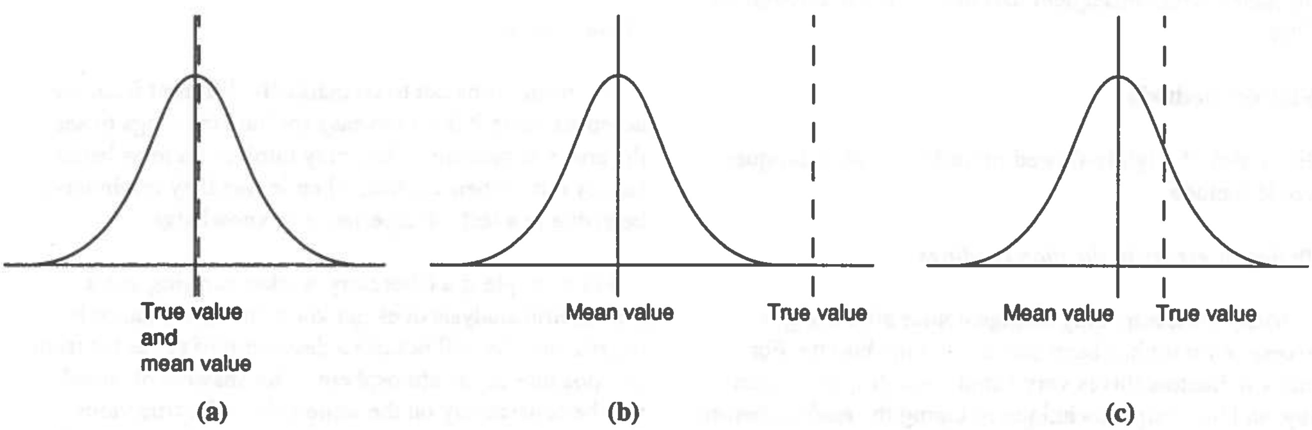

Fig. 2 Distributions showing systematic error

readings. In 2(a) the readings are scattered to an equal extent on both sides of the true value, or commonly accepted value, ie the mean coincides with the true value and no systematic error was operating. If a large bias operates (2(b)), whilst the readings are still symmetrically distributed on either side of the mean due to random errors, the mean is displaced from the true value. Often the bias is not as large as that and the situation of 2(c) is found where the true value lies in one of the arms of the random error distribution curve.

Sources of systematic error

A number of examples are given in the context of chemical analysis. Teachers or pupils of other subjects should however spot useful parallels and suggest other illustrations from their own specialist viewpoint.

Incorrect calibrations

One example would be a burette which delivers a total volume of 50.4 cm^3 when the level of titrant is run from zero to the 50.00 cm^3 graduation. Another example would be where a balance reads high by say 0.1g in 100g.

Poor personal technique

Carelessness is likely to cause random errors, but bad technique can be consistent. If a pupil always blows out the last drop of liquid from a pipette, then the resulting errors will always be on the same side of the true value.

Another example is that of a laboratory worker who tends to overwash precipitates for gravimetric analysis. His or her results will always be on the low side. If there is a tendency to underwash then some of the soluble precipitating reagent may be left in the precipitate and the results will always be on the high side.

Similarly the quality of technique will affect conditions under which the precipitation is carried out. That will affect the purity of the precipitate and its graininess. That in turn will affect the ease of filtration and any colloid formation with consequent loss of precipitate through the filter.

Flawed methods

Examples of slightly flawed procedures and techniques could include :

Indicator errors in titration readings

Many indicators only change colour after a slight excess of titrant has been added from the burette. For many indicators this is very small, one drop or $^1/_{30}$ cm^3 say, and the simple technique of taking the reading before the addition of each drop is added near the end point will remove virtually all of this error. Some indicators require a larger excess before they change and if there is doubt, then a "blank" titration should be performed. Here the substance being titrated is replaced by water or by a salt solution of similar ionic strength and the titrant slowly added until the indicator changes. This value is then subtracted from the other readings.

Parallax errors

These may be made in reading a burette, say, or any other analogue instrument; this particular error can be ironed out by learning a better technique.

Incomplete reactions

If the reaction on which the calculation is based is not perfectly stoichiometric or does not go 100% to completion, then clearly the answer will consistently lie on one side of the true value. If there was some doubt, then the method could be tested on a substance for which the answer was accurately known.

Impure reagents

Most analytical reagents are typically >99.9% pure but a few will be less than this. For example, if you used impure sodium carbonate to prepare a standard solution against which to standardise solutions of acids, all of your calculated results would be out by the same factor. If a reagent cannot be obtained in form of high purity, you can either look up the supplier's specification and make allowance in the calculations or carry out a determination on a substance for which the answer will be accurately known. This is in effect standardising this solution also, rather than using it as a primary standard.

Interfering substances.

An example of this might be in the determination of calcium in a sample of water or rock type by titration against EDTA and not realising the sample also contains magnesium ions. These too will complex with the EDTA and consistently give a higher answer.

Human nature

If a result turns out to be markedly different from the accepted value it is all too easy for human beings to see the errors as random. They may think of them as being largely out of their control, when in fact they might have been due to a lack of experience or knowledge.

For example if a laboratory worker carrying out a gravimetric analysis does not know that a substance is hygroscopic he will not use a dessicator to protect it from the moisture of the atmosphere. The answers obtained will be consistently on the same side of the true value. The worker may still not recognise their systematic rather than random nature because of a lack of knowledge or experience.

Another personal failing is prejudice. For example if three measurements have been made which are fairly close together and there is a degree of uncertainty in reading the fourth, there is sometimes a tendency to move in the direction of the first three. Some workers have even been known to discard the fourth.

Detection of systematic errors

The presence of *random errors* is recognised fairly easily, but it is harder to recognise whether or not a bias due to sources of the types listed above is operating, thereby producing a systematic error. Some ways of finding out if systematic errors are operating are given below:

1. If the correct or expected answer is known, then it will be obvious if all results fall on the same side of this value. In research the true answer is not usually known in advance.

2. The total method can be tested using a 'known'. For example in the EDTA determination of calcium ions referred to above, the method can be tried with pure calcium carbonate dissolved in dilute hydrochloric acid and the pH adjusted in place of the water or rock sample. This will tell you if there is a systematic error caused by the presence of some interfering substance in the sample.

3. If the answer can also be determined by some other totally different method and this concurs, then you can have confidence that systematic errors are not operating, eg, if the percentage of calcium determined by a gravimetric method concurred with that from an EDTA titration. If a third, totally different method such as AAS (Atomic Absorption Spectroscopy) gave a result close to the others, then we could be confident that systematic errors were not large. This is akin to a mariner finding his position by astrofix, satellite fix and radio direction finding.

The total systematic error in the final calculated answer can be a sum or compound of several individual errors which may be operating. These might cancel one another out to some extent. A case of two wrongs making a right, if they are operating in opposite directions, is not unknown - but if they are operating in the same direction the errors augment.

Design of experiment and minimising errors

As seen above, it is not always easy to remove the factors causing systematic errors, but the magnitude of random errors can often be reduced by a bit of thought and better technique.

The uncertainty in reading an instrument is often fixed, ie, is independent of the size of the reading. In such cases the larger the quantity measured the smaller will be the percentage error. If a burette is reckoned to have an uncertainty of ± 0.05 cm^3 and if an unknown solution of sodium hydroxide had a concentration close to 0.01 mol l^{-1}, the first attempt at titrating 25 cm^3 of it with 0.1 mol l^{-1} hydrochloric acid will give a titre of about 2.5 cm^3. The percentage error resulting from the uncertainty in reading the burette will be (0.1/2.5) x 100, or 4%. Carrying out the subsequent titrations with 0.01 mol l^{-1} acid will reduce the percentage error to 0.4%.

You might be tempted to carry this logic to extremes by arranging for very large titration readings. However a number of factors militate against this. The burette will have to be refilled several times. This would require extra readings, and hence introduce further reading errors. The gain will be slight if the uncertainty of other measurements is not also lessened.

Estimating errors and uncertainties

As will be obvious it is virtually impossible to completely eliminate errors. Therefore it is necessary for an experimenter to present his answer together with some measure of the uncertainty. An example of this might be :

Density of ethanoic acid at 20°C = 1.025 ± 0.002 g cm^{-3}

The person who made the measurements is stating that the density lies between 1.023 and 1.027 g cm^{-3}.

To arrive at the uncertainty it is necessary to find out :

(i) the errors in the instrumentation itself, and
(ii) those which arise from the reading of the instruments, and
(iii) those arising from the experimental technique.

For the first type, ie *instrumentation errors*, manufacturers of equipment will state the levels of accuracy as *tolerances*. Over the page are some examples of the *tolerances* in liquid volume measuring apparatus supplied by some manufacturers (Table 2). The *grade* is normally engraved on the glassware together with the temperature at which the calibration is correct.

The volume delivered by a burette is the difference of two readings. The total uncertainty for a 50 cm^3 Grade B burette will be the sum of the two reading uncertainties, each say 0.03 cm^3, plus the tolerance, which, from Table 2, is 0.01 cm^3. The simplest way of combining these errors is by addition, ie (2 x 0.03) + 0.1 = 0.16.

The tolerance is the maximum total error in the volume of the vessel arising out of manufacture. For a given burette or pipette this will produce a small error which will be systematic. Do not confuse the *tolerance* with the *reproducibility*. Reproducibility is the random error associated with taking a reading. Both factors will

Capacity	Measuring cylinder	Burette Grade A	Burette Grade B	Pipette Grade A	Pipette Grade B	Measuring flask grade B
(cm^3)	(cm^3)	(cm^3)	(cm^3)	(cm^3)	(cm^3)	(cm^3)
500	±5	-	-	-	-	±0.5
250	±2	-	-	-	-	±0.30
100	±1	±0.10	±0.20	±0.06	±0.12	±0.20
50	±1	±0.05	±0.10	±0.04	±0.08	±0.12
25	±0.5	±0.03	±0.05	±0.03	±0.06	±0.08
10	±0.2	±0.01	±0.02	±0.02	±0.04	±0.05
5	±0.1	±0.01	±0.02	±0.015	±0.03	±0.05
1	-	±0.006	±0.01	±0.007	±0.015	-

Table 2 Glassware tolerances

combine to constitute the uncertainty in a value that has been obtained by measurement.

The uncertainty of ± 0.16 cm^3 calculated by simple addition as shown on the previous page gives a high estimate. The alternative method of squaring each uncertainty, then summing the squares and taking the square root of the sum probably gives a better estimate. If U_{total} is the combined uncertainty and U_1, U_2, etc. are individual uncertainties, then

$$U_{total} = (U_1^2 + U_2^2 + U_3^2 + \cdots)^{1/2}$$

Using this *square root sum* method for combining the uncertainties when measuring a volume delivered by a Grade B burette, the total uncertainty then becomes :

$$U_{total} = \pm (0.03^2 + 0.03^2 + 0.1^2)^{1/2} \text{ cm}^3$$

$$= \pm 0.11 \text{ cm}^3$$

$$= \pm 0.1 \text{ cm}^3 \quad \text{(rounding off error to 1 digit)}$$

This example shows nicely that when uncertainties are combined, the largest uncertainty, in this example the burette tolerance of ± 0.1 cm^3, or the largest percentage uncertainty, is usually a good estimate of the error in the result. Because of the square root sum formula, other smaller uncertainties have a negligible contribution.

The use of pipette fillers can introduce an error. Pipettes only deliver the stated volume (to the stated tolerances of course) if allowed to drain at the speed specified and provided by natural drainage. Those fillers which release the liquid by opening a valve to admit air to the space above the liquid will be satisfactory, but the simple piston type could be used to expel the liquid at a much higher speed. This will result in delivery of a slightly smaller volume due to the liquid left on the sides of the glass behind the rapidly falling liquid surface. If in doubt the thing to do might be to fill the pipette with the piston filler to above the mark. Then remove the piston filler and control the liquid with the finger on the top in the manner used before the invention of fillers.

Reading a scale

In reading an instrument with an analogue scale, for example a ruler or burette, it is often necessary to interpolate and to estimate the least significant digit. In the example below (Fig. 3), the reading could be stated as 1.26, or 1.27, or 1.28, or 1.27 ± 0.01, or whatever.

Some would aver that an analogue scale can only be interpolated to one half of a scale division, with a reading error of one quarter division. What then is the reading in Figure 3 ? With this rule it could be 1.25 ± 0.025, or 1.25 ± 0.03, or 1.30 ± 0.03.

It would seem advisable not to have a hard and fast rule on interpolation. The precision of each scale should be decided upon on its own merits. Some scales can only be read to the nearest division; some to the nearest half-division; some to the nearest tenth division, and so on. Factors to consider would include :

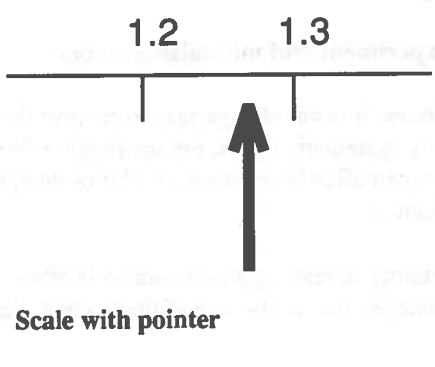

Fig. 3 Scale with pointer

- sharpness of scale marks
- separation of marks
- accuity of pointer
- presence of mirror behind pointer
- flicker or movement of pointer

Instruments with digital readout

The experimenter has little difficulty in reading these and often gets the mistaken impression that both accuracy and precision are higher than that of an equivalent analogue instrument. Digital instruments may or may not be as accurate or precise as the number of figures on the display might seem to indicate. The data for digital instruments are presented in slightly different terms. Examples of part of the specification supplied by different manufacturers of three electronic balances are given in Table 3 below :

	Model I	Model II	Model III
Capacity (g)	6000	1500	310
Readability (g)	0.1	0.01	0.0001
Reproducibility (g) (Standard deviation)	0.05	0.01	0.0002
Linearity (g)	0.1	0.02	0.0003

Table 3 Balance specifications

The term *readability* is the resolution of the balance. Because we are referring here to digital balances, there is an error term associated with readability. This is the *uncertain digit correction.*

The manufacturers will have determined the standard deviations by recording many readings for the same weight and analysing the data. The term *reproducibility* is equivalent to standard deviation. The *standard deviation* is a measure of the randomness or scatter of readings about the true value. When a large number of weighings of any measurement are made, 68% of them lie inside one standard deviation, 95% inside two SDs and 99% within 3 SDs of the true weight.

Thus the random uncertainty in a reading should properly be specified with confidence limits. Many balance manufacturers have adopted a 95.0% confidence limit, which is equivalent to 2.26 times the standard deviation of random errors for a sample size of 10. This multiplication factor is referred to later in the article.

Using the balance data in Table 3, if we were to load up the first balance with standard weights and plot a graph, it may look something like the curve in Fig. 4. At some intermediate point(s) where the curve crosses the

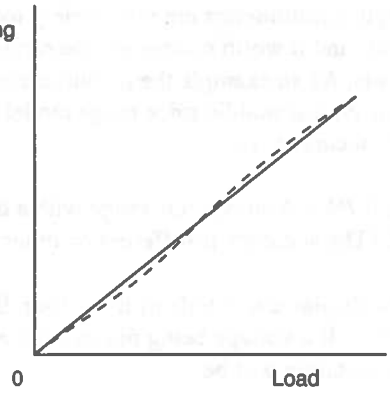

Fig. 4 Graph of possible non-linear behaviour of balance with exaggerated effect

straight line, the non-linear error will be zero. Since we won't know where this lies, the specified *linearity* error usually has to be combined with the other balance errors. However for two weighings which are almost the same, the linearity errors will also be very similar in magnitude.

The solid line (Fig. 4) would represent the performance of a balance with no linearity errors.

For most weighings by difference it is probably not necessary to include the linearity component. This is because the two non-linearity errors will almost certainly be in the same direction and subtract from each other. However if the two weighings were greatly different, there is a bigger chance that these errors will be in the opposite direction (see Fig. 4) and will add on to rather than cancel out one another.

If the balance referred to as Model II (Table 3) displayed 500.24 g, the error can be worked out as follows :

$$U_{total} = \pm ((2.26 \times U_{reproducibility})^2 + U_{readability}^2 + U_{linearity}^2)^{1/2}$$

$$U_{total} = \pm ((2.26 \times 0.01)^2 + 0.01^2 + 0.02^2)^{1/2} \text{ g}$$

$$= \pm 0.03 \text{ g}$$

The measurement should then be written as 500.24 ± 0.03 g.

If weighing by difference where the two weights are fairly close, the linearity error may be ignored. The uncertainty then works out as :

$$U_{total} = \pm ((2.26 \times 0.01)^2 + 0.01^2)^{1/2} \text{ g}$$

$$= \pm 0.02 \text{ g}$$

Digital multimeters are now widely used in all science subjects and it worth examining the errors in their readouts. As an example the manufacturer's specification for one typical middle price range model states that the "basic accuracy" is:

$\pm$ 0.7% + 4 on one d.c. range with a display count of 1999. (The accuracy is different on other ranges.)

The display count tells us it has four digits, reading up to 1999. If a voltage being measured read as 1000 mV the uncertainty will be

$\pm$ [(1000 x 0.007) + 4] mV

ie $\pm$ 11 mV and the reading should be expressed as 1000 $\pm$ 11 mV.

The $\pm$ 0.7% is a proportional error dependent on the reading. The $\pm$ 4 is a fixed error which is independent of the reading. This is sometimes called the *uncertain digit error*. Thus it can be seen from the above that, whilst digital instruments do not suffer from an error during the reading of the display, few of them live up to the accuracy with which many of us credit them.

Combining uncertainties

When readings and measurements which carry some uncertainties are processed to get an answer then that final answer will contain a particular uncertainty. The rules traditionally used are :

for *sums* and *differences* to add the uncertainties

$$(A \pm a) + (B \pm b) = (A + B) \pm (a + b)$$

for *products* and *quotients* to first convert each uncertainty to fractional or percentage uncertainty, add them to get the percentage uncertainty in the answer. In another method the fractional errors in each measurement are squared, added and then the square root of that sum taken to give the fractional error in the final answer :

$$(A \pm a) \times (B \pm b) = AB \pm (a/A + b/B) \times AB$$

or $$= AB \pm [(a/A)^2 + (b/B)^2]^{1/2} \times AB$$

Guare [1] has recently reminded us of a commonsense way of achieving the same mathematical process and result. Many of you will be familiar with this approach and will know of the benefit of having the same method for all error estimations without the need of having to remember different formulae for different situations. It has the other advantage of allowing the experimenter to see, and of encouraging him or her to think about, how particular uncertainties in measurements affect the total uncertainty in the final calculated answer. Formulae often encourage the user to adopt the mechanical approach of inserting numbers and waiting for the answer to fall out of the end rather than to think from first principles.

You simply take the numbers as stated and calculate the *maximum* and *minimum* values and the *best estimate*. The uncertainties of the answer are then obvious.

A + B Sum of 17.2 $\pm$ 0.2 and 12.5 $\pm$ 0.1

Best estimate	= 17.2 + 12.5	= 29.7
Maximum sum	= 17.4 + 12.6	= 30.0
Minimum sum	= 17.0 + 12.4	= 29.4
Uncertainty	= (30.0 - 29.4)/2	= 0.3
and the sum	= 29.7 $\pm$ 0.3	

A - B The initial reading on a burette is 0.5 cm^3 and the final reading 25.3 cm^3. If the 50 cm^3 burette has a reading uncertainty of 0.03 cm^3, express the volume delivered together with its uncertainty.

Best estimate	= 25.3 - 0.5	= 24.8
Maximum sum	= 25.33 - 0.47	= 24.86
Minimum sum	= 25.27 - 0.53	= 24.74
Uncertainty	= (24.86 - 24.74)/2 =	0.06

and the volume of titrant delivered = 24.8 $\pm$ 0.06 cm^3

A* x *B What is the number of coulombs passed when 10.0 $\pm$ 0.1 mA flows for 90 $\pm$ 1 seconds?

Best estimate	= 10 x 90	= 900 mC
Maximum sum	= 10.1 x 91	= 919.1 mC
Minimum sum	= 9.9 x 89	= 881.1 mC
Uncertainty	= (919.1 - 881.1)/2	= 19.0 mC

Number of coulombs passed = (900 $\pm$ 19) x 10^{-3}

For sums and differences, the maximum and minimum method appears to be a bit pedantic and cumbersome, but it is much easier to use than the usual rule for products and quotients. The superiority of the maximum and minimum method over the original should increase as the formula for calculating the final result becomes more complex. But not quite always! Consider the next few examples. One is awkward!

If the determination of the percentage of calcium worked out at (40.3 $\pm$ 0.1)%, but the error in the tenfold dilution effected by pipetting 10 cm^3 of the solution into a 250 cm^3 volumetric measuring flask (both Grade B) had not been allowed for, what is the uncertainty in the answer? The manufacturer's tolerances (Table 2) were given as $\pm$ 0.3 cm^3 for the 250 cm^3 flask and $\pm$ 0.06 cm^3 for the pipette.

Best answer for dilution factor	= 10	
Max. answer for dilution factor	= 250.3/24.94	
	= 10.036	
Min. answer for dilution factor	= 249.7/25.06	
	= 9.964	

Since this factor is a multiplying factor the final answer will lie between

Maximum value	= (40.3 + 0.1) x 1.0036	= 40.55
Minimum value	= (40.3 - 0.1) x 0.9964	= 40.06
Uncertainty	= 0.49/2	= 0.245

Therefore the best estimate for percentage of calcium is 40.3 ± 0.2 %

Combining uncertainties of very different sizes

As a general rule where one of the errors is less than one third of the others, it can be ignored in estimating the uncertainty in the final answer. Three examples below show that this needs to be qualified:

Example 1 : In the first summation below, ignoring the error of 0.01 makes negligible difference to the final answer.

(10.1 ± 0.1) + (11.30 ± 0.01) + (14.2 ± 0.1)
= 35.6 0 ± 0.2

However if the measurements were being combined in a different way this rule can fail as illustrated in some examples below :

Example 2 : Division $\frac{(10.20 \pm 0.20)}{(11.21 \pm 0.01)}$

The uncertainties in the final answer obtained by first ignoring and then including the smaller of the two measurement uncertainties are (± 0.0178) and (± 0.0186). These are very close and in fact when they are rounded off are the same value of (± 0.02). The smaller uncertainty could well have been ignored.

Using the *square root sum* method with fractional uncertainties the uncertainty in the answer is 0.0196; again confirming that the smaller error could have been left out of the calculation and a lot of effort saved.

Example 3 : Division $\frac{(10.20 \pm 0.20)}{(0.11 \pm 0.01)}$

The uncertainties in the final answer obtained by first ignoring and then including the smaller of the two measurement uncertainties now are (± 1.82) and (± 10.35). There is now a vast difference to the uncertainty if the error of 0.01 is ignored. What matters in a calculation like this, where a quotient or product is involved, is the difference in the fractional or percentage error. Of course if you use the method of maximum and minimums rather than the addition of fractional uncertainties, then whether or not one uncertainty is significant compared to another doesn't matter.

The fourth example shows this same principle operating in reverse. If one of the measurements has a very large uncertainty, then this does not necessarily come out in the uncertainty of the final answer. You may often have heard someone say that since one of the measurements is very inaccurate, ... They may be right and they may not; as shown below it all depends on the actual formula or calculation and on the fractional errors.

Example 4 :

The efficiency of absorption (E) of a gas on a solid, is calculated from the simple formula

$$E = (R - r)/R$$

R was found to be (90.2 ± 0.1) and r was 0.1 with a 25% error.

The value of E works out at 0.999 ± 0.002, or as a percentage efficiency of (99.9 ± 0.2)%.

On the other hand if either R were smaller or r were larger, more of this high percentage error would have come through in the final answer. Let us in Example 5 take a situation where r had been 11 and the other measurement had stayed at the same value.

Example 5 :

The 25% error of 11.0 is now appreciable at 2.75. Using the maximum and minumum method

Best estimate	= (90.2 - 11.0)/90.2	= 0.878
Max estimate	= (90.2 - 8.25)/90.2	= 0.909
Min estimate	= (90.2 - 13.75)/90.2	= 0.848
Uncertainty	= (0.909 - 0.848)/2	= 0.061/2
		= 0.031

Therefore E = 0.88 ± 0.03 or (88 ± 3) %

Standard deviations by the long and the short methods

As shown earlier in this article the greater the precision with which several measurements of the same property have been made, the smaller will be the spread of the results about their average and the narrower will be the neck of the bell-shaped distribution curve (Fig. 1).

The degree of precision of a set of results is often represented by a parameter called the *standard deviation* (SD). This section shows how this is worked out and compares the formal method with an alternative rapid method.

The formula for calculating standard deviation by paper and pencil is

$$SD\ (\sigma) = [\ \Sigma (x_i - x_m)^2 / (n - 1)\ ]^{1/2}$$

Finding the standard deviation of the measurements consists in summing all the results x_i, calculating the mean x_m and then the deviation of each result from that mean $(x_i - x_m)$. Some deviations are positive where the result is greater than the average and others negative. The deviations are squared, added, divided by $(n - 1)$ where n equals the number of readings and the square root taken.

Illustrating the process, the results obtained by the two pupils (Table 1) are used to show the method of working to calculate the SDs for the two sets of results.

	Measurement set 1	Deviation	Squared deviation
	x_i	$x_i - x_m$	$(x_i - x_m)^2$
	18.35	- 0.08	0.0064
	18.42	- 0.01	0.0001
	18.50	+ 0.07	0.0049
	18.50	+ 0.07	0.0049
	18.45	+ 0.02	0.0004
	18.40	- 0.03	0.0009
	18.38	- 0.05	0.0025
Mean (x_m)	18.43	$\Sigma (x_i - x_m)^2$ = 0.0201	

$$SD = [0.0201/6]^{1/2}$$

$$= 0.058$$

The rapid method described by Lyon [2] for finding the standard deviation is simple and seems to give values close to that worked out from the formula above.

First work out the range, which is the difference between the largest and the lowest reading, and divide it by the square root of the number of readings

range = (18.50 - 18.35) = 0.15

n = 7

$SD = 0.15 / (7)^{1/2} = 0.057$

	Measurement set 2	Deviation	Squared deviation
	x_i	$x_i - x_m$	$(x_i - x_m)^2$
	18.02	+ 0.03	0.0009
	17.73	- 0.26	0.0676
	18.41	+ 0.42	0.1764
	18.13	+ 0.14	0.0196
	17.86	- 0.13	0.0169
	18.20	+ 0.21	0.0441
	17.60	- 0.39	0.1521
Mean (x_m)	17.99	$\Sigma (x_i - x_m)^2$ = 0.4776	

$$SD = [0.4776/6]^{1/2}$$

$$= 0.282$$

Using the rapid method to find standard deviation :

range = (18.41 - 17.60) = 0.81

n = 7

$SD = 0.81/ (7)^{1/2} = 0.306$

In both cases this rapid method compares reasonably well with the SD proper. The rapid method works well when the population of results does not exceed 12, provided of course that the above results are part of a random variation. If the population is greater than 12, then the results should be divided up into groups not exceeding $n = 12$. The SD range is worked out for each batch and then combined. For methods of combining, please consult Lyon [2].

Standard deviation in the mean

A more useful concept than the standard deviation in a single observation SD is the standard deviation in the mean SD_{mean}. This provides us with a way of assessing the size of the uncertainty associated with the mean value of a set of n observations. The relationship between SD and SD_{mean} is

$$SD_{mean} = SD / n^{1/2}$$

If the range method is used, then SD_{mean} can be found very simply from

$$SD_{mean} = \text{range} / n$$

From Measurement Set 1, the standard deviation of the mean works out as

$$SD_{mean} = 0.15 / 7 = 0.02$$

Confidence limits

If the sample had an infinite number of measurements, 95% would have had a deviation from the mean of less than 2·SD. On the other hand, the value of the mean could be estimated as having a 95% probability of lying within $2 \cdot SD_{mean}$ of x_m. This could be used in expressing the uncertainty in the result in the form of

$$\text{result} = x_m \pm 2 \cdot SD_{mean} \quad \text{(95\% confidence probability)}$$

In school work we usually make relatively few measurements and cannot therefore express the uncertainty with this relationship. Allowances for a reduced level of confidence when a small number of measurements are made can be arrived at by consulting statistical tables. For instance, Student's t table specifies correction factor *t* for a 95% confidence probability versus the number of measurements *n*.

n	2	3	4	5	7	10	20
t	12.7	4.3	3.2	2.8	2.5	2.3	2.1

Thus using Measurement Set 1 as an example, the answer obtained, with a 95% confidence probability, would be :

$$\text{Best value} = 18.43 \pm 2.5 \times 0.058 / 7^{1/2}$$
$$= 18.43 \pm 0.05$$

Lyon [2] gives some empirical formulae for estimating the uncertainties for various confidence probabilities. His method is simple and nifty. The formulae for a 95% confidence probability, where *U* is the uncertainty, *w* is the range and *n* is the number of measurements are :

$U \approx 2w / (n - 1)$ where $4 \le n \le 12$
$U \approx 1.3\,w$ where $n = 3$
$U \approx 6\,w$ where $n = 2$

If again we use Measurement Set 1 for the analysis, by Lyon's method the error in the mean, with a 95% confidence probability, can be assessed as follows :

$w = 0.15 \qquad n = 7$

$$U = 2w / (n - 1)$$
$$= (2 \times 0.15) / 6$$
$$= 0.05$$

Best value = 18.43 ± 0.05 (95% confidence)

How many readings ?

How many readings do I take? Does taking additional readings improve the accuracy?

As was pointed out earlier, the best way to improve the precision of a set of measurements is by refining the experimental method (Fig. 1). The precision of a result can also be improved as far as random or accidental errors are concerned by increasing the number of measurements taken; however the systematic errors will not be reduced. Another way of saying this is that the standard deviation of the mean of a set of measurements decreases as the number of measurements made increases.

The deviation of the observed mean from the true mean does not decrease in inverse proportion to the number of readings, but to the inverse of the square root of the number of readings. Thus as the number of readings is increased a law of diminishing returns soon begins to operate where the taking of extra readings only results in a further slight increase in precision.

If the deviation of the mean obtained from making *n* determinations is *V* then the deviation reduces as shown below :

$2n$ determinations is $V/2^{1/2}$ or $0.71\,V$
$3n$ determinations is $V/3^{1/2}$ or $0.58\,V$
$5n$ determinations is $V/5^{1/2}$ or $0.447\,V$
$9n$ determinations is $V/9^{1/2}$ or $0.33\,V$
$20n$ determinations is $V/20^{1/2}$ or $0.22\,V$

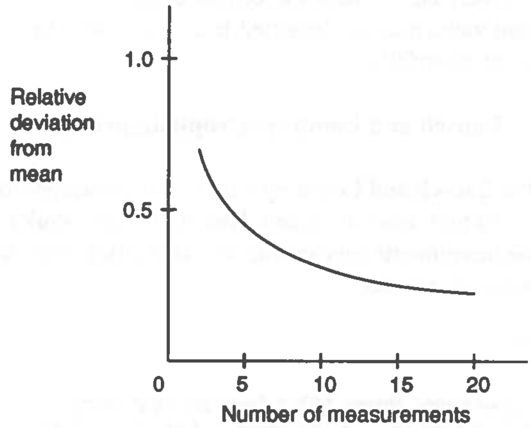

Fig. 5 Relative deviation from mean versus number of measurements

Clearly for many purposes it is not going to be worthwhile taking more than 5 or 7 readings. Much more is to be gained from going back and looking at the experimental method and possible ways of reducing types of error. This should increase precision to a greater extent than by taking a large number of readings and may improve on the accuracy at the same time.

References

1 Guare C J, *Error, Precision and Uncertainty*, Journal of Chemical Education, 1991, 68 8 649-652.

2 Lyon A J, *Rapid statistical methods: part 1*, Physics Education, 1980, 15 78-83.

Surplus Equipment Offers

Items are arranged by similarity of application, or for other reasons, and not by stock number sequence. Often the item number serves only for stock identification by us in making up orders.

The prices quoted do not include VAT. However it is added to every customer's order. Local authority establishments will be able to reclaim this input VAT.

Postage and, where necessary, packing, will be charged for. It is therefore best not to send cash with an order, but wait for us to bill you. Official orders may be used. Please try and ask for at least £10 worth of goods because the administrative costs of handling orders are significant.

Cash / Cheque with orders

Please do not send payment with your order. Wait until you receive our advice note upon which payment may be made. This saves unnecessary complications e.g. when items are out of stock, failure to make provision for VAT or if a delivery charge needs to be made. Items of equivalent value may be deducted from your order to balance any shortfall.

Ballot : Bausch and Lomb spectrophotometers

All the Bausch and Lomb Spectronic 20 spectrophotometers have now been allocated. Reconditioning work to make the instruments serviceable will take place over the next couple of months.

Motors

778 Stepper motor, Philips MB11, been stored in damp conditions but unused and retested. 4 phase, 12 V d.c., 100 mA per coil, 120 Ω coil per phase, step angle 7.5°, with 7 mm x 2 mm dia. output shaft. Dimensions 21 mm x 46 mm dia. on oval mounting plate with 2 fixing holes, diam. 3 mm, pitch 42 mm, at 56 mm centres. Circuit diagram supplied. £2.50

755 Pulley wheel kit comprising:
- plastic pulley wheel, 30 mm dia., with deep V-notch to fit 4 mm dia. shaft,
- two M4 grub screws to secure pulley wheel,
- Allen key for grub screws, and
- 3 mm to 4 mm axle adaptor.

The whole making up a kit devised for SSERC tachogenerators with 3 mm shafts. Specially supplied to SSERC by Unilab. £1.25

779 Miniature motor, 13.2 V d.c., smooth running, speed governor, no load current 24 mA at 12 V, dims. 36 mm x 39 mm dia., shaft 10 mm x 2 mm dia. £1.25

614 Miniature motor, 3 V to 6 V d.c., no load current 220 mA at 9600 r.p.m. and 3 V, stall torque 110 mN m, dims. 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia. 45p

593 Miniature motor, 1.5 V to 3 V d.c., no load current 350 mA at 14800 r.p.m. and 3 V, stall torque 50 mN m, dims. 25 mm x 21 mm dia., shaft 8 mm x 2 mm dia. 30p

621 Miniature motor, 1.5 V to 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

739 Miniature motor, 1.5 V d.c., dimensions 23 mm x 15 mm dia., shaft 8 mm x 1.7 mm dia. 25p

732 Motor with gear box, high torque, 1.5 V to 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, or any other mechanism requiring a slow drive £6.00

773 Tachometer (ex equipment) £2.25

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 dia. fixing hole. 75p

642 Encoder disk, 30 slots, stainless steel, 30 mm dia. with 4 mm fixing hole. £1.30

772 Encoder disk, 4-bit Gray code, stainless steel, 81.28 mm dia., 3 mm fixing hole, slots sized to register with components mounted on 0.1" stripboard. Applications: shaft position sensing, wind direction indicator.
For related electronic circuitry see Bulletin 146 £3.00

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. 55p

710 Sonic switch and motor assembly. First sound starts the motor, a second reverses the direction of rotation, a third 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 to 4 bar (i.e. above atmospheric). With rear fitting for 1/8" BSP. Suitable for use as indicator for pneumatic circuits in Technological Studies. 75p

313 Thermostat, open construction, adjustable, temperature range +10° to +65°C. Rated at 6 A, 250 V, but low voltage switching also possible. 60p

165 Bimetallic strip, length 10 cm;
high expansivity metal: Ni/Cr/Fe - 22/3/75
low expansivity metal: Ni/Fe - 36/64 (invar) 15p

166 Ditto, but 30 cm length. 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

753 Submersible pump, 6 V to 12 V d.c., 8 litres/min., 0.6 bar, dry operation protected. £4.55

371 Ferrite rod aerial, two coils MW and LW, dimensions 140 mm x 10 mm dia. 85p

758 Loudspeaker, 8 Ω, 0.5 W, 66 mm dia. 50p

771 Neodymium magnet, 13.5 mm dia. x 3.5 mm thick. £1.30

745 Sub-miniature microphone insert (ex James Bond?), dia. 9 mm, overall depth 5 mm, solder pad connections. 40p

776 Toggle switch, panel mounting, 2 Amp rating, SPST, mounting bush 0.468 inch, flattened white 10 mm lever. 35p

776 Toggle switch, panel mounting, 3 Amp rating, SPST, mounting bush 0.468 inch, flattened black 18 mm toggle. 35p

723 Microswitch, miniature, SPDT, lever operated. 40p

740 Microswitch, miniature, SPDT, button operated. 25p

354 Reed switch, SPST, 46 mm long overall, fits RS reed operating coil Type 3. 10p

738 Relay, 6 V coil, DPDT, contacts rated 3 A, 24 V d.c. or 110 V a.c. 75p

774 Solenoid, 12 V, stroke length 30 mm, spring not provided £2.25

742 Key switch, 8 pole changeover. 40p

382 Wafer switch, rotary, 6 pole, 8 way. 70p

688 Croc clip, miniature, insulated, red. 5p
759 Ditto, black. 5p

741 LES lamp, 6 V. 15p

770 LES lamp, 12 V. 15p

690 MES lamp, 6 V, 150 mA. 9p

691 MES battenholder. 20p

692 Battery holder, C-type cell, holds 4 cells, PP3 outlet 20p

730 Battery holder, AA-type cell, holds 4 cells, PP3 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
760 14 way 7p
776 16 way 8p

716 3-core cable with heat resisting silicone rubber insulation, 0.75 mm² conductors, can be used to re-wire soldering irons as per Safety Notes, Bulletin 166. Per metre. £1.35

756 Silicone coated, braided glass sleeving, yellow, 2.5 mm dia., gives both heat and electrical insulation to conductors (e.g. for autoclave rewiring). Price per metre. 55p

714 Sign "Radioactive substance" to BS spec., 145 x 105 mm, semi-rigid plastic material. Suitable for labelling a radioactive materials store. With pictogram and legend. £2.30

763 Sign "DANGER, Electric shock risk" to BS spec., rigid plastic, 200 x 150 mm. £2.70

764 Sign "DANGER, Laser hazard" to BS spec., rigid plastic, 200 x 150 mm. £2.70

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

752 Shandon chromatography solvent trough. £1.00

754 Stereo microscope, Vickers long arm type with knuckle joint, mechanically coupled eyepiece tube, x10 eyepiece, x1 and x2 objectives on tumble change, built-in illuminator with either top or basal illumination, weight 12 kg, very stable even with arm swung away from base. Suitable for biology, primary, electronics, geology, etc. Equivalent present day model would cost in excess of £250. Delivery can be arranged for multiple purchases, otherwise has to be uplifted. £100.00

Components - resistors

328 Potentiometer, wire wound, 15 Ω, lin., 36 mm dia. 30p

737 Ditto, 22 Ω, lin., 36 mm dia. 30p

329 Ditto, 33 Ω, lin., 36 mm dia. 30p

330 Ditto, 50 Ω, lin., 40 mm dia. 30p

331 Ditto, 100 Ω, lin., 36 mm dia. 30p

421 DIL resistor networks, following values available: 62R. 100R, 1K0, 1K2, 6K8, 10K, 20K, 150K. Per 10. 30p

420 resistors, 5% tolerance, ¼ W : 1R5, 4R7, 5R6, 6R8, 8R2, 10R, 15R, 22R, 33R, 47R, 56R, 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, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M. Per 10. 6p

BP100 Precision Helipots, Beckman, mainly 10 turn. 10p-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, 220 nF, 680 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. 1p

358 Capacitor, electrolytic, 28 µF, 400 V. £1.00

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

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); for making thermocouples, see Bulletins 158 and 165. £2.20

640 Disk thermistor, resistance of 15 kΩ at 25°C, $\beta = 4200$ 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. £2.90

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. For application see SG Physics Technical Guide, Vol.2, pp 34-5. 50p

751 Hacksaw blade with pair of strain gauges, terminal pads and leads attached. Suitable for impulse measurement as described in Bulletin 171. Delivery time 3 months. £12.50

501 Kynar film, screened, 28 µm thick, surface area 18 x 100 mm, coaxial lead and 4 mm connectors. Applications: impulse (Bulletins 155 and 174), long wave infrared (Bulletin 155, SG Physics Technical Guide, Vol.2, pp 33-4) £20.00

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, ¼ W. £1.40

Opto-electronic devices

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

508 LEDs, 3 mm, red. Price per 10. 50p
761 Ditto, yellow. Per 10. 50p
762 Ditto, green. Per 10. 50p

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 are only available to callers because of 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

663 Flat bottom round flask, 250 ml. 50p

664 Flat bottom round flask, 500 ml. 50p

747 Quickfit vented receiver, 10 ml. 20p

768 Sodium lamp, low pressure, 35 W. Notes on method of control available on application. 85p

Chemicals

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

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

668 500 ml dodecan-1-ol. 50p

670 500 g Keiselguhr acid, washed. 25p

672 500 g Magnesite native lump. 25p

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

674 250 g manganese(II) sulphate AR. 25p

676 500 g quartz, native lump. 25p

677 100 g sodium n-butyrate. 25p

678 500 g strontium chloride AR. 25p

681 Zinc acetate (ethanoate) AR. 25p

682 2.25 litre ammonia solution. 50p

685 500 ml n-decanoic Acid (Lauric acid). 25p

769 500 ml 1,1,1-trichloroethene. 50p

712 Smoke pellets. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans, etc. 50p

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