

SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences

ISSN 0267-7474
Number 178

September 1993

Contents

Foreword	Sponsorship : ScottishPower	1
Opinion	DNA, dinosaurs and dangers	2
Safety Notes	Laboratory acquired infections	3
	- AIDS and BSE	9
	- Electrothermal heating mantles	
Technical Articles	Accentuate the experiment	10
	- lead and enzymes	14
Equipment Notes	To measure the length of a metre stick	22
	Digital multimeters	28
	Plastic rulers	
Technical tips	That old flame again	30
	Electrolysis of melts	32
	Fun with neodymium	34
	- Lenz's Law and Newton 3	
Surplus equipment offers		36
Announcement	Software copyright	39
Trade News		40

ISSN 0267-7474

© SSERC 1993

Copyright is held to be waived only for bona-fide educational uses within Scottish schools and colleges in current membership of SSERC.

Typeset by SSERC in Trinity and Homerton on an Acorn Archimedes 440 with Arm3 processor running Computer Concepts *Impression II* DTP software, Acorn *IDraw* and 4Mation's *Vector*. The line drawings were compiled from elements of the *SSERC Graphics Libraries* and *SSERC Graphics CD-ROM*. Cover design by SSERC.

Acknowledgement : The photographs used for the front and rear covers of this issue were originally produced by :
The Team Design Consultants of The Church Hall, 120 Putney Bridge Road, London SW15 2NQ.

Foreword

Sponsorship

This issue has been sponsored by ScottishPower plc. We are most grateful to educational advisory staff in ScottishPower for their interest in and support for the work of the Centre. Once again this sponsorship 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 third party firms or organisations 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. ScottishPower has kindly provided us with an account of the Company's educational advisory system.

ScottishPower : Educational Advisory Service

ScottishPower : Educational Links

Electricity's impact on every aspect of life and work in Scotland is frequently, if understandably, taken for granted. Yet how it is generated, distributed and supplied - and the efficiency with which we all use it - is of vital importance to our future. Consequently, a greater understanding of the nature of electricity, of what it can provide and of how best to optimise its versatility in the most efficient way, is something we cannot begin to gain too early in our lives.

Electricity may well be one of the biggest single forces to have shaped the social and industrial fabric of the nation.

Men and women with a multitude of different skills work around the clock, 365 days a year, to ensure that when a customer flicks a switch the power goes on. This is an engineering miracle. It involves the integration of many different processes some of which involve complex modern technologies and many of which are not fully understood by the public at large.

This is a major reason why ScottishPower - which generates, transmits and distributes electricity to some 1.7 million customers - has adopted a role in assisting with the education of Scotland's young people. This it is doing by forging strong links with Scottish universities and schools.

Over the past eighteen months or so the Company has been further strengthening these valued bonds through two full-time Energy Education Advisors - Lesley Brown working in the West and Maria Smith¹ in the East of Scotland. Both seek to work closely with teachers and pupils throughout ScottishPower's area to promote a better understanding of electricity.

Coverage

The subject of electricity in itself is fascinating. It is one which may easily provide stimulating project ideas for a wide range of pupils and students. There are the scientific, technological and engineering aspects. These can enable children to discover how electricity is generated, transmitted and distributed to home and workplace.

Then there is the historical tale of how electricity has influenced industrial and commercial affairs, of its enhancement of economic development and of how it has affected the social fabric of today's developed world. Then there are the financial and political aspects of electricity. Companies which generate and sell it, and those who supply the basic fuels, are each themselves major industries. All are governed under a complex web of UK and EC legislation. And, possibly most topical of all, there are the environmental aspects of electricity production which, at ScottishPower, is greener than most people would imagine.

Maria and Lesley, ScottishPower's two Energy Education Advisors, work to support teachers and students in curriculum development. As well as practical advice and help, they can offer - through the Electricity Association's Understanding Electricity Scheme - a catalogue of educational resources including booklets, posters, video and computer packages. Many of these resources are free to schools. In addition to such material assistance they can also provide or arrange help with school projects such as in Environmental Studies for the 5 to 14 age range. Maria and Lesley regularly run practical workshops on electricity for teachers and they can also arrange placements for teachers or pupils in different parts of ScottishPower's business.

¹Lesley Brown, West of Scotland Education Advisor, can be contacted on : 0698 281777 and Maria Smith, ScottishPower's Education Advisor in the East of Scotland, on : 031 225 2323

Opinion

DNA, dinosaurs and dangers

Some months ago we received a DNA Technology Kit from the Science and Plants for Schools Project (SAPS). It was intended that we test and evaluate it both for safety and educational relevance etc. We were extremely busy at the time (how unusual!). Apart from doing a quick check that the power supply for the electrophoresis apparatus was reasonably safe and unlikely to fry anyone, we could only promise to put the kit in what was, and remains, a long queue.

When we eventually got time to look at the kit in more detail it was the Summer silly season. Spielberg's spectacular Jurassic junket had been released. This was a nag - a constant reminder of the likely current high interest in genetic matters molecular. Dinosaur and DNA mania served as constant conscience prickers - ever present reminders that we ought really to do something, preferably useful, with the kit. Reading the instructions however merely brought understanding of the SAPS policy of only supplying kits to those teachers who had first been on one of their DNA Technology Workshops. A couple of 'phone calls later and we were booked in for our own specially arranged tour of DNA Disneyland at the Royal Botanic Gardens.

We got on fine, eventually, although I have to confess that in the micro-scale manipulation, DNA digestion and agarose gel quality stakes I was soundly beaten. The score was an undisputed two-nil to Marjorie Hamilton, SSERC technician and professional gloater.

It wasn't that which got me jumping up and down and sufficiently energised to pen an "Opinion". What impressed was that the extraction of DNA and the cutting of it with restriction enzymes should prove so simple.

Despite the imperfections of first efforts in loading an electrophoresis gel, in less than an hour beforehand we had extracted enough plant DNA to see it with ease, precipitated in a centrifuge tube. On the very first attempt we had both cut up DNA and separated the resulting fragments. All was done with a kit of parts and materials costing less than fifty pounds¹.

A couple of years back I presented a talk at an Institute of Biology Annual Symposium. This was entitled *Genetic Engineering and the Limits of Science Teaching*. Part of that lecture was devoted to ethical and moral issues. It was proposed that science teachers had a special capacity, a duty even, to raise awareness and inform debate on such matters.

Once such ethical debate ensued, it was argued, scientists and scientific method have nothing special to offer. We have the same rights - no more, no less - than any other citizen. Claiming a privileged position because we are "expert and thus better informed" is a Catch 22. It doesn't wash since it is our duty, in a supposedly free and democratic society, to ensure that our fellow citizens are also sufficiently well informed. Whatever the outcome we scientists and technologists have to thole it.

All of that argument was based on an intellectual abstraction. Now that I have in person and in practice abstracted and manipulated DNA, however crudely, it leaves me utterly convinced of the need to further modernise parts of the biology syllabus and to introduce into schools resources like the SAPS Kit.

At SSERC we have long argued for the retention in schools of practical work on ionising radiations. Those arguments were partly based on principles similar to those already outlined. DNA technology presents reasons orders of magnitude stronger.

Nuclear technologies, like most others, offer opportunities for great evil as well as for the general good. Many of the techniques of nuclear weaponry are now in the public domain. They are however relatively expensive to put in place and difficult to conceal.

In contrast genetic manipulation is a cheap and cheerful business. Its potential to enhance the quality of life in the widest sense is immense. On the other hand any malevolent misapplication will be much more difficult to detect and police.

It is perhaps well past the time that pupils learned that dinosaurs have no monopoly in the extinction business.

¹ Our initial impressions of this kit were favourable. A full review is planned for publication in Bulletin 179 or 180.

Safety Notes

Laboratory acquired infections

A number of school practical activities are re-assessed in the light of current knowledge of likely degrees of risk of acquiring certain infections from materials of living origin.

The major intention is to re-open or encourage further discussion, local and national, on the desirability or otherwise of continuing some current practical activities. There is also the possibility of re-instating others, which some science teachers may have abandoned.

Background

This article was triggered by a letter from a biology teacher. This was the latest of a number of enquiries on the risks attendant on a range of practicals which involve the use either of living organisms or materials of living origin. This particular enquiry was to do with continuing the use of buccal smears (cheek cell scrapes¹ to you and me) as a source of specimens of *typical* animal cells. The principles it raises however appear to us as being of much wider application.

It has also been some time since either Central or Local Government bodies have pronounced on matters to do with AIDS or BSE and science teaching. Some dust has now settled on all the various circulars and policy statements. The time thus seems ripe for a calmer, possibly more objective, re-appraisal of hazard and risk in these areas.

Intention

The article is intended as an informed lay review rather than as authoritative and definitive advice. Given all of the on-going scientific work in these areas such an approach seems unavoidable. In any case, some of that work is itself controversial - including the actual nature of some of the infective agents and the test protocols intended to reveal their presence. That does not mean that this isn't a good time to stand back and look carefully at what hard scientific evidence we do (or do not?) have and re-assess science teaching practice in that light.

¹ "scrape" is unfortunate since it carries with it the implication of physical damage to the lining of the mouth - something which in this context is best avoided.

Scope

We concentrate on activities possibly affected by two infective agents. The exact nature of both of these and many of the details of their modes of transmission are subject to great uncertainty. One gives rise to that condition in humans known as AIDS (Acquired Immune Deficiency Syndrome). The other is a disease which, when it presents in cattle, is known as BSE (Bovine Spongiform Encephalopathy).

There is evidence which suggests that, whatever the nature of the agent which causes BSE, it has crossed at least one so-called *species barrier*. Whether or not it may also be a zoonosis - a disease transmissible between humans and other species - is almost totally uncertain at present.

Not covered in this article are those ethical and health education issues which are more properly the domain of other specialists - health education and guidance staff for example. We do however indicate where science teaching can offer its own specific contribution to the education of young people in these broader matters. One such instance is that rational precautions to control risks in practical work offer opportunities to teach by example rather than exhortation.

Principles and approach

In our training courses on COSHH², and more recent sessions on the Management of Health and Safety at Work Regulations 1992, we have had many questions on issues such as AIDS and BSE. This has led to the formulation of an approach based on the techniques related to the central requirement of both sets of legislation. These are the principles and techniques of *risk assessment*.

The first step in a risk assessment is identification of the hazards. In this context *hazard* has a specific meaning - it is the potential to cause harm. It is the next step though which is crucial. This involves an assessment of the likelihood that harm will result in the actual circumstances of a particular activity or procedure.

This probability of actual harm is the *risk*.

² COSHH - The Control of Substances Hazardous to Health Regulations, 1988, SI No.1657, as amended.

The magnitude of this risk may be controlled in a number of ways, which usually hinge on the details of practical procedures.

On occasion the hazards presented by a particular substance or organism are so great that the only sensible action involves the elimination of their use. This may be followed by the substitution of something inherently less hazardous or, more rarely, the total abandonment of a process. Because of certain peculiarities, the cases of AIDS and BSE present particular difficulties to such an approach. These problems are worth examining in a little more detail.

AIDS and BSE

That both types of infection have a potential to cause harm to humans - i.e. present a hazard - is not in any doubt. In the case of AIDS that potential for harm means the possibility of chronic and fatal illness. In the case of BSE some hazard to animals other than humans can certainly be identified but it can be assessed only with varying degrees of certainty which seem species-dependent. The hazard for humans is at the moment almost wholly theoretical¹.

Not the least of our problems in attempting a rational assessment of the risks - probabilities of actual harm - is a lack of any consensus in the scientific community itself.

For example :

(a) Infective agents

For neither AIDS nor BSE is there any agreement currently on the nature of the infective agent(s).

In the case of BSE there are at least three possibilities (four if you accept the description *unconventional agent*). With AIDS the accepted view is that the agent is a virus commonly designated "HIV". There is though a significant minority in this field which maintains that whilst there may well be a correlation between the symptoms of full-blown AIDS and the presence in the blood of antibodies to HIV, there is as yet no evidence that this relationship is causal.

(b) Diagnostic tests

(i) AIDS : There used also to be majority agreement that the possibility of presenting so-called full-blown AIDS was predictable from the presence of certain antibodies in human blood. If it was accepted that the causative agent of AIDS was HIV (see above) then it seemed reasonable to argue that the presence of what

were reckoned to be antibodies to that virus was predictive of the possibility of developing the full symptoms.

Work published shortly before the time of writing casts doubt on the reliability of the HIV test itself and hence also on its use as a predictor of the possibility of full-blown AIDS.

(ii) BSE : As far as we aware, there are as yet no routine biochemical or other clinical test procedures which can detect BSE infection prior to the presentation of the recognised symptoms of the disease. Recognition that the disease has been transferred either within or between species has to await development of symptoms and firm confirmation has to await post-mortem.

Risks in science teaching

Despite this background of uncertainty we can still identify the general hazard. It is the *possibility* of infection. In order to assess the *probability* of such infection - i.e. the risk - we need to look in detail at those practical activities which offer possibilities of both mode and route.

AIDS

Enough epidemiological and other evidence has now accumulated for us to state with a degree of confidence that the infective agent of AIDS is transmitted via human body fluids. One of the most important of these is blood or other fluids contaminated with blood. We also are fairly sure that outside of the human body the agent is relatively delicate, in the sense that it is not too difficult to inactivate. It is destroyed at high temperatures or by treatment with disinfectants, the most effective of which are probably those whose action relies on *free* chlorine e.g. bleach or other hypochlorite [chlorate(I)] solutions.

Hazardous procedures

Given the above mode of transmission and other factors, in science education any procedure which involves handling human body fluids carries a hazard of infection. What are the details however which will determine the probability of infection actually occurring - i.e. the risk?

(a) Blood smears

Background

In the mid-eighties Central Government advice and Education Authority policy directives led to this activity being discontinued, at least in schools. It may still be carried out in FE colleges - particularly in some vocational courses.

¹ Despite some very recent and sensationalist press reports.

Procedures

These involve the taking of a drop or two of human blood and making a smear on a microscope slide. Each pupil is instructed only to use their own blood. Disposable lancets, and sometimes special mechanical devices, are employed to prick a finger or thumb. Sterile slides are used to accept the smear. Disposal of these is via a discard jar containing a chlorine based disinfectant.

Re-appraisal

Infection by direct blood to blood transmission was fairly well established early in the study of AIDS. Further evidence has served only to confirm that this is one important mode of transmission. Laboratory acquired AIDS infection in medical workers - via needle-stick injuries for example - is now well documented and further cases are regularly reported in the specialist health and safety press.

Conclusion

Theoretically, the procedures described would adequately control the risk. But the activity involves deliberately making a wound, however small, and brings the possibility of direct blood to blood contact. We must also consider the prognosis should full blown AIDS be a consequence - however remote.

Despite the agreed educational worth of this activity it seems prudent therefore to recommend that what is effectively a ban upon it in schools should remain.

At FE level however, close specialist supervision of older students can ensure that safe protocols are always followed. The nature of some FE courses may actually require that such protocols be learned. Obvious examples are courses related to medical laboratory technology and other para-medical subjects. In these circumstances there is no reason why the risks should not be adequately controlled and the preparation of blood smears continued.

In schools also there is no reason why pupils should not continue to examine commercially prepared microscope slides of human blood. Once such smears have been fixed, stained and mounted the risk of infection from them is so remote as to be insignificant.

Some teachers have asked about the possible use of time-expired whole blood from transfusion services blood banks both for this and other teaching purposes. Now that all such blood and blood products are screened and heat treated there would seem to be no theoretical objection to such a substitution. In practice however it may prove both difficult and somewhat bureaucratic to arrange.

(b) Cheek cells

Background

The 1987 "three nation" guidance document issued by the DES (now DFE), and the Scottish and Welsh Offices advised that :

"- in the interests of safety, to avoid the possibility of accidental inoculation with infected blood, the taking of blood or cell samples for class use in schools or for non-advanced further education work in colleges should be discontinued."

Third parties interpreted "cell samples" as including cells taken from the lining of the buccal cavity - cheek cell samples, also known as buccal smears. The Association for Science Education (ASE) reluctantly, and a number Education Authorities subsequently, issued advice that the taking of cheek cell samples should cease.

The Institute of Biology (IOB) took a different line. Whilst the Institute supported the recommendation that blood sampling be discontinued it also sought expert advice, which included guidance from other professional bodies and organisations such as the British Medical Association (BMA). As a result of such consultation the IOB decided that it could not endorse DFE advice that the taking of buccal smears should cease in schools and colleges. Instead the Institute drew up a protocol for the preparation of temporary mounts of human cheek cells.

This protocol was then published by the Institute together with a statement advising teachers and education authorities to continue to allow cheek cell sampling so long as they used the IOB's procedure¹. They also stated that so long as the procedure was followed there were :

". . . absolutely no reasons why any student or teacher should be exposed to the risk of infection by the transmission of pathogens."

Procedures

The only evidence that AIDS may be transmitted by the transfer of whole somatic cells seems to have come from work done in tissue culture systems. A far more likely hazard arises from the possibility of contamination of the cheek epithelium sample by blood. That may well occur if the implement used to take the sample is metallic or of some other hard material. The IOB protocol uses a cotton bud to gently remove the sample from the inner lining of the cheek and the outside edge of the lower gum. (See Appendix to this article).

The other possibility of blood contamination arises if the subject is suffering at the time from gingivitis or some other infection which causes the gums to bleed easily.

The overall risk may be minimised if pupils are only allowed to handle and examine cell samples from their own mouths. The more specific risk from those with gum conditions is also controlled partly by this means and partly by the general rule of laboratory hygiene that no-one with an open cut or abrasions should take part in certain kinds of practical work.

Re-appraisal

In March 1991 the IOB again raised the matter with the DES (DFE) and requested a clarification of the status of the advice and the Department's comment as to whether there was any new evidence to suggest that taking buccal smears using the IOB's techniques might in any way be inconsistent with safe practice.

Interestingly the DFE reply then took the line adopted consistently from the outset by the Scottish Office Education Department (SOED) viz : that the 1987 (DES) guidance was :

"advisory rather than mandatory; the aim is to provide a framework, not a substitute, for local consideration of and decision upon the issues by those professionally involved."

The reply went on to say that : the guidance still stood; that the Department thought it necessary to err on the side of caution and that much hinged on whether or not close supervision could be ensured and that pupils did not disregard the procedures and thus be exposed to risk.

Leaving aside the question of contributory negligence of those who disregard clear instruction, we would to a large extent agree that the key to this activity lies in following closely the IOB protocol.

Conclusions

Teachers know their own pupils best. It should perhaps thus be left to their professional judgement in deciding whether or not such indiscipline is likely in a particular group and to judge that this will increase the risks to an unacceptable level. They can then decide that this practical may not be carried out as a pupil activity with certain classes.

Where pupils are responsible and can be relied upon to follow specific instructions we see no reason why cheek cells should not be taken and examined using the IOB procedures. It seems to us unreasonable that the biological education of the majority of sensible young people should suffer because of the irresponsibility of a minority. A blanket ban thus seems wrong-headed since it totally misplaces the emphasis. The safe procedure which controls the risks has far more positive things to teach young people than merely what epithelial cells look like under a microscope.

(c) Saliva

Background

Human saliva has long been used in secondary school courses as a source of the enzyme amylase for practicals on the digestion of starch. Some teachers, EA's and other organisations seem to have needlessly, if logically, extrapolated Central Government guidance (already recognised as ultra-cautious - see above) and extended the perceived ban on cheek cell samples to the use of saliva.

Procedures

The taking of samples of salivary fluid does not involve the use of any implement which is likely to cause or encourage bleeding. So long as pupils take and use only their own saliva the risks would seem well controlled. Normal rules of hygiene need to be observed and used samples carefully disinfected before disposal.

Alternative procedures using proprietary preparations of amylase are available. These lack the immediacy for pupils of using an enzyme from their own bodies. Care is also needed however in selecting the right enzyme source and grade for experiments since some samples of amylase have contaminants e.g. small amounts of reducing sugars, which may well complicate the experimental design.

Re-appraisal

From our point of view none is required since we have never suggested that saliva be abandoned as a source of amylase.

Conclusion

Except in extreme cases, where discipline is not at all to be relied upon, the risks are readily controlled by observing normal hygienic practice. There was never any need to abandon the use of saliva as a source of amylase. Those departments, schools or EA's who have done so could usefully and sensibly re-consider that policy.

BSE

Uncertainties as to the nature and transmission of the infective agent of AIDS are as nothing compared to those surrounding BSE. In the interests of brevity here is a summary of what little we do know :

- the infective agent in BSE behaves similarly to that which causes the ovine disease commonly called scrapie;

- the disease became evident in cattle given feed with some constituents derived from sheep;

- at about this time several manufacturers of feed which utilised ovine remains had simplified their sterilisation processes missing out a solvent treatment step and relying on heat sterilisation alone. (It is worth noting that the major processor in Scotland never abandoned this part of the sterilisation process and that this correlates with a low incidence of BSE in Scotland);

- despite the fact that scrapie has been recognised since the 18th century as endemic in the British sheep flock and despite recent decades of intensive research, an infective agent has never been isolated or identified;

- it is known however that, whatever its nature, the agent resides for long periods in central nervous tissue and that the effects of the disease are gradual (chronic);

- over time the result is degradation of nerve tissues eventually causing fatal damage to the brain;

- this degradation leads to symptoms of loss of motor control (hence mad cow disease) and at post mortem there are visual (histological) signs of excessive vacuolation of brain cells (hence *spongiform* encephalopathy);

- the similarities of the bovine condition to that of scrapie in sheep combined with evidence linking BSE with feed containing ovine material raise the suspicion that the infective agent has crossed a species barrier;

- various reports have raised the possibility that the same or a similar condition may have been transmitted to the pig and to the domestic cat;

- spongiform encephalopathy conditions have been recorded in humans but are very rare. Several cases were recorded until the mid-fifties in New Guinea, but there the evidence suggests that the route has been inter-human rather than from some other mammal to man;

- in laboratory based work the disease has been transmitted to mice but the only successful procedure of which we know was injection of relatively large amounts of infected nervous tissue into the mouse's bloodstream.

Hazard

So, as with AIDS, there is an identifiable, if uncertain, hazard from BSE in some laboratory based procedures. Again as for AIDS, that hazard is the possibility of acquiring a chronic and potentially fatal disease. In order to assess the risk we need to examine more closely those procedures.

Hazardous procedures

Our BSE summary suggests that we need to look at procedures which bring teachers and pupils into contact with nervous tissues of either bovine or ovine origin. This is especially so where there is the possibility that such tissue might conceivably contaminate a cut or skin abrasion so that such nervous tissue might enter the bloodstream.

(a) Dissection of eyes

Background

In March 1990 the Scottish Office Education Department issued guidance in the form of a letter to all Scottish EA's. SOED advised that it would be desirable to discontinue the practice of dissecting bovine eyes in science lessons. In any case earlier legislation connected with BSE¹ had already prohibited the sale of certain kinds of offal from cattle more than six months old. This included items such as the brain and spinal cord. Although bovine eyes were not covered by these regulations, several abattoirs which had previously supplied eyes from cattle to schools ceased to do so.

The SOED in its advice only suggested the use of anatomical models and other visual aids as alternatives to the dissection. Other agencies suggested however that schools should substitute eyes from either sheep or pigs for those of cattle.

Procedures

Eyes used commonly to be dissected either as a pupil practical or a teacher demonstration both in early secondary science courses and in biology or physics classes at first examination level. Bovine eyes were most frequently used because of their size, which eased identification of the salient functional parts.

Instruments such as scissors and scalpels would be used for such dissections. Accidental cuts and wounds are thus always a possibility. Indeed such minor wounds are amongst the most commonly reported accidents in school science. The outer layer of the bovine eyeball is made of fairly tough connective tissue. The possibility of a slip with a scalpel resulting in a cut is therefore not remote. A major part of the rest of the eye is made up of nervous tissue.

Re-appraisal

Although at the time we were unhappy with the way the SOED guidance had been formulated - in particular the lack of any wide consultation - reluctantly we had to endorse the advice given. It was at least logically defensible using what little scientific evidence was available at the time.

¹ Statutory Instrument No.2061 : The Bovine Offal (Prohibition) Regulations 1989 (HMSO) ISBN 0110980611.

Nonetheless from a scientific viewpoint the basis of the SOED advice was, and remains, precarious.

We would however refute such advice if it became a matter of extending the effective prohibition to other bovine organs or tissues such as those of liver or heart. At present such offal is freely available and is retailed to the general public. We can therefore see no rational argument for banning its use as a source of enzymes say or in anatomical demonstrations. Offal presenting discernible risk - brain and spinal cord etc - is in any case already not available to schools.

While, in this whole matter of BSE, it seems entirely reasonable to assign some degree of risk, it should also be noted that :

- so long as the material is coming from some local, Scottish, source (see *Background*) then

- the epidemiological and other evidence suggests that of the relative differences in degrees of risk one might assess, all are themselves encompassed within an overall range of risk which, in absolute terms, is very small¹.

In school science we aim, amongst other things, to teach young people to act according to logical and objective assessment of evidence from observation and experimentation. To ban the dissection of offal of non-nervous system origin would be to act in the face of the evidence.

There may be other, wider, ethical and political (note the small "p") considerations which in some areas make aspects of dissection problematic in schools. Discussion of these would take another whole article.

On health and safety grounds however, whilst we continue to give reluctant support to the advice on bovine eyes, we currently see no justification for any extension of the SOED guidance to other bovine materials.

Ovine material

Sheep organs, sometimes including eyes, have been used in schools for anatomical examination over many years. A number of agencies thus suggested that they would be a suitable routine substitute for the eyes of cattle².

Given the possible relation between BSE and scrapie such a suggestion does not seem entirely rational. In parallel with our comments on bovine offal however we continue to see no objection on safety grounds to the continued use of sheep heart, lung or liver material in school science.

¹ It is in practice so small as to be effectively insignificant.

² That suggestion was not made in the original SOED circular.

Similar advice would apply to such materials of porcine origin except that the case against the use of pigs' eyes seems very doubtful.

Conclusions

It seems prudent meantime to continue avoiding the use of bovine eyes for dissection.

There is at present no serious safety case for a ban on the use of bovine offal other than that of nervous system origin.

The use of sheeps' eyes as substitutes for cattle eyes is without logical or scientific grounds. Other ovine organs long used in schools despite the pre-existence of scrapie, can continue to be used³.

Summary

AIDS and BSE both present the hazard of infection, the probability of which is small but potentially extremely serious. These risks can be effectively controlled through a combination of:

- in a very few cases abandoning meantime a specific practical activity and

- exercise of classroom control in ensuring that common sense procedures of good hygiene are followed.

Simple precautions will not only safeguard staff and pupils but in themselves may serve also valuable educational purposes. Pupils need not only to be alerted as to hazards but also taught how to behave so as to deal with and limit the concomitant risks.

Blood sampling and dissection of bovine eyes are examples of activities best avoided. The taking of buccal smears for the examination of human epithelial cells, the use of human saliva as a source of amylase and the use of offal, or of other organs and tissues retailed as human foodstuffs, for anatomical illustration etc. should continue to be allowed in schools.

Caution

Teachers are reminded that, whatever may have been written here, in matters of health and safety they have a duty to follow the instructions of their employer. Teachers are also entitled however to question such decisions, especially where they impinge on specialist educational issues. They may ask for the reasons behind particular policies and seek to have them revised. SSERC would also welcome constructive criticism and comments on any aspect of this article.

³ With the reasonable exception of sheep brain and spinal cord material.

Appendix

Institute of Biology : Cheek cell sampling

With the permission of the Institute, we reproduce below the IOB procedure for the preparation of temporary mounts of human cheek epithelial cells.

The Institute still advises teachers and Education Authorities that they continue to allow cheek cell sampling using this recommended procedure. The Institute further states that there is no evidence that any disease has ever been transmitted via such cell sampling in school laboratories. The IOB is confident that so long as this procedure is followed then neither pupils nor staff will be in any form of danger.

Procedure

- "1. Take a cotton bud from a newly opened pack.
2. Move the cotton bud over the inside of the cheek on one side of the mouth and along the outer lower side of the gum.
3. Smear the cotton bud over a small area of a clean microscope slide.
4. Place the used cotton bud immediately in a small volume of 70% alcohol in a suitable container (e.g. 5 cm³ of 70% alcohol in a 10 cm³ specimen tube).
5. Place 3 drops of 1% methylene blue from a dropper pipette onto the smear and cover with a cover slip.
6. Observe the smear under the low power magnification of a microscope. When the cells are in focus increase the power of the objective to achieve maximum magnification and resolution. The cytoplasm will be stained pale blue and the nucleus will be stained a darker blue.

7. After the cells have been observed, immerse the slide and cover slip in a beaker of laboratory disinfectant.
8. The teacher or laboratory technician should place the used [disinfected] cotton buds in a polythene bag which should be sealed and then disposed in accordance with any local regulations governing disposal of laboratory waste.
9. Slides and cover slips should be washed thoroughly, dried and re-used according to normal practice.

If the above safe procedure is followed there are absolutely no reasons why any student or teacher should be exposed to the risk of infection by the transmission of pathogens."

SSERC comments

Whilst we find the IOB procedure more than adequate there are a number of minor amendments which would clarify or marginally improve one or two steps within it.

In step 4 the 70% alcohol could be conveniently made up from IMS rather than ethanol or it could be propan-2-ol. There is an obvious, but small, fire risk but teachers are well versed in the control of this.

An alternative, possibly more effective but corrosive, disinfectant both for this part and for step 7 would be a chlorate(I) solution. This could be made up either from sodium chlorate(I) [hypochlorite] or by diluting domestic bleach. As with all disinfectants, to be effective it must be freshly made up just before use.

Electrothermal heating mantles

We have received notice from Electrothermal Engineering Limited through one of their distributors, Philip Harris, of a condition that can arise with certain controlled heating mantles whereby, if a particular combination of faults occur, apparatus can continue to heat without control from the energy regulator while the unit is switched on. The manufacturers stress that this condition does not represent an electrical safety hazard to the user.

While Philip Harris have dealt with their own customers directly, the manufacturers have recommended that users can carry out a relatively simple wiring modification on the affected products to ensure that heating control is maintained by the energy regulator. They suggest that this

modification is carried out along with the next routine electrical equipment checks, in line with GS23 advice, by technically competent personnel.

Products having this fault condition and relevant to schools include EM or EMV mantles with /CE suffix, or /E suffix when used with MC227 or MC228 controls. Within this range, units affected are easily identifiable. They either carry no mark number, or are labelled Mark 1 or Mark 2.

Details of the recommended wiring modification can be obtained directly from the manufacturer.

Please refer to the inside rear cover for Electrothermal's address and telephone number.

Technical Articles

Accentuate the experiment - eliminate that variable!

In the first of a short series of articles some technical difficulties with biological practical work suggested for Standard Grade and the revised Higher syllabus are discussed. Traps for the unwary are indicated. Ways to avoid some of these are suggested and further discussion and comment are invited on others.

Introduction and acknowledgement

We are most grateful to Mr Jim Shields, currently Principal Teacher of Biology at Balfron High, for bringing several of these problems to our attention.

He discovered these practical difficulties when on secondment to a TVEI funded project. This involved developing practical activities using datalogging techniques. Most of the work was intended for use at Standard Grade and the overall aim was to keep things relatively simple. Nonetheless many of the technical snags he discovered may also affect similar work at the Higher Grade.

Lead ions and enzymes

Background

In Bulletin 173 [1] we described a technique for monitoring what we thought at the time was the effect of lead ions in inhibiting the action of the catalase. That technique used a pressure sensor to follow the rate of oxygen evolution from hydrogen peroxide solutions. We

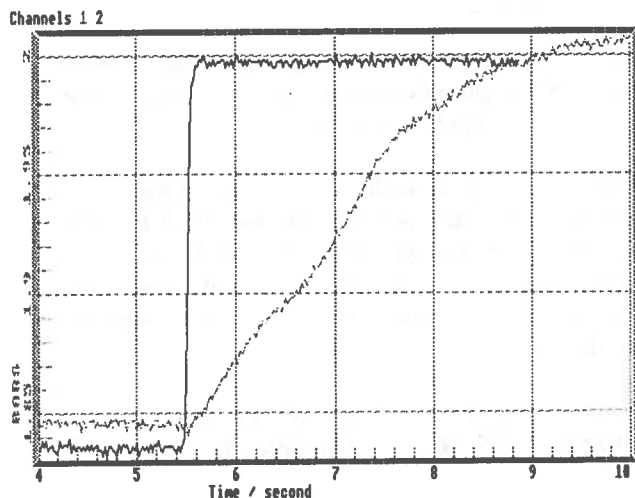


Fig. 1 - Pressure v. time {lesser slope is with $\text{Pb}(\text{NO}_3)_2$ }

used lead nitrate solutions of different molarities as the source of lead ions. The technique appeared to work very well as Figure 1 will testify.

Despite these excellent results, small alarm bells did ring about the possibility of effects from other variables such as pH and not isolating or controlling same. Jim Shield's experiences suggest that those alarm bells should have been heeded.

Jim repeated but extended our work. He used a gravimetric technique which we had developed with an interfaced electronic balance and software. He too wondered about the need to isolate and control other variables. First however he repeated our earlier lead nitrate based work but using the weight loss technique on an Oertling OB152 balance interfaced to an Acorn (BBC) microcomputer with Oertling's own software.

This method also gave excellent results (see Figure 2) which seemed to confirm the inhibitory effects of lead ions. It was when he went on to use the same basic procedure directly to investigate the effects of pH that suspicions were again aroused over the earlier results for lead nitrate. That in turn caused both he and SSERC to repeat the investigation but this time using a different lead compound as a source of lead ions.

Effect of lead nitrate on catalase activity

The basic gravimetric procedure was as follows :

1. Soak a single 2 g piece of calf's liver (see Safety Notes in this issue!) for 5 minutes in 10 cm³ of either deionised water as a control or in various molarities of lead nitrate solution (1M, 1M x 10⁻¹, 1M x 10⁻² or 1M x 10⁻³).
2. Meantime add 30 cm³ of 20 volume hydrogen peroxide solution to a 250 cm³ beaker and add a drop of anti-foaming agent (our suggestion - a silicone based agent from BDH - breaks up the bubbles of oxygen ensuring that they actually escape from the vessel and cause weight loss).
3. Place the beaker on a piece of filter paper on the balance pan.
4. After 5 minutes incubation of the liver remove it and use filter paper or tissue to blot off excess liquid (take care since although the solutions are dilute the lead nitrate is very toxic).
5. Set up the software to log weight loss against time. (300 readings per second is an appropriate rate).

6. Place the liver on the paper already on the balance pan alongside, not in, the beaker.

7. In unbroken sequence : tare the balance, transfer the piece of liver into the hydrogen peroxide and tap the spacebar to begin the datalogging.

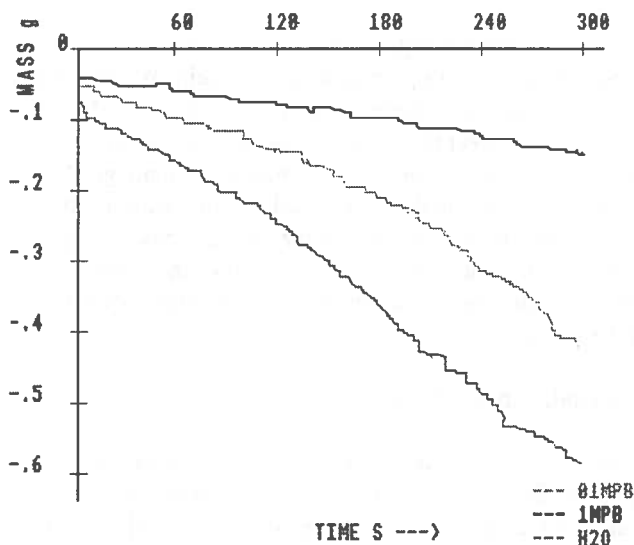


Fig. 2 Typical results weight loss v. time

Apart from the fact that the anti-foaming agent didn't seem to make much difference to the rate of weight loss the technique worked well. Typical results are shown in Figure 2.

A major purpose of the project was however to put together a number of investigations on enzyme action including other important teaching points such as optimal temperature and pH for enzymically mediated reactions. It was this latter which was next scheduled for development again using catalase as the enzyme.

Effect of pH on catalase activity

This followed the same basic weight loss procedure as above except that 4 g rather than 2 g of liver were used and there was no prior incubation.

The pH of each 30 cm³ aliquot of hydrogen peroxide solution was adjusted by adding three drops of each of :

- 1 M hydrochloric acid (yields H₂O₂ of approx. pH 3)
- De-ionised water (H₂O₂ of ca. pH 7).
- 1 M sodium hydroxide (H₂O₂ of ca. pH 9).

The remainder of the procedure is otherwise identical - placing of the separate materials on the balance pan followed by taring the balance, adding the liver to the hydrogen peroxide and immediately tapping the space bar to start logging.

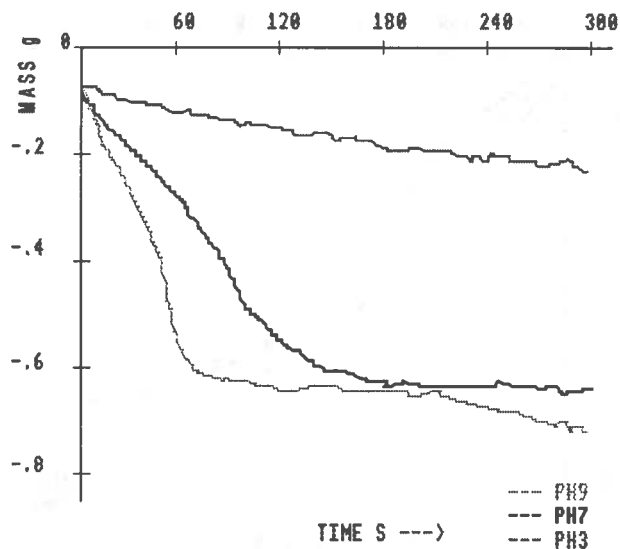


Fig. 3 Effect of pH

The results of this experiment (Fig. 3) show quite clearly that catalase works best at neutral or alkaline pH and is slowed down markedly in acidic conditions.

Lead nitrate effect : pH dependent?

Comparison of the results for the pH investigation with those for supposed effects of lead nitrate then begged an obvious question. Had we (and possibly lots of others) committed the cardinal sin of so concentrating on the investigation of the effects of one variable as to fail to isolate and control those of others?

We had used lead nitrate because it is one of the few very soluble salts of lead. We can all probably parrot the rule "all nitrates are soluble". This also shows the old fashioned way that I was taught physical chemistry. In that quaint old style lead nitrate can be thought of as the salt of a weak base and a strong acid. This means that when it ionises in water it dissociates so as to form an acidic solution. The lead nitrate solutions we were using were therefore at approximately pH 5.

This begs the obvious question : Was the observed effect on the rate of the catalase mediated reaction that of a specific inhibition by the lead ions acting on the enzyme as a protein structure or was it caused merely by having a pH value several units lower than the optimum?

Effect of lead ethanoate

Lead ethanoate (acetate) is one of the few other soluble lead compounds. Although it is markedly less soluble than the nitrate, a saturated solution nonetheless contains a lot of lead ions. It is however the salt of a weak base and a weak acid. When it dissociates it forms a neutral solution - about pH 7 - optimal for catalase.

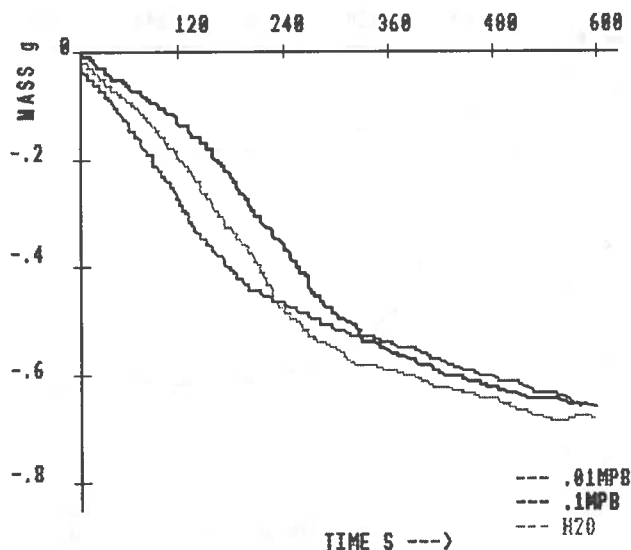


Fig. 4 Effect of lead ethanoate - balance method

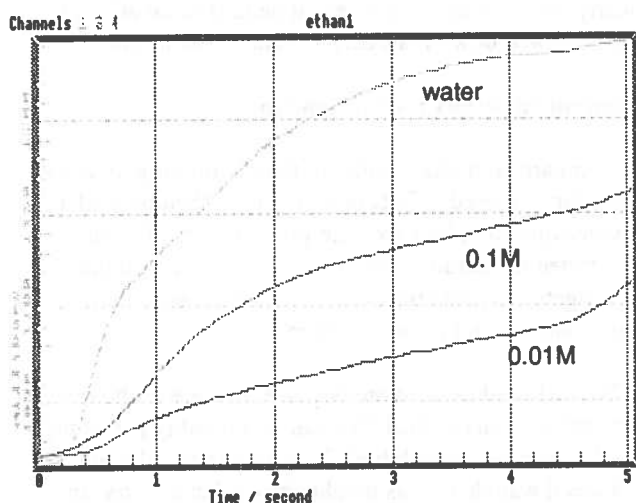


Fig. 5 Effect of lead ethanoate - pressure sensor method

Both Jim Shields and ourselves repeated our experiments. He used the electronic balance technique and we employed the pressure transducer. The results are shown in Figures 4 and 5 respectively. They are - to say the least - confusing.

The results of the gravimetric method would suggest that lead ions from a neutral lead ethanoate solution have little or no overall effect. The pressure sensor technique with Datadisc Plus software however allows us to look more closely at the initial rates of reaction in the first few seconds. There would then seem to be significant effects of lead from lead ethanoate.

Surprisingly a 0.01 M lead solution seems to be a more effective inhibitor than the more concentrated 0.1 M solution. This further complicates matters. Might there also be osmotic effects on the liver cells because the lead ethanoate solutions are nowhere near isotonic?

Unlike the balance method other trials with and without anti-foaming agent did show differences the effects of lead at both concentrations, being less marked in the absence of anti-foaming agent.

Incubation time

The lead ions are supposed to inhibit catalase because of effects on aspects of its structure as a protein. We also teach pupils that cell membranes contain proteins. Surely heavy metals might affect these also? Suppose incubation times are short and the first effect were membrane damage. That might mean one initial effect would be the release of more catalase than otherwise might have been the case. Only where the incubation time then also allows the catalase itself to be affected would we see the full inhibitory effects of the heavy metal.

Alternative procedures

We then tried the obvious alternative of adjusting the pH of the lead nitrate solutions or buffering them. This was done in an attempt to remove the influence of pH as a variable so isolating the effects of the lead ions. Unfortunately this only resulted in the formation of insoluble lead hydroxide or phosphates and the precipitating out of the lead.

Effects on other enzymes

Work on the effects of lead on other enzyme systems was then re-examined. Chief of these was the catecholase system which leads to the formation of brown and black phenolic complexes in damaged or cut fruit and vegetables such as apples, avocados, bananas and potatoes. The biochemistry of the general reaction is summarised in Figures 6 and 7 opposite.

The action of the catecholase system is also fairly well documented in the relevant section of the SCCC exemplar materials for the course [2]. We also intend devoting more space to this fascinating enzyme system in some future issue. For now the point of emphasis is that these reactions, in common with many other enzymic processes, operate most quickly over a narrow pH range. Catecholase, like catalase, works best at pH 7 or somewhat above. It is severely inhibited in acidic conditions.

This is the whole basis of the use of acidic citrus juices in order to prevent the browning of cut surfaces of fruit or vegetables. This is why the crafty cook pours lemon or orange juice into the bottom of the fresh fruit salad bowl before peeling, slicing and putting in fruit susceptible to browning such as apples or bananas.

A series of experiments have been suggested for use in Higher Biology wherein, amongst other things, the effect of heavy metals on such browning of fruit is suggested. The method is simple. Slices of fruit or potato of roughly equal size or weight are placed in Petri dishes or crystallising

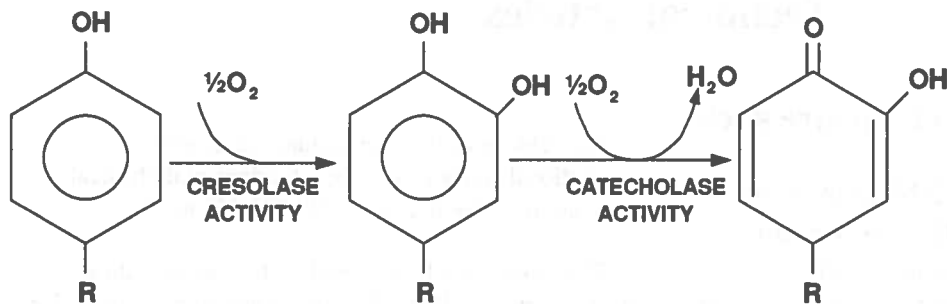


Fig. 6 Cresolase oxidizes a monophenol to an ortho-diphenol and catecholase in turn converts this to an ortho-quinone

dishes and treated with various metallic or other reagents to test their efficacy in inhibiting browning. One suggested reagent (no doubt by now you're well ahead of us) was - you guessed it - a dilute solution of lead nitrate.

We had tried out these practicals and even used them in a number of training workshops for teachers. We all found that lead nitrate was indeed a very effective inhibitor of catecholase. It had a marked preventative action in the browning of cut surfaces of apples and potatoes. When we repeated these investigations with a neutral solution of lead ethanoate (acetate) we found that the inhibition seemed insignificant. There was no discernible difference between the lead ethanoate treated surfaces and the controls in deionised water.

We suspect therefore that some effects of lead nitrate solutions are due to their relatively low pH values. This explanation may be more likely than one based on any

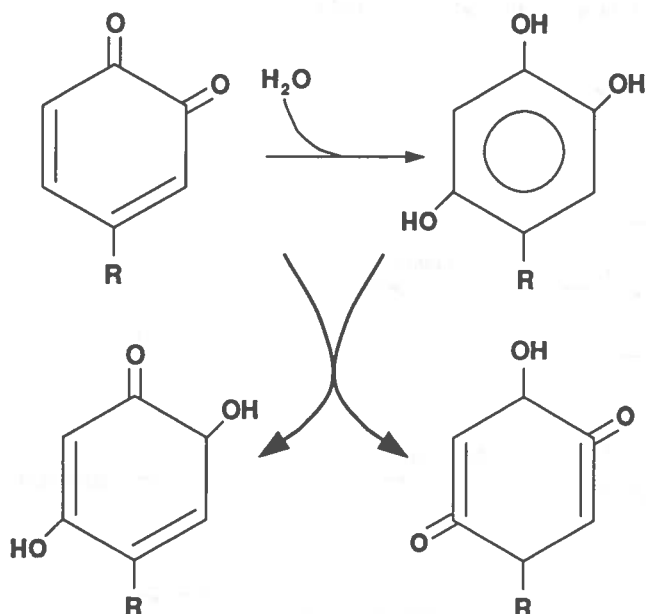


Fig. 7 Ortho-quinones are spontaneously converted to hydroxyquinones whence they readily polymerize forming brown or black phenolic polymers

direct chemical mechanism whereby the lead ions affect the protein structure or other aspects of the action of the enzyme itself. We would welcome comment on this from teachers and others more expert in biochemistry than ourselves. We would also like to hear from anyone who knows of a buffer which will control the pH of a lead nitrate solution without precipitating out the lead.

Endpiece

Other parts of this issue emphasise the importance of an appreciation in science and technology of the nature and sources of error in measurement. The advent of new techniques and technical developments in instrumentation does not diminish the importance of such awareness and understanding. In experimental design likewise, it doesn't do to neglect the fundamentals. All of the likely variables are to be identified and controlled. We trust that this little parable - a tale of how we re-learned that, the hard way - will prove useful.

We are reminded of a variant of McTavish's Law which was promulgated in the Journal of Biological Education. This quote is a favourite with Livingston Russell and thanks to him now also with science education students at Moray House Institute. The final rider however, I think, is all his own work.

"When all of the variables have been identified and each of them, bar the experimental, has been isolated or controlled, then the organism will do whatever the h... it likes - sometimes".

Next issue we will further explore the applications of this law to other aspects of the study of enzymes. In particular we will be looking at the action of urease and the interacting effects of temperature and pH. We will also tell the tale of the disappearing blue-black starch and iodine complex.

References

1. *Higher Grade Human Biology : Instrumentation*, SSERC Bulletin 173, SSERC, April 1992.
2. *Cell Biology : Teachers' Guide, Exemplar Materials*, Revised Higher Grade, SCCC, 1990.

Technical Articles

To measure the length of a metre stick

If laser light is modulated at 5 MHz by a signal from a quartz crystal oscillator then we can measure the time in nanoseconds taken by the light beam to travel an integral number of metre stick lengths. Because the velocity of light is exactly defined, we can obtain a value for the length of a metre stick.

Introduction

Why should any school try to measure the length of a metre stick? Well for one thing objects that traditionally comprised our standards of length aren't quite as stable as once might have been hoped for. Since a person's height can vary by 2 cm in the course of a day, to base a standard on the linear dimensions of a king would not be suitable nowadays. For this reason, and for others, the current definition of the metre no longer depends on material objects, animate or inanimate:

The metre is the length of the path travelled by light in vacuum during a time interval of $1/299\,792\,458$ of a second.

For although the metre is one of the seven SI base units, it is determined by two other physical quantities, one, velocity, whose value is defined exactly, and the other, time, whose magnitude can be measured to 1 part in 10^{13} .

The velocity of light in vacuum is accepted by international convention to be a fundamental physical constant. Its value is exactly $299\,792\,458\text{ m s}^{-1}$.

Time pulses can be obtained quite cheaply with a quartz crystal oscillator. The frequency stability of such a crystal is typically 50 p.p.m. across the widest temperature fluctuations that might reasonably be expected. As a percentage error, this is $\pm 0.005\%$ - a trivial magnitude in the experiment to be described.

Method

Light from a laser diode is modulated at exactly 5.00 MHz by a signal from a home-made quartz crystal oscillator. The modulated light is reflected back by double internal reflection in a 90° prism to a photodiode detector sited alongside the laser. This type of reflector is preferable to a mirror because it is far easier with a prism to reflect light back parallel to the incident beam. The time difference t between the transmitted and received 5.00 MHz signals shows as a phase difference on a dual trace CRO with 20 MHz bandwidth (Fig. 1).

If the total light path length is s the separation between the laser diode module and prism is $s/2$, as is the distance between the prism and photodiode. Distance s can then be obtained from :

$$s = vt$$

where v is the velocity of light.

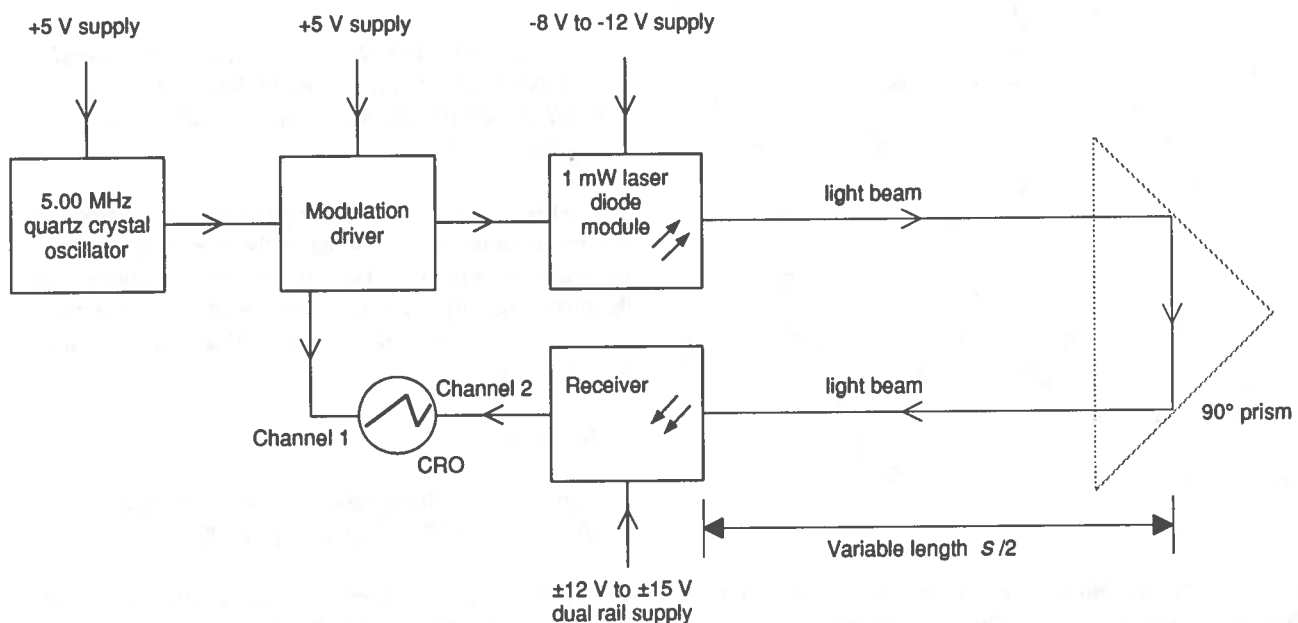


Fig. 1 Schematic arrangement of experiment

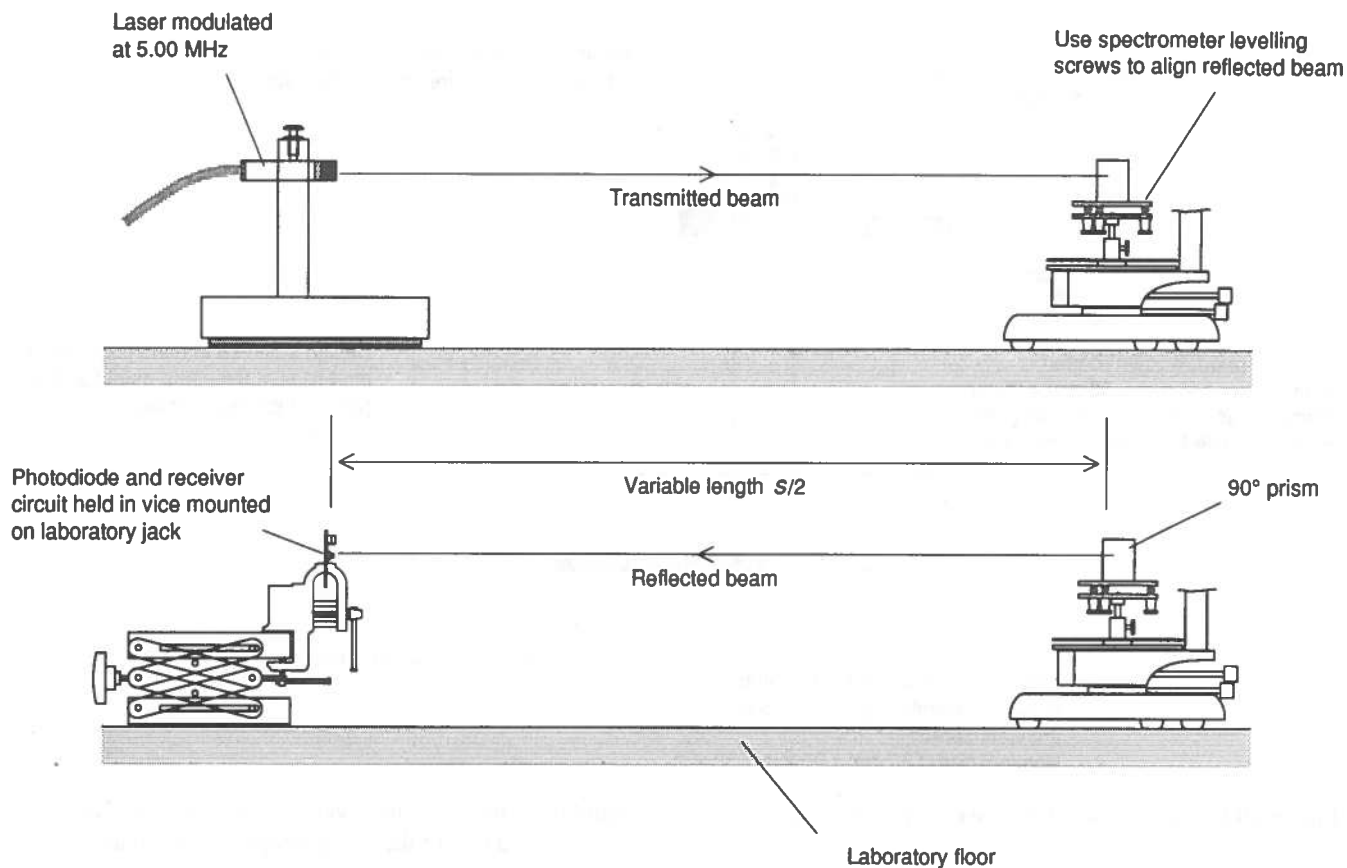


Fig. 2 Optical apparatus

We chose to set up our apparatus on the laboratory floor (Fig. 2) because we did not have sufficient bench run to accommodate a long beam length. By using the floor, there is the added safety benefit that the laser beam should at all times be well below eye level.

The position of the laser diode module was kept fixed throughout the experiment. The prism was mounted on a spectrometer table. By means of the three levelling screws which adjust the table, we were able to direct the reflected beam at, or near to, the detector. Some minor movement in the position of the detector was also sometimes needed. The laser beam position was found by slipping a sheet of paper into its path.

The floor between the laser and prism was marked with a series of parallel lines at 50 cm separations taken off the metre stick whose length we were attempting to measure. By shifting the spectrometer and prism from one marker to another, the path length could thence be varied by integral amounts of metre stick lengths. The maximum range we operated with was 7.5 m nominal, which gives a path length of 15 m nominal.

If a series of readings are taken for a succession of different light path lengths nl where l is the length of the metre stick (constant) and n is the integral number of metre stick lengths (variable) we get an ordered set of pairs of variables from which a value of l can be obtained.

From the relationship

$$nl = vt$$

we can rearrange to get

$$t = (l/v)n$$

By plotting a graph of ordered pairs (n, t) , we can get a value for the gradient l/v , and hence get a value for l .

Apparatus

The laser should be securely held in a clamp. Whilst a laboratory clamp stand in good working order would quite satisfactorily hold the laser steady, we felt that such an arrangement lacks permanency. It would be all too easy for a pupil to unclamp the laser and point it at another person. We therefore constructed a stand comprising of a vertically mounted wooden batten fastened by dowels to a heavy wood laminate base (Fig. 3). This stood on an anti-vibration rubber mat, which helped grip the stand to the floor as well as prevent the laser beam from shaking. Anti-vibration matting can be obtained by stripping off from old machinery, or as an off-cut from a dealer. If neither means prove fruitful, then a piece of rubber matting, such as carpet underlay, can be substituted. The laser is clamped in place by a plastic screw of the sort sold, complete with a socket, by DIY shops to secure kitchen furniture.

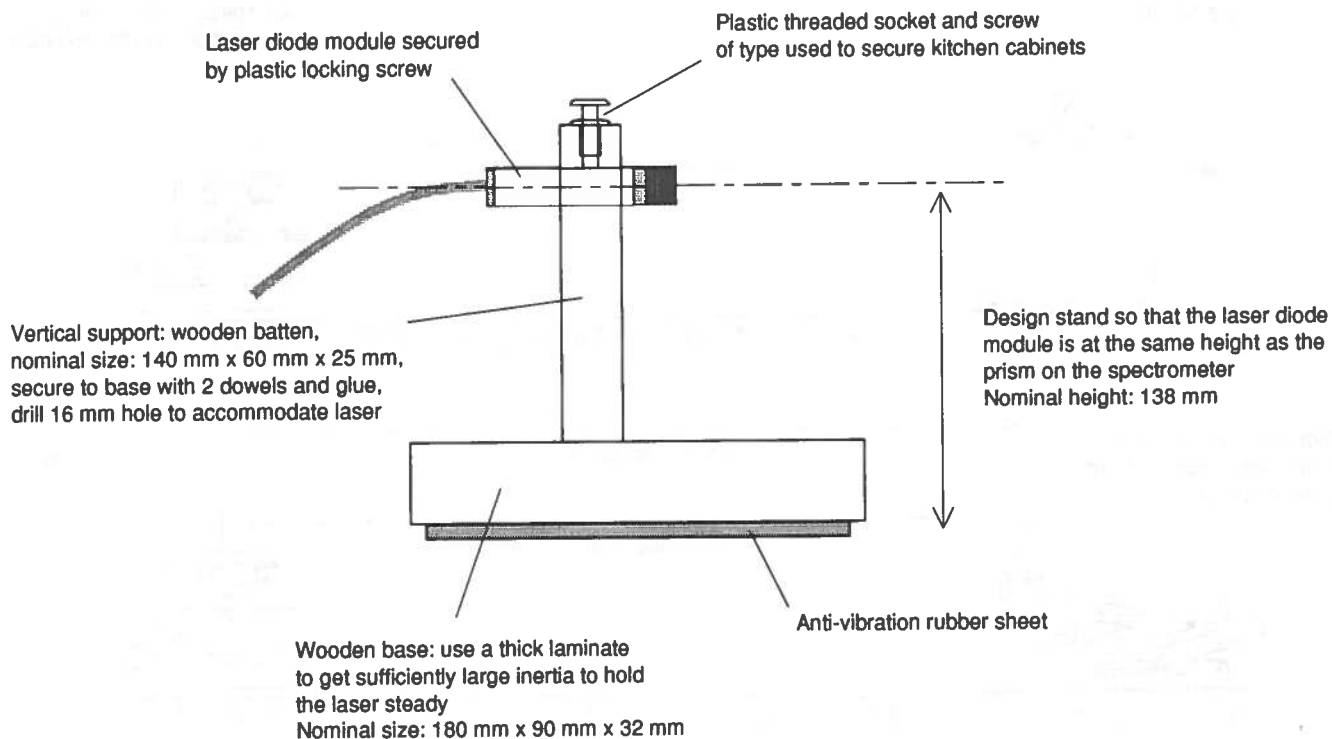


Fig. 3 DIY apparatus to hold laser diode module

The stripboard to which the photodiode and receiver circuit were soldered was held in the jaws of a small vice. This was clamped to a laboratory jack (Fig. 4). The assembly had several merits. The massiveness of the vice and jack kept the photodiode sufficiently steady for obtaining a stable output signal. The height of the sensor could be finely adjusted to catch the light beam by turning the jack screw. Fine lateral movement could be accomplished by sliding the jack across the floor.

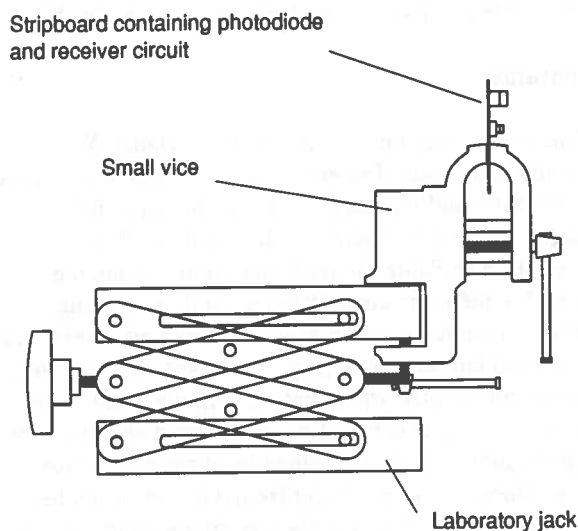


Fig. 4 Method of mounting photodiode and receiver circuit

Light takes about 3 ns to travel one metre in air. The calibrated sweep rate of the oscilloscope should be at least as fast as 20 ns/div so as to be able to resolve time periods of 3 ns. The maximum sweep rate of 20 ns/div can be found on some of the better 20 MHz dual trace oscilloscopes. Those with this facility were listed in a recent Bulletin issue [1].

Electronic circuits

The laser in the experiment is a laser diode module (RS 564-504) that emits visible red light with a power output of 1 mW. It thus meets the requirements of Class 2 construction. When using the laser, you are advised to follow the recommended code of practice [2].

Electrical connections to the laser are made through flying leads which are colour coded:

Green	0 volts
Black	Negative supply
White	Interlock
Blue	TTL disable
Green & Yellow (Twisted pair)	Modulation

The laser power supply voltage is negative. It should lie between -8 V and -12 V with respect to the 0 V terminals. Exceeding -12 V is likely to destroy the laser. The operating current is 110 mA at -8 V, or 130 mA at -12 V. A suitable power supply would be the negative rail of a dual rail voltage regulated supply rated at 250 mA or higher. Failing that, a 9 V battery can be used, but you would be draining a lot of current from it.

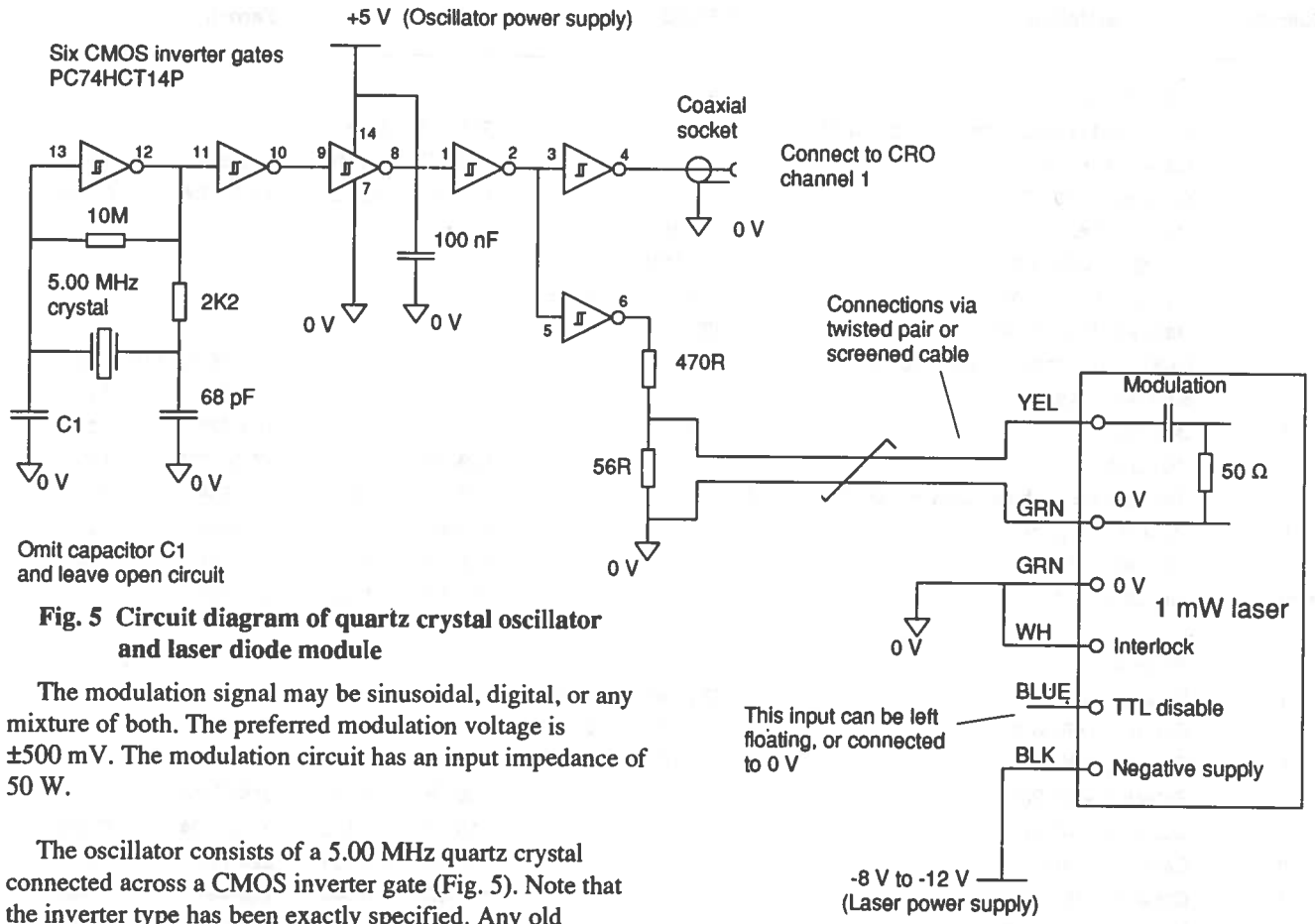


Fig. 5 Circuit diagram of quartz crystal oscillator and laser diode module

The modulation signal may be sinusoidal, digital, or any mixture of both. The preferred modulation voltage is ± 500 mV. The modulation circuit has an input impedance of 50 Ω .

The oscillator consists of a 5.00 MHz quartz crystal connected across a CMOS inverter gate (Fig. 5). Note that the inverter type has been exactly specified. Any old inverter substituted for a PC74HCT14P is unlikely to work [3]. Quartz crystal circuits are notoriously fickle. Textbook circuits include the capacitor C1 between the gate input and ground. However we found that the circuit would only oscillate if this capacitor was left out and the input to ground connection was left open circuit.

Because the PC74HCT14P has CMOS circuitry, every input not in use must be tied high or low. That's why all six inverter gates are chained in use.

The circuit should be screened by enclosing it within a diecast aluminium box. The output to the laser modulation circuit should be via the green and yellow twisted pair connected to the laser. A BNC coaxial socket should be fitted to the box for connecting to the CRO through a screened cable.

If you are prepared to forgo the excitement of working with a discrete crystal, and don't mind spending an additional pound or so, then you should buy a crystal oscillator module in place of building the oscillator circuit. RS sell a 6.0 MHz oscillator module (658-839) for £3.66. The output is TTL compatible and, from its specification, should readily drive two TTL loads (Fig. 5), one of which would drive the laser modulation circuit, and the other of which would drive CRO Channel 1.

The photodiode BPW34 (Fig. 6) has been chosen because of its sensitivity to red light, its low price and large surface

area. We get it switching fast (at 5 MHz) by placing a large reverse bias voltage (12 V to 15 V) across it. If light falls on the photodiode, the bias current generates a voltage on the op-amp's output. The op-amp type, LM6364, has a fast response and is able to operate at the 5 MHz required of it. The lead connecting to the cathode on the BPW34 has a tiny dot of blue ink for identification.

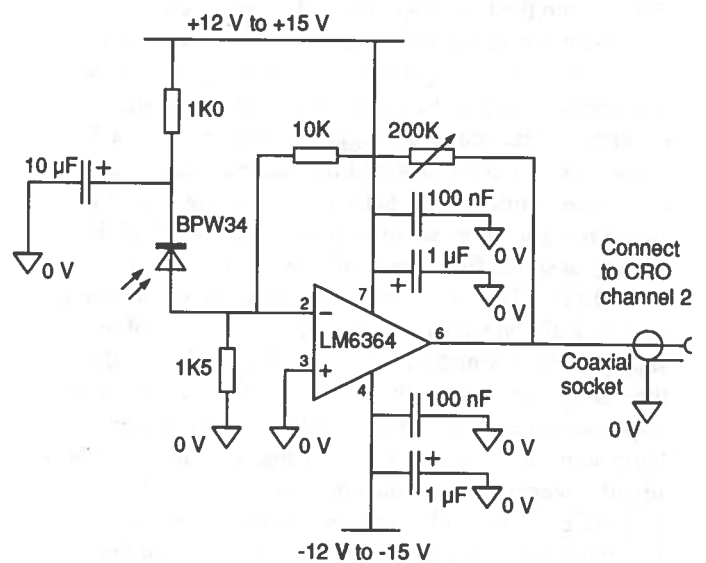


Fig. 6 Circuit diagram of photodiode and receiver amplifier

Quantity	Part description	SSERC	£	RS	£	Farnell	£
<i>5.00 MHz oscillator and laser</i>							
1	Laser diode module, modulating, 1 mW	-	-	564-504	155.00	-	-
1	Capacitor, 68 pF	-	-	113-257	0.116	105-059	0.114
1	Capacitor, 100 nF	-	-	115-988	0.122	37021104	0.095
1	Resistor, 2K2, ¼ W	420-2K2	0.006	-	-	-	-
1	Resistor, 10M, ¼ W	420-10M	0.006	-	-	-	-
1	Resistor, 56R, ¼ W	420-56R	0.006	-	-	-	-
1	Resistor, 470R, ¼ W	420-470R	0.006	-	-	-	-
1	CMOS hex Schmitt inverter PC74HCT14P	-	-	-	-	PCF74HCT14P	0.78
1	5.00 MHz crystal	-	-	-	-	109-913	0.65
1	BNC socket	-	-	455-810	1.42	143-779	1.37
1	Diecast box	-	-	509-989	2.80	27134-PSL	1.74
6	Steel slotted panhead screws, M3 x 10, per 100	-	-	560-760	3.62	149-506	0.96
10	M3 nuts, per pack	-	-	526-439	3.77	149-680	0.87
1	DIL socket, 14-way	-	-	402-765	0.083	179-881	1.80
part	Stripboard, 0.1"	-	-	433-826	4.55	147-899	5.55
<i>Receiver</i>							
1	Resistor, 1K0, ¼ W	420-1K0	0.006	-	-	-	-
1	Resistor, 1K5, ¼ W	420-1K5	0.006	-	-	-	-
1	Resistor, 10K, ¼ W	420-10K	0.006	-	-	-	-
1	Potentiometer, 200K	-	-	186-788	0.44	3886P 200K	0.41
2	Capacitor, 100 nF	-	-	115-988	0.122	37021104	0.095
2	Capacitor, 1 µF	-	-	107-561	0.054	228-710	0.048
1	Capacitor, 10 µF	-	-	107-303	0.046	228-461	0.042
1	Photodiode, BPW 34	-	-	-	-	BPW 34	1.01
1	Op-amp, LM6364N	-	-	648-624	3.28	LM6364N	3.28
1	DIL socket, 8-way	-	-	402-759	0.049	179-880	2.04

Table 1 Electronics parts list, with suppliers and prices

Procedure

The photodiode initially should be set up pointing directly into the laser's aperture. This gives you an opportunity of seeing that each part of the system works - or fails to work, as may be! The oscilloscope should be triggered on channel 1 by the signal from the quartz oscillator. Alternate mode triggering must not be used. Were it to be used, you would be unable to register a difference in time delays between the two signals. The sweep rate should be set to 20 ns/div. You will find that the digital signal from the oscillator has a rise-time of about 12 ns. (The rise-time is the time taken by the rising edge of a digital signal to rise from 10% to 90% of the supply voltage, which in this case is 5.0 V.) Much of this time delay is caused by the CRO amplifier's slowness of response. On channel 2, the signal from the receiver is fairly sinusoidal about 0 V. The rising slope may have a slightly steeper gradient than the falling slope. The amplitudes of the peaks and troughs may differ by 5%. The gain on the receiver amplifier should be kept fairly low. The amplitude at which we got best performance across the overall range was 2 V peak value. Final

adjustment of the gain control should be delayed until the next stage of the procedure, when the light beam path length is at a maximum. Optimum y-amplifier settings are 2 V/div on channel 1 and 1 V/div on channel 2 (Fig. 7).

For the second part of the procedure, the photodiode should be placed alongside the laser in the position it will occupy for most of the the rest of the experiment (as in Figures 1 and 2). The prism should be sited at the furthest point to be used. Because the path length has been maximized, the return signal strength should now be at a minimum. The collimating lens on the laser should be adjusted so that light is focused at the maximum path length. The position of the prism and the level of the spectrometer table should be adjusted so that the beam is directed at, or near to, the photodiode. Some final change in the position, and height, of the jack will probably be necessary. As a result of these adjustments, the laser beam should fall centrally on the photodiode. The gain control on the receiver amplifier should now be finally set to give a peak voltage on channel 2 of 2.0 V. The x-position on the CRO trace where the channel 2 signal rises through 0 V should be determined (Fig. 7).

The spectrometer table should be moved to the next distance marker closer to the laser and the light beam redirected at the photodiode. If the signal strength is larger than 2.0 V peak the photodiode should be displaced partly out of the beam to reduce the magnitude to this value. The second measurement should be taken.

This procedure should be repeated for as many readings as is required. From our experience, the time it takes to align the beam and take a reading once you have gained some experience in handling the apparatus is 7 minutes. One of the readings should be for a range of 0 m, which requires placing the photodiode in front of the laser again, as in the preliminary stage of the procedure. The peak voltage tolerance is 10% - i.e. the amplitude should lie between 1.8 V and 2.2 V.

Oscilloscope trace procedure

The main observational difficulty is being able to accurately measure the time difference between arbitrary fixed points on the two waveforms. The traces are triggered by the oscillator output. Ideally, the trace on channel 1 will be immutable. However this cannot be taken for granted. In one experimental run, the waveform shifted 1 mm leftwards during the warm-up period. This is a time step of 2 ns, corresponding to an error in length of 0.7 m.

The following method was used to check on the position of the trace on channel 1. Firstly the input coupling was grounded and the trace was centred on a horizontal grid line. Then on d.c. coupling, the low part of the signal *AB* (Fig. 7) was inspected to see that it lay exactly on 0 V and the high part *CD* was inspected to see that it was centred on 5.0 V. This being seen to be so, the horizontal positions of the rising edges at 2.0 V (*E* and *F*) were recorded to the nearest 0.5 mm. The method thus first checks that there has been no vertical drift or expansion in the trace, then records the position where the trace has its greatest horizontal sensitivity.

On channel 2, the input coupling should periodically be grounded to check that the trace is centred on a horizontal grid line. If the trace has drifted off the line, then it should be moved back over the line by adjusting the vertical shift control.

The position of trace 2 should be measured by recording where the trace rises through 0 V (point *G*). The measurement precision should be to the nearest 0.5 mm, corresponding to a time resolution of 1 ns.

Analysis of measurements ⇨

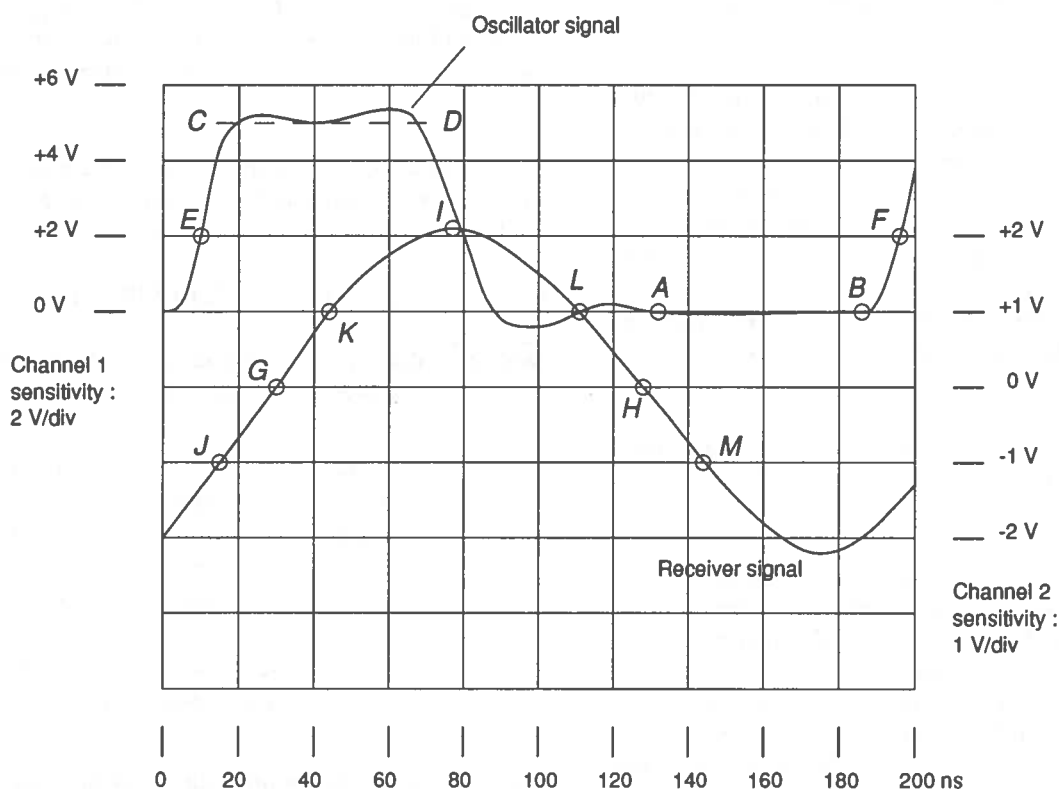


Fig. 7 Waveforms on CRO : top trace is the transmitted signal; bottom trace is the received signal

Analysis of measurements

A set of ordered pairs of time t versus integral number of metre stick lengths n is shown in Table 2.

n	t (ns)
0	31 ± 1
1	35 ± 1
3	41 ± 1
6	50 ± 1
9	60 ± 1
12	68 ± 1
15	80 ± 1

Table 2 Experimental data

One way of analysing the data is graphical. A graph of ordered pairs of n versus t can be seen to be a straight line. By measuring the gradient, a value for l/v can be obtained, from whence you can get a value for l , the length of the metre stick.

Analysis can also be done by computational means, such as using the linear regression function on a scientific calculator. Following this approach the gradient l/v of the set of data (n, t) is 3.177 ns. Multiplying this by v (299 792 458 m s⁻¹) gives a value for l of 0.952 m.

There is however a systematic error in our data. Because the 20 MHz oscilloscope is operating at the edge of its capability, its specified sweep rate tolerance at 20 ns/div is ±5%, somewhat larger than across lower sweep rates. The error can be noticed on the oscillator signal in Figure 7. Points E and F are 94 mm apart - not 100 mm, had the sweep rate been accurate. Because this signal comes from a quartz oscillator, we can have reasonable confidence that its oscillation period is 200 ns exact. The oscilloscope time base is therefore reading 6% slow.

By applying a correction factor of $\times 1.064$, the gradient l/v becomes 3.380 ns giving a value for l which is 1.013 m.

In estimating the error of our result, the main source would seem to lie in the method of marking the position of the signals on the oscilloscope. Several different methods of tagging the horizontal position of the waveform have been tried. As well as noting where the signal rises through 0 V (point G , Fig. 7), we have recorded where it falls through 0 V (point H), the position of the maximum (point I) and the mean of the -1.0 V and +1.0 V positions for rising (J and K) and falling (L and M) values. Values for the gradients incorporating the $\times 1.064$ correction factor are given in Table 3. It can be seen from the correlation coefficients that the least accurate method would appear to be that of recording the

position of the maximum. There appears to be little to choose from between the other four tagging methods.

The variation in values of l obtained by these five tagging methods provides a way of estimating the random error in reading the oscilloscope. The standard deviation in the values of l is 0.017 m. Using probability statistics, the mean value has a random error with a 95% confidence probability of ±0.021 m.

Any non-linearity in the oscilloscope sweep rate sensitivity has not been assessed. Were there to be non-linearity, it would be the edges of the screen where the effect would be liable to occur.

The one other sizeable error is that associated with estimating the accuracy of the sweep rate. The uncertainty in estimating the separation of points E and F is ±1 mm. This uncertainty would lead to there being a systematic error in the time base correction coefficient, causing a systematic error in l of ±0.011 m.

Combining these errors¹ using

$$U = [0.021^2 + 0.011^2]^{1/2}$$

gives a combined uncertainty of ±0.023 m.

Using the mean value of l from the different tagging methods (Table 3), the best estimate of the length of the metre stick is 0.995 m, with a 95% confidence level of ±0.023 m.

How does this compare with the simpler method of using two sets of measurements. Using values of (n, t) from Table 2 for values of n of 0 and 15, we get

$$l = vt/n = 0.299\ 792 \times (80 - 31) \times 1.064 / 15 = 1.04\ \text{m}$$

Method	Corrected gradient (ns)	Correlation coefficient	Metre stick length l (m)
G	3.380	0.9991	1.013
H	3.297	0.9995	0.988
I	3.363	0.9957	1.008
JK	3.330	0.9996	0.998
LM	3.234	0.9992	0.970
		Mean value of $l =$	0.995
		Standard deviation =	0.017

Table 3 Analysis of results obtained from 5 different methods for measuring time

¹ Strictly, this relationship should only be used when combining errors of known, similar, confidence levels. However in this case the error with the unknown confidence level would seem to be sufficiently small as to be negligible.

If the uncertainties in reading time off the oscilloscope is ± 1 ns, we get maximum and minimum values of l of 1.08 m and 1.00 m respectively. Thus the result can be expressed as $1.04 \text{ m} \pm 0.04 \text{ m}$, where the confidence level of the error is unknown.

Conclusion and comment

The method relies upon a new optoelectronic product - the laser diode module. Advantage is made of the high intensity and collimation of its light beam, and the facility for modulating the beam at very high frequency. Also needed is a modern twin beam oscilloscope with a sweep rate of at least 20 ns/div. No other expensive specialist equipment is needed. The cost of the quartz oscillator and other electronic components does not exceed £12.

Even although the oscilloscope is being operated at its limit, where the precision of any single reading is low, the methods of analysing results by drawing the best fit line through a set of ordered pairs of data and obtaining a gradient, and of statistical methods, have been shown to yield a result with an error of only about $\pm 2\%$.

Some readers may question the wisdom of framing the experiment in the manner done so here. Might not it be more appropriate at school level to measure the velocity of light? I have some sympathy for this view. However having consulted with Dr R C Dougal of Edinburgh University Physics Department, with staff at the National Physical Laboratory and with an HM Inspector of Schools, I am persuaded that the purpose of the experiment is as stated here.

References

1. *Oscilloscopes, Equipment Notes*, Bulletin 176, SSERC, 1993.
2. *Laser safety and laser diodes, Safety Notes*, Bulletin 176, SSERC, 1993.
3. *Quartz crystal oscillator*, Bulletin 151, SSERC, 1986.

SSERC SOFT 93 Software for Serious Science & Technology

THE SSERC GRAPHICS CD-ROM

For CHEMISTRY, PHYSICS, BIOLOGY, TECHNOLOGY, I.T., COMPUTING.

Existing users of our Graphics Libraries qualify for a discount of £3 off the price below for each Library disc previously bought.

Vector
Libraries

One price = £150 for a full school licence

The advertisement features several graphical elements:

- Vector Libraries:** A cluster of spheres representing molecular models.
- * Sprites:** A screenshot of a 'Dual Beam Oscilloscope' interface with various control knobs and a waveform display.
- * Drawfiles:** A detailed drawing of a human skeleton.
- * Friendly front-end program:** A screenshot of a search interface titled 'SSERC Graphics Collections' with fields for 'Search for:', 'Keyword/title: anyword', and checkboxes for 'DrawFiles', 'Sprites', 'DXF files', 'Applications', and 'Data files'.
- * New Graphics:** A screenshot of a 'MICROMETER GRID' interface with various measurement controls.
- * Programs:** A screenshot of a 'POWER SUPPLY' interface with various electrical parameters.

plus Helpfiles, Draw Practical Guides, DXF files, Text-Path, Interfacing data and more.
 SSERC, 24 Bernard Terrace, Edinburgh EH8 9NX Tel. 031 668 4421 or Fax. 031 667 9344
 Please make all cheques payable to SSERC or SAE (£1 please) for full information pack. Add VAT above.

Equipment Notes

Digital multimeters

Multimeter model	Supplier	Order code	Price (£)	Special or quantity discounts		
Altai ALT 26	Tait Components		14.96			
Digitek DT 3900	RMR Measurements		29.00	less 10% educational discount		
Digitek DT 9101	RMR Measurements		31.00	less 10% educational discount		
ISO - TECH IDM 65	RS Components	214-451	48.95	47.73 (5+)	46.50 (10+)	45.28 (20+)
ISO - TECH IDM 600	RS Components	205-564	53.95	51.26 (5+)	48.56 (10+)	45.88 (20+)
MAXCOM MX 200	CPC	INMX-200	12.83	12.45 (3+)	12.09 (10+)	11.42 (50+)
MAXCOM MX 280	CPC	INMX-280	27.78	26.41 (3+)	25.42 (10+)	24.80 (50+)
Metex Testlab DM 1030	Ravencourt	RY123GC	39.95	37.95 (10+)		
Metex Testlab M-3800	Tait Components		23.45			
Wavetek DM5XL	Tait Components		26.81			
Wavetek DM10XL	Tait Components		35.06			
Wavetek DM15XL	Tait Components		43.31			
Yu Fong YF 3501	CPC	INYP 3501	31.18	30.20 (3+)	29.99 (10+)	28.85 (50+)
Yu Fong YF 3503	CPC	INYP 3503	30.65	29.69 (3+)	28.79 (10+)	28.36 (50+)

Table 1 Multimeter suppliers, order codes and prices

Scope of report

In this report we look at a batch of 14 digital multimeters (DMM). Most of our sample (Table 1) are at the bottom end of the market where, because they do not cost very much, they will be of interest to schools. One specialist meter, of use where voltages might be at hazardous live, is also reviewed.

The best buy of the last batch we reported on in 1990 is compared with the recommendations from this lot.

Because there are far more multimeters on the market than the Centre can possibly test, there may be meters you are interested in buying which have not been tested by us. We therefore offer, within reason, and if feasible, to test any other model of meter for a school at their request.

Functions

A review of curricular requirements was given in our last multimeter test report [1]. In summary, measurement of a.c. and d.c. current and voltage, and also resistance, are the main required functions. Table 2a shows which meters have these basic functions.

Provided you already have a class set of meters with all of these functions there may be a financial benefit from buying another set of meters with a restricted range of functions - perhaps missing out on a.c. current only, or both of a.c. and d.c. current.

Of the extra functions (Table 2b), continuity testing is certainly very useful. Logic level testing is of restricted use in digital electronics. Capacitance measurement is occasionally wanted, but this function clutters up what is usually already a very crowded set of markings. And so does frequency measurement - which seldom do we find to be accurate on low priced DMMs.

The safety feature on the Wavetek DM10XL lets you detect the presence of voltages, including hazardous live voltages, even when the DMM battery is dead.

All three Wavetek meters emit an audible bleep if a connector is inserted into a current socket while the rotary switch has not been set to one of the current ranges particular to that socket. This is done by using a 4 mm socket with split sides which only conduct with each other when a plug is inserted. It is a nice idea and should reduce the incidence of blown fuses. However we found that certain types of 4 mm plug made intermittent connection with this type of socket.

Safety

In normal school usage, multimeters are put in circuits which are at very low voltage - certainly below the criteria for hazardous live we published in a recent Bulletin issue [2]. All of the meters in our batch have voltage ranges that extend into regions that could be hazardous. Except for the ISO - TECH IDM 600, which has been specifically designed for such use, we recommend that none of these meters are used at hazardous live. Specifically, none of the test leads supplied with these meters are safe for such work.

Multimeter model	Voltage d.c.	Voltage a.c.	Current d.c.	Current a.c.	Resistance
Altai ALT 26	20 V, 200 V	500 V	10 A	-	2 k Ω , 2 M Ω
Digitek DT 3900	200 mV - 1000 V	200 mV - 700 V	20 μ A - 20 A	20 μ A - 20 A	200 Ω - 20 M Ω
Digitek DT 9101	200 mV - 1000 V	200 mV - 750 V	20 μ A - 20 A	20 μ A - 20 A	200 Ω - 20 M Ω
ISO - TECH IDM 65	200 mV - 600 V	2 V - 600 V	-	-	200 Ω - 20 M Ω
ISO - TECH IDM 600	200 mV - 600 V	2 V - 600 V	-	-	200 Ω - 2 M Ω
MAXCOM MX 200	200 mV - 1000 V	200 V, 750 V	200 μ A - 10 A	-	200 Ω - 2 M Ω
MAXCOM MX 280	200 mV - 1000 V	200 mV - 750 V	2 mA - 200 mA, 20 A	2 mA - 200 mA, 20 A	200 Ω - 20 M Ω
Metex Testlab DM 1030	200 mV - 1000 V	2 V - 700 V	20 mA, 2 A, 10 A	20 mA, 2 A, 10 A	200 Ω - 20 M Ω
Metex Testlab M-3800	200 mV - 1000 V	200 mV - 700 V	20 μ A - 20 A	20 μ A - 20 A	200 Ω - 20 M Ω
Wavetek DM5XL	200 mV - 1000 V	200 V, 500 V	200 μ A - 200 mA	-	200 Ω - 2 M Ω
Wavetek DM10XL	200 mV - 1000 V	200 V, 750 V	200 μ A - 200 mA, 10 A	-	200 Ω - 20 M Ω
Wavetek DM15XL	200 mV - 1000 V	200 mV - 750 V	200 μ A - 200 mA, 10 A	200 μ A - 200 mA, 10 A	200 Ω - 20 M Ω , 2 G Ω
Yu Fong YF 3501	200 mV - 1000 V	200 mV - 750 V	20 mA, 200 mA, 20 A	20 mA, 200 mA, 20 A	200 Ω - 20 M Ω
Yu Fong YF 3503	200 mV - 1000 V	200 mV - 750 V	200 μ A - 200 mA, 20 A	200 μ A - 200 mA, 20 A	200 Ω - 20 M Ω

Table 2a Multimeter basic functions ; V, I and R

Multimeter model	Capacitance	Frequency	Diode	Continuity	h_{FE}	Logic
Altai ALT 26	-	-	Y	-	-	-
Digitek DT 3900	-	-	Y	Y	Y	-
Digitek DT 9101	-	-	Y	Y	Y	-
ISO - TECH IDM 65	2 μ F - 200 μ F	-	Y	Y	-	-
ISO - TECH IDM 600	-	-	Y	Y	-	-
MAXCOM MX 200	-	-	Y	-	-	-
MAXCOM MX 280	2 nF - 20 μ F	2 kHz - 200 kHz	Y	Y	Y	-
Metex Testlab DM 1030	-	-	Y	Y	Y	-
metex Testlab M-3800	-	-	Y	Y	Y	-
Wavetek DM5XL	-	-	Y	Y	-	-
Wavetek DM10XL	-	-	Y	Y	-	-
Wavetek DM15XL	-	-	Y	Y	-	Y
Yu Fong YF 3501	-	-	Y	Y	-	-
Yu Fong YF 3503	2 nF - 20 μ F	-	Y	Y	Y	Y

Table 2b Multimeter functions extra to V, I and R

Features

The following comments relate to data given in Tables 3a and 3b.

Key : N = no; Y = Yes

Common terminal : Avoid meters with a common terminal for V, mA and Ω ranges. The common terminal raises the chance of mis-use, leading to more nuisance fusing than on meters with separate mA terminals.

Fuse protection : In most circumstances the lack of fuse protection on the 10 A or 20 A range is not a nuisance since few laboratory power supplies can deliver currents greater than 10 A. However if a multimeter were to be used for measurements on the mains supply, or indeed on any hazardous live supply, all the current ranges should have fuse protection. Because there is a risk of mis-use of test equipment in schools, it would be good practice to buy only those meters that were fully fused on all current ranges.

Battery current : The battery current drawn by all the meters in the batch is reasonably low.

Auto power off : This feature is desirable, but only found on the more expensive models.

Range selection : All the autoranging meters show the appropriate SI unit on the LCD display. This is excellent. Key :

A = autoranging; M = manual; A/M = autoranging & manual

Markings : Markings must not be ambiguous. Any meter with a switch setting showing two different ranges or functions is given a lower assessment. Key :

A = clear; B = tolerably clear; C = unclear, significant chance of misinterpreting

Number of digits : All of the displays have $3\frac{1}{2}$ digits, meaning that the maximum value is 1999.

Display height : Because the display height of the Digitek DT 9101 is an impressive 25 mm, and because the display is on a swivel, allowing it to be raised off the meter, this meter is well suited for demonstration experiments.

SI units : SI units on the LCD display feature on the autoranging models only.

Hold : This pushbutton freezes the display. It is useful for taking a series of measurements at regular periods of a changing signal.

Offset : When this button is depressed, the last two significant digits are stored and subtracted from all the following input values. It is a sophisticated function that could be confusing for beginners. To give an example of its usefulness, when taking resistance measurements, the resistance of leads could be removed from readings.

Protective holster : This is a flexible plastic holster encasing the meter while in operation. Were the meter dropped, the holster would prevent damage.

Robustness : In rank order, the ISO - TECH meters were mechanically robust, the Wavetek and Yu Fong were also reasonably robust, but the others were less so. None fell apart in our examinations. Key :

A = mechanically robust, unlikely to be damaged by dropping

B = reasonably robust, liable to be damaged by dropping

Multimeter model	Common V and / terminal	mA ranges fused	10/20 A range fused	Battery type	Battery current (mA)	Auto-power off	Range selection	Markings	Dimensions L B D (mm)
Altai ALT 26	N	-	N	PP3	1.1	N	M	B	150 x 73 x 33
Digitek DT 3900	N	Y	N	PP3	1.2	N	M	C	183 x 88 x 48
Digitek DT 9101	N	Y	N	PP3	1.9	N	M	A	185 x 84 x 34
ISO - TECH IDM 65	-	-	-	PP3	2	Y	A/M	A	164 x 79 x 38
ISO - TECH IDM 600	-	-	-	PP3	2.2	Y	A/M	A	190 x 93 x 52
MAXCOM MX 200	Y	Y	N	PP3	1	N	M	C	125 x 69 x 25
MAXCOM MX 280	N	Y	N	PP3	2	N	M	C	189 x 88 x 33
Metex Testlab DM 1030	N	Y	N	2 AA	0.45	N	A	B	94 x 90 x 74
Metex Testlab M-3800	N	Y	N	PP3	1.3	N	M	B	172 x 88 x 40
Wavetek DM5XL	N	Y	-	PP3	1.8	N	M	A	183 x 80 x 38
Wavetek DM10XL	N	Y	Y	PP3	1.5	N	M	A	183 x 80 x 38
Wavetek DM15XL	N	Y	Y	PP3	1.9	N	M	A	183 x 80 x 38
Yu Fong YF 3501	Y	Y	N	2 AA	0.4	N	A/M	A	140 x 73 x 38
Yu Fong YF 3503	Y	Y	N	PP3	2.8	N	M	B	140 x 73 x 38

Table 3a Multimeter features, Part A

Multimeter model	No. of display digits	Display height (mm)	SI units shown	Hold	Offset	Protective holster	Enclosure colour	Robustness
Altai ALT 26	3½	12.5	N	N	N	N	Orange	B
Digitek DT 3900	3½	17	N	N	N	N	Orange	B
Digitek DT 9101	3½	25	N	N	N	N	Dark grey	B
ISO - TECH IDM 65	3½	12	Y	Y	Y	Y	Dark grey	A
ISO - TECH IDM 600	3½	15	Y	Y	Y	Y	Orange	A
MAXCOM MX 200	3½	12	N	N	N	N	Orange	B
MAXCOM MX 280	3½	24	N	N	N	N	Orange	B
Metex Testlab DM 1030	3½	10	Y	Y	N	N	Orange	B
Metex Testlab M-3800	3½	17	N	N	N	N	Orange	B
Wavetek DM5XL	3½	17	N	N	N	N	Dark grey	B
Wavetek DM10XL	3½	17	N	N	N	N	Dark grey	B
Wavetek DM15XL	3½	17	N	N	N	N	Dark grey	B
Yu Fong YF 3501	3½	19	Y	Y	N	N	Dark grey	B
Yu Fong YF 3503	3½	22	N	N	N	N	Dark grey	B

Table 3b Multimeter features, Part B

Specifications

The tolerance table (Table 4) lists two values taken from manufacturers' specifications :

The percentage error (e.g. $\pm 0.5\%$) is a percentage of the reading.

The digit uncertainty (e.g. $\pm 3d$) is the uncertainty in the value of the least significant digit.

Only the basic or best specifications are quoted in Table 4. Usually these are for mid sensitivity ranges. Often the lowest and highest sensitivity range has a poorer tolerance than that listed by us here.

Because none of the manufacturers give confidence levels for their DMM specifications, these specifications are all meaningless. We have however had to base our performance testing on the values given. We have assigned 95% confidence limits. This is an arbitrary choice on our part.

To give an example, the Yu Fong 3503 a.c. current specification is $\pm 1.2\%$ of the reading ± 3 digits. If the display value is 10.00 on the 20 mA a.c. range, then

1.2% of reading	= ± 0.12 mA
final digit uncertainty	= ± 0.03 mA
total uncertainty	= ± 0.15 mA

Therefore current = 10.00 mA ± 0.15 mA
with an unknown probability of the actual value lying within this uncertainty.

Performance

The key to our performance table summary (Table 5) is

- A = performs to specification
- B = performs slightly poorer than specification
- C = performs considerably worse than specification

Most of the meters performed to specification most of the time. Where they tended not to perform to specification was at the extremes of their ranges. Sometimes when only the extremes are affected, this poor performance is of no practical significance. The table is then marked A - C, with a comment indicated by a superscript. For instance none of the meters measured a.c. voltage accurately at values of 500 V and above. The performance of the 20 μ A a.c. range on three of the four meters with such a range was poor. Other troublespots are shown.

Best buys

The Altai ALT 26 (£14.96) is very cheap and performs well. It does not have an ACA function, and its number of ranges on the functions it does have is restricted. The current range is not fuse protected.

All of the Wavetek¹ models (£26.81, £35.06, £43.31) performed well. Their markings are good. 10 A protection fuses are fitted. Models 5XL and 10XL have restricted current ranges. The 15XL has a resistance range reading to 2 G Ω .

The Yu Fong YF 3503 (£30.65) performs well, has good markings, a robust case, and measures capacitance as an extra function. However it has a common terminal for mA, V and W, which may increase the incidence of blown fuses, and it does not have fuse protection on its 20 A range.

Both ISO - TECH models performed well. Good quality features include the provision of merely two terminals and the absence of current ranges, which reduce the confusion in what is being measured and prevent a dangerously high short circuit current from flowing - excellent safety features. Other qualities include auto power off, automatic and manual ranging with SI units marked on the display, good markings and clear switch settings, robust construction and protection against damage by dropping. The IDM 65 (£48.95) is designed for general lab work. It would suit those teachers willing to pay for the above qualities. The IDM 600 (£53.95) is designed for test and measurement with circuits that might be at hazardous live. For this function it should be used with GS38 test leads (RS 212-966 at £17.95). Any school where staff work at hazardous live should only do so with a meter of this design standard.

The Digitek DT 9101 did not perform to specification in all its ranges. However it is worth considering as a demonstration meter because of its tilting LCD screen with large digits and because of its good markings. This meter does not have fuse protection on its 20 A range.

How does this batch of meters compare with the last lot reported on in 1990? All in all, our best buy then, the Rapid 310 (order code 85-0710) still has a considerable advantage over all of this present batch as a general purpose school multimeter. It also has a proven 3 year track record. It remains our best buy, qualified by the fact that it does not have fuse protection on the 10 A range. The 310's price breaks are £25.50 (1+), £23.50 (5+), £21.70 (10+) and £20.50 (25+).

References

1. *Digital multimeters, Equipment Notes*, Bulletin 167, SSERC, September 1990, pp 36-40.
2. *Preventing electric shock*, Bulletin 173, SSERC, April 1992, pp 5-13.

¹ These models were formerly made by Beckman Industrial Limited. That company has now been taken over by the British owned multinational company, Wavetek.

Multimeter model	DC Input impedance (M Ω)	AC max. frequency (Hz)	DC volts accuracy	AC volts accuracy	DC current accuracy	AC current accuracy	Resistance accuracy
Altai ALT 26	1	450	$\pm 0.7\%$ $\pm 5d$	$\pm 1.2\%$ $\pm 5d$	$\pm 1.5\%$ $\pm 5d$	-	$\pm 0.75\%$ $\pm 5d$
Digitek DT 3900	10	200	$\pm 0.5\%$ $\pm 1d$	$\pm 0.8\%$ $\pm 3d$	$\pm 0.5\%$ $\pm 1d$	$\pm 1\%$ $\pm 3d$	$\pm 0.8\%$ $\pm 1d$
Digitek DT 9101	10	400	$\pm 0.5\%$ $\pm 1d$	$\pm 0.8\%$ $\pm 3d$	$\pm 0.5\%$ $\pm 1d$	$\pm 1\%$ $\pm 3d$	$\pm 0.8\%$ $\pm 1d$
ISO - TECH IDM 65	10	400	$\pm 0.5\%$ $\pm 2d$	$\pm 1.5\%$ $\pm 4d$	-	-	$\pm 0.8\%$ $\pm 2d$
ISO - TECH IDM 600	10	500	$\pm 0.5\%$ $\pm 1d$	$\pm 1.25\%$ $\pm 5d$	-	-	$\pm 0.75\%$ $\pm 1d$
MAXCOM MX 200	1	450	$\pm 0.5\%$	$\pm 1.2\%$	$\pm 2\%$	-	$\pm 0.8\%$ $\pm 2d$
MAXCOM MX 280	10	400	$\pm 0.5\%$	$\pm 1.2\%$	$\pm 0.5\%$	$\pm 1.2\%$	$\pm 0.8\%$
Metex Testlab DM 1030	10	1000	$\pm 0.8\%$ $\pm 2d$	$\pm 1\%$ $\pm 5d$	$\pm 1.2\%$ $\pm 2d$	$\pm 1.5\%$ $\pm 5d$	$\pm 1\%$ $\pm 2d$
Metex Testlab M-3800	10	unspec.	$\pm 0.5\%$ $\pm 1d$	$\pm 0.8\%$ $\pm 3d$	$\pm 0.5\%$ $\pm 1d$	$\pm 1\%$ $\pm 3d$	$\pm 0.5\%$ $\pm 1d$
Wavetek DM5XL	1	500	$\pm 0.8\%$ $\pm 1d$	$\pm 1.2\%$ $\pm 10d$	$\pm 1.2\%$ $\pm 1d$	-	$\pm 1.2\%$ $\pm 2d$
Wavetek DM10XL	10	500	$\pm 0.7\%$ $\pm 1d$	$\pm 1\%$ $\pm 4d$	$\pm 1\%$ $\pm 1d$	-	$\pm 1\%$ $\pm 1d$
Wavetek DM15XL	10	500	$\pm 0.5\%$ $\pm 1d$	$\pm 1\%$ $\pm 4d$	$\pm 1\%$ $\pm 1d$	$\pm 1.5\%$ $\pm 4d$	$\pm 1\%$ $\pm 1d$
Yu Fong YF 3501	10	500	$\pm 0.8\%$ $\pm 1d$	$\pm 1.2\%$ $\pm 5d$	$\pm 1.2\%$ $\pm 1d$	$\pm 1.5\%$ $\pm 5d$	$\pm 0.8\%$ $\pm 1d$
Yu Fong YF 3503	10	500	$\pm 0.5\%$ $\pm 1d$	$\pm 1.2\%$ $\pm 3d$	$\pm 0.8\%$ $\pm 1d$	$\pm 1.2\%$ $\pm 3d$	$\pm 2\%$ $\pm 2d$

Table 4 Multimeter specifications

Multimeter model	DCV	ACV	DCA	ACA	R	Frequency
Altai ALT 26	A	A - C ¹	B	-	A	-
Digitek DT 3900	B	A - C ⁴	A - B	A - C ²	A	-
Digitek DT 9101	A - C ³	A - C ⁴	A - B	A - C ²	A	-
ISO - TECH IDM 65	A	A - C ⁴	-	-	A - B	-
ISO - TECH IDM 600	A	A - C ⁴	-	-	A	-
MAXCOM MX 200	C ⁵	C ⁵	A - B	-	A	-
MAXCOM MX 280	B - C ⁶	B - C ⁷	A - C ⁸	C ⁵	B - C ⁹	B - C ¹³
Metex Testlab DM 1030	A	B	B	A	A	-
Metex Testlab M-3800	A	B - C ⁴	A	A - C ²	A	-
Wavetek DM5XL	A	A - C ⁴	A - C ¹⁰	-	A	-
Wavetek DM10XL	A	A - C ⁴	A - C ¹¹	-	B	-
Wavetek DM15XL	A	A - C ⁴	A	A	A	-
Yu Fong YF 3501	A - C ¹²	B - C ⁴	B	B	A - B	-
Yu Fong YF 3503	A	A - C ⁴	A	A	A	-

Table 5 Multimeter performance

- 1 ACV values > 200 V
- 2 20 μ A AC range
- 3 200 mV DC range
- 4 ACV values > 500 V
- 5 All ranges
- 6 2 V DC and 20 V DC ranges
- 7 2 V, 20 V, 200 V and 700 V AC ranges
- 8 200 mA and 20 A DC ranges
- 9 200 ohm range
- 10 DCA values < 10 μ A
- 11 DCA values at 10 A
- 12 Values at 2 V on 20 V DC range
- 13 seldom able to register signals < 1000 kHz

Equipment Notes

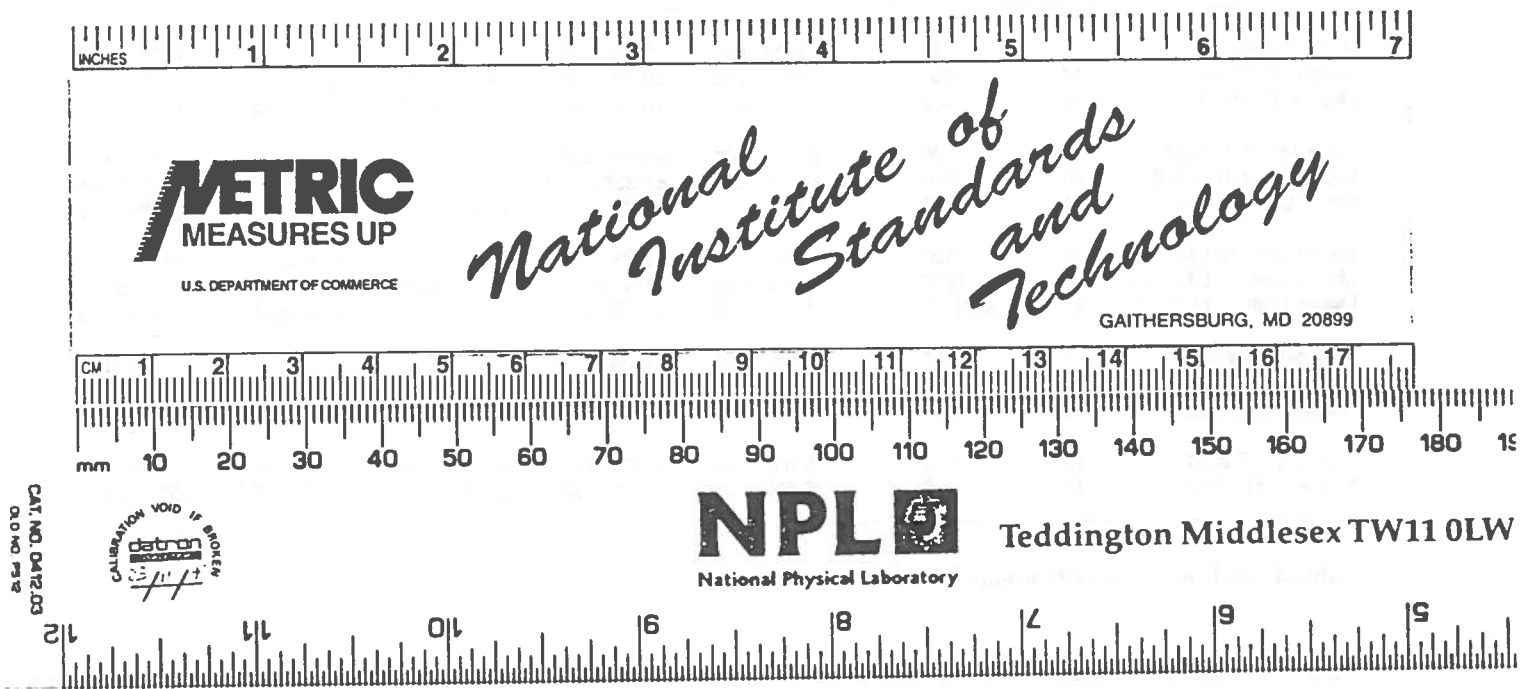


Fig. 1 Ruler scales which do not register

Plastic rulers

Above is a photocopy (Fig. 1) of two plastic rulers laid alongside each other. The rulers are just ordinary plastic rulers. It is their places of origin which are extraordinary. One comes from the National Physical Laboratory in Middlesex. The other is from the National Institute of Standards and Technology in Washington, USA. These are two of the world's top metrological laboratories. When it comes to standards, they are jointly the ultimate.

We do not intend to embarrass either of these two laboratories. However, regarding these giveaway mementos, it is unfortunate that a lapse in standards has occurred. It is in fact the NIST rule that has the systematic 1% error - or to put it metrologically, an error of 10 000 p.p.m. This has been caused by the transparency bearing the ruler gradations shrinking as it was being bonded by heat treatment to the acetate backing when the NIST rule was being manufactured.

There are several lessons for all of us. One is to be sceptical of measurements. The accuracy of any instrument should always be questioned. Ideally, there should be a specification which tells you the size of the possible error and the probability of a reading falling

within the specified error range. But only if there is traceability back to standards can such a specification be trusted.

For most educational instruments, with the notable exception of the balance, no such traceability generally exists. In schools we should therefore be specially sceptical of any measurement being true.

Another lesson is that it is helpful to know how the instrument works. The likely performance is then capable of being appreciated. Steel rulers are likely to be more accurate than wooden ones because steel has a more predictable temperature coefficient, does not absorb water and is less likely to deform. On the other hand, perspex is even more likely to deform than is wood. It is therefore scarcely worth the effort in ensuring that the gradations on a perspex rule are engraved with a lot of accuracy. Errors of 0.5% on perspex rules are commonplace.

Test report

Batches of three types of plastic rule were compared against a steel rule, which was taken to be our standard. One type of plastic rule had a length of 6" and was marked *MADE IN CHINA*. Three measurements of 10 cm were made: between the 2 cm and 12 cm, the 3 cm and 13 cm, and the 4 cm and 14 cm marks. Two types of 12" plastic rule were tested, one marked *UNIVERSAL OFFICE SUPPLIES RULER 12"*, the other unlabelled. On the 12"

1 cm -11 cm	5 cm - 15 cm	10 cm - 20 cm	15 cm - 25 cm	19 cm - 29 cm	Range	Extreme range
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
100.05	99.7	99.65	99.95	100.2	0.55	0.65
100.15	99.8	99.65	100.0	100.3	0.65	
100.05	99.75	99.7	100.0	100.3	0.6	
100.1	99.75	99.7	100.05	100.3	0.6	
100.1	99.75	99.75	100.05	100.3	0.55	
100.15	99.75	99.7	100.05	100.3	0.6	
100.1	99.7	99.7	100.0	100.3	0.6	
100.1	99.7	99.7	100.0	100.3	0.6	
100.1	99.7	99.7	100.05	100.2	0.5	
100.05	99.75	99.7	100.0	100.25	0.55	

Table 1 - Pattern of values seen in different samples of same type of rule

rulers, five measurements of 10 cm were made: between the 1 cm and 11 cm, the 5 cm and 15 cm, the 10 cm and 20 cm, the 15 cm and 25 cm, and the 19 cm and 29 cm marks.

We found that within each batch of rulers there was a characteristic pattern of errors. An example is shown in Table 1. This error pattern clearly is related to the manufacturing process and to the material of which the ruler is composed. The measurements were therefore analysed in separate groups according to type of make.

An analysis of our tests is shown in Table 2. It can be seen that the mean values of both the Chinese and unmarked rulers lie within 0.1 mm of the true value.

68% of all values will fall within one standard deviation on either side of the mean. The low standard deviation of the measurements made with the Chinese rule indicates that the spread of measurements made with this instrument was small. This is born out by the small value for extreme range. The absolute maximum and minimum values were 100.0 mm and 99.75 mm.

The Universal rule had the largest extreme range, with values of 100.25 mm and 99.45 mm. These readings were made on separate Universal rules.

The unnamed rule had the worst average variation. It had the largest standard deviation, and the greatest mean range, which is the average of the range of readings made by each rule. That is to say, any one of this type of rule had on average a spread of values of 0.6 mm.

The maximum absolute error for a length of 100.0 mm was 0.55 mm. It was found on occurrences with two Universal rules, and also on a Helix J01 6" rule.

Conclusion

Measurements made with plastic rules should be used cautiously. Reliance can only be placed on a measurement if there is traceability back to standards. It can be advantageous taking the average of a set of readings made on different parts of the rule.

Acknowledgement

The NPL and NIST ruler disparity was shown to us by Datron Wavetek, the Norwich manufacturers of precision electrical instruments. They kindly made available the photocopy reproduced here.

Ruler type	Number of sample	Number of measurements	Mean value (mm)	Standard deviation (mm)	Max. value (mm)	Min. value (mm)	Extreme range (mm)	Mean range (mm)
6" Chinese	11	33	99.93	0.06	100.0	99.75	0.25	0.10
12" Universal	5	25	99.70	0.20	100.25	99.45	0.8	0.45
12" unmarked	10	50	99.96	0.22	100.3	99.65	0.65	0.6

Table 2 - Test analysis for three types of rule

Technical tips

That old flame, again!

In Bulletins 129 [1] and 175 [2] we described a number of ways in which persistent flame colours could be produced. This was for the purposes of visual examination of flames carrying metallic ions, simple emission spectroscopy and for modelling an atomic absorption spectroscope. The basis of this work was the modification of a Bunsen burner so that an aerosol of a metal salt was drawn in through its air intake.

More recently we have received a number of useful technical hints and tips from Our Lady's High School in Motherwell. One of these was the result, literally, of some lateral thinking. The burner is simply turned on its side. It is clamped in this horizontal position with the salt and the hydrochloric acid/zinc aerosol generator on the bench immediately below the air hole in the burner regulator (see Fig.1).

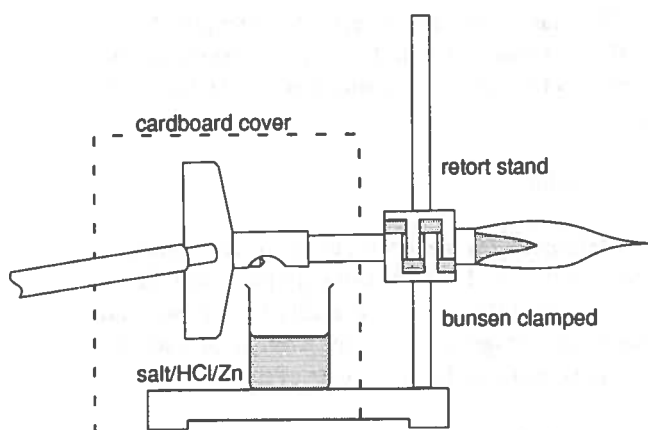


Fig. 1

When we tried this out we found the flame colorations to be more intense than with our other, more complicated, modifications to the burner. Presumably with this method more of the aerosol is picked up by the Bunsen. These intense flame colours are ideal for the kinds of simple demonstrations described in our first account of simple modelling of absorption spectroscopy or for certain observations with a direct vision spectroscope.

COSHH considerations

The problem of a breathable corrosive aerosol of an acid/salt mixture remains. The precautions suggested in Bulletin 175 are still needed. An additional control measure suggested by the school was a small hood cut from a plastic bottle and which covers the top side of the burner, and the wee crucible containing the salt, acid, zinc mixture. This can also be fashioned by cutting, folding and stapling together a piece of light cardboard in the shape of a hood. It must obviously be positioned clear of the flame! Alternatively a redundant, small card box of suitable size could be tailored to do the job. This cover should catch a large proportion of any of the aerosol not drawn into the air-gas stream of the burner.

Other control measures

These are largely as described in our earlier account [2]. That is to :

- use this system only in a well ventilated room, preferably a darkroom with forced ventilation. It is however true that smaller darkrooms in schools have ventilation systems not designed to cope with pollutants generated at this rate. In such cases a fume cupboard should be used. A temporary blackout arranged at the sides of the cupboard will allow the flame colours to be seen in fuller glory.
- run the experiment for as short a time as possible or have persons in that room for the shortest time necessary to make their observations and measurements
- reduce the scale of the aerosol consistent with still obtaining a reasonably bright flame; not so easy since all chemical reactions commence at high speed and then gradually slow down
- substitute where possible those harmful substances in the aerosol. (This can include use of some of the alternative approaches described in the second part of this article). Because of significant acute toxicity particular care needs to be taken if salts of lithium are to be used (see standard references such as Hazcards, Topics in Safety etc. or the relevant MSDS for lithium and its compounds).
- wear eye protection and pvc gloves to assist in controlling the risks from handling the corrosive acid salt mixtures
- use an explosion screen is wise since there is a small, but foreseeable, risk of flashback.

Copper flame

The difficulty of producing an intense green from copper halides is well known¹. The technician at Our Lady's however also supplied details of a means of producing such a flame. He had found that copper turnings dropped into 50% nitric acid, in a small crucible or beaker below the burner air hole, produces a more intensely green flame than that obtained by the Zn/HCl/salt method. We tried out this nitric acid method and can confirm this to be the case.

The main disadvantage is the toxicity of the nitrogen dioxide also evolved. This will react with the moisture in the lungs to form nitric acid and thereby cause much damage. That fraction drawn into the burner may be dissociated into nitric oxide and oxygen. But that's not too much help since, once in the air, the nitric oxide recombines with oxygen to again form nitrogen dioxide. The use of good ventilation - probably in the form of an efficient fume cupboard - and of the other controls noted above, including eye protection and gloves, are even more important.

Alternative arrangements

We tried a number of other ways of generating the aerosol. The ideal technique is one which

(i) easily produces an aerosol on demand at the turn of a switch or tap rather than one dependent on a chemical reaction which starts off fast and then slows down from then on and

(ii) produces less of any harmful aerosols.

Many of these were dismal failures, but a few proved promising.

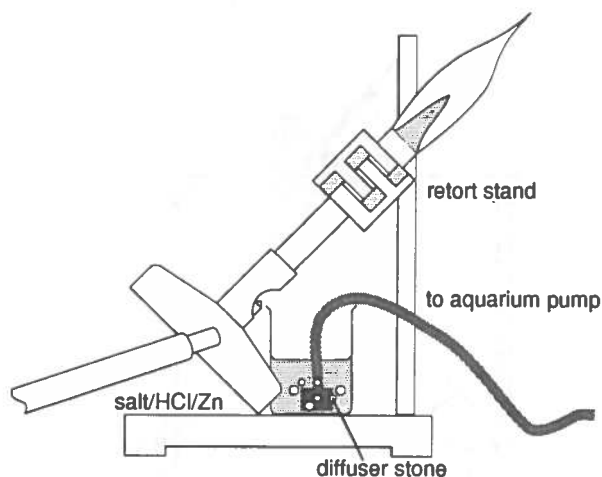


Fig. 2

¹ It is strange that the halides of copper should produce such an inferior flame compared with those of other metals - we would welcome any suggestions or explanations please.

Mechanically produced aerosol

An airstream from an aquarium pump driven through a diffuser into a solution of the metal salt had some success, but the flame was a bit unstable. Flame stability was improved however when the burner was raised from the horizontal to an angle of 45 degrees (Fig 2). A finer diffuser block would also improve matters in ensuring that more of metal ions enter the aerosol and are drawn into the airhole.

Electrolytically generated aerosols

A small beaker, 100 cm³ is about right, was fitted with two carbon electrodes in a thin holder. The more usual two-hole bung arrangement for electrolysis is avoided since it would block the escape of the aerosol (Fig. 3). The salt solution of the metal used to colour the flame is then placed in this simple cell and electrolysed by applying a suitable d.c. voltage across the electrodes (about 12 to 14 V).

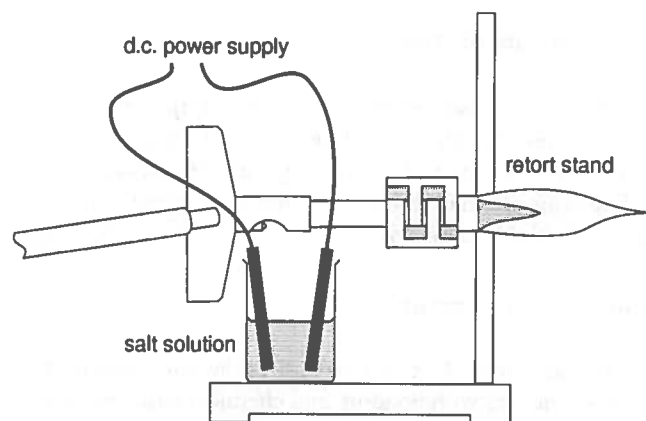


Fig.3

This technique worked particularly well both with alkali metal and alkaline earth metal salts. The attached power supply may seem to make the arrangement more than a wee bit cumbersome. But varying the applied voltage provides excellent control of the rate of aerosol production. With a sodium salt the brightness of the yellow flame seems to be proportionate to the voltage applied across the electrolytic cell².

Other salts

Normally for flame tests there is a tendency to use the halides of the metals. This is because of their greater volatility in the flame. In this electrolytic method we found that sulphates and other salts worked just as well. Use of these other salts has the advantage, over use of the metal halides, that they don't produce chlorine at the

² An opportunity for a little project here.

anode. With these other salts the net change is the electrolysis of water. The salt solutions gradually become more concentrated, with small quantities of hydrogen and oxygen forming at the electrodes. These merely burn gently in the burner flame, reforming as water vapour.

There should be no attempt to enclose the electrolytic cell or to deliberately lead the aerosol into the burner regulator hole. This is because the flame could then flashback into the cell and spray the salt all over the place.

COSHH

This method with alternative salts removes the more harmful acid aerosol produced by the Zn/HCl/salt method. The aerosol of the salt itself however remains. Although for the majority of salts this is a less harmful procedure overall, the ventilation and other control measures given above are still strongly recommended. In the case of lithium salts they are essential.

Other precautions

As with the other methods there is a small risk of flashback and eye protection should be worn. An explosion screen is a useful additional precaution.

In all of these methods the burner should be cleaned out immediately after use. This is to avoid unnecessarily accelerated corrosion because of accrued deposits of salts etc.

References

1. *Constructional details for an atomic absorption spectroscopy model*, SSERC Bulletin 129, November 1981, 13-15.
2. *Sodium flame pencil substitute*, SSERC Bulletin 175, October 1992.

Electrolysis of melts

This note is based on yet another useful tip from Our Lady's High. It is on a substitute for a lead salt in the electrolysis of a melt, thus reviving a use of potassium iodide. This alternative was first employed many years ago in *Nuffield* chemistry courses.

Curricular background

Standard Grade Chemistry requires the introduction of ideas connected with bonding and chemical structure. For this purpose it is much better for pupils to see the electrolysis of a melt rather than of a solution of a salt. The former may be a bit more difficult technically, but the concept is much easier for pupils to grasp if that otherwise ubiquitous third party, water, is absent.

Practicalities

Of those electrolytes with sufficiently low melting points for this application, some of the more toxic such as cadmium iodide, have been already dispensed with. Lead(II) bromide however is still used to great effect, usually in a teacher demonstration. It has the advantage that the two products are readily and visually identifiable. The bromine is visible at the time as a brown vapour. After the electrolysed melt has re-solidified and cooled sufficiently a shiny button of lead can be seen through the bottom of the beaker. In the later stages of teaching this piece of lead can even be weighed in order to calculate the Faraday and the charge on ions, etc.

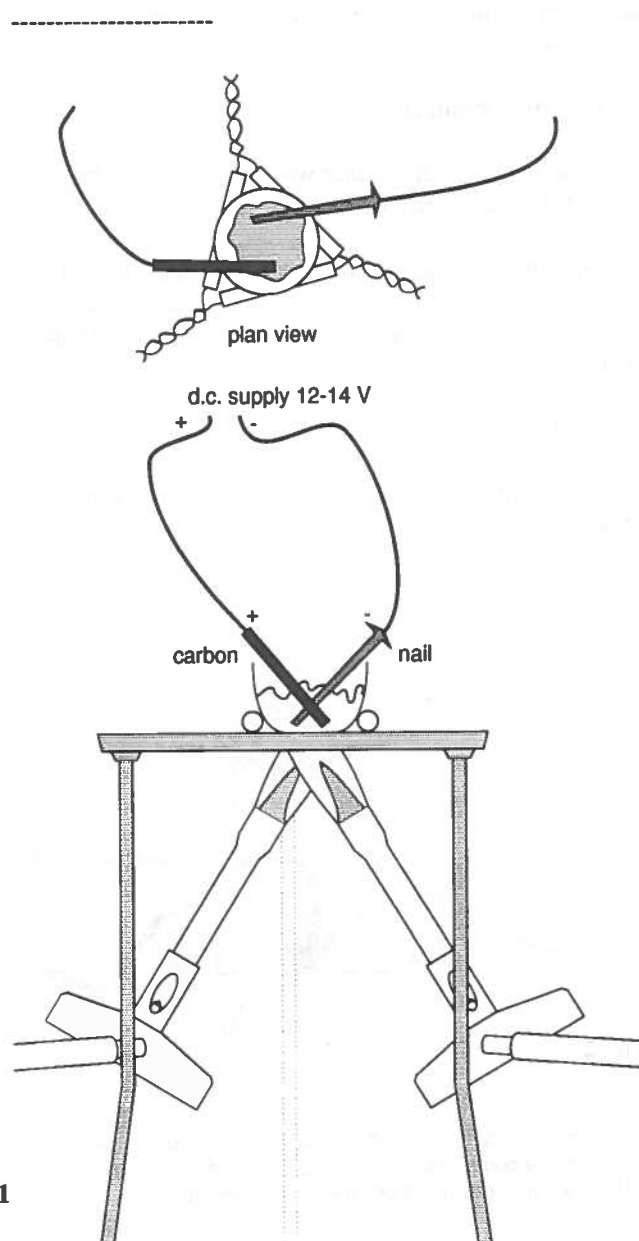


Fig. 1

COSHH

Great care needs to be taken however to avoid any inhalation of the fumes of lead bromide or of those of bromine itself. This means that :

- a fume cupboard is to be used;
- heat has to be supplied at a minimal rate, just enough to melt the salt.

Potassium iodide

As the technician at Our Lady's reminded us potassium iodide also can be melted relatively easily. The arrangement we used is shown as Figure 1. This shows two burners because we found they did a better job on a crucible three quarters full of the salt. A large iron nail was used for the negative electrode and a carbon rod for the positive electrode. Clamping the anode and cathode at an angle on opposite sides, as shown, brings the benefit of not melting or burning either the jaws of the clamp or the electrical connections. In a 15 cm³ crucible the electrodes are relatively close together and 12 volts was sufficient to ensure electrolysis.

As for lead(II) bromide, this method has the advantage of identifiable products of electrolysis. The violet iodine vapour can be seen escaping at the positive electrode. From time to time small, bright flashes are seen at the negative electrode. These can be presumed to be caused by the potassium burning in air.

COSHH

Potassium iodide is clearly of much lower toxicity than lead bromide. But, as a scan of a BDH or other material safety data sheet (MSDS) will show, it is by no means harmless. For example, although highly unlikely, continued ingestion may cause mental depression, insomnia and sexual impotence. As with most salts, potassium iodide - should it enter the eyes - causes significant irritation.

Small amounts of iodine vapour are formed in this procedure and this is harmful by inhalation.

Potassium oxide and hydroxide aerosol will also be formed and are corrosive by inhalation.

Assessment

The small scale - a 15 cm³ crucible $\frac{3}{4}$ full of the salt - itself provides good control. The quantities of iodine vapour and potassium oxides formed then also will be small and the work may be done in a well ventilated open lab. Severe burns are a possibility if either the crucible or electrodes are handled before they cool down fully.

Acknowledgement

We are most grateful to Mr K.R. Johnstone of Our Lady's High School, Motherwell for writing to us with these ideas and for agreeing to their publication in the Bulletin.

SSERC CHEMICAL MODELLER

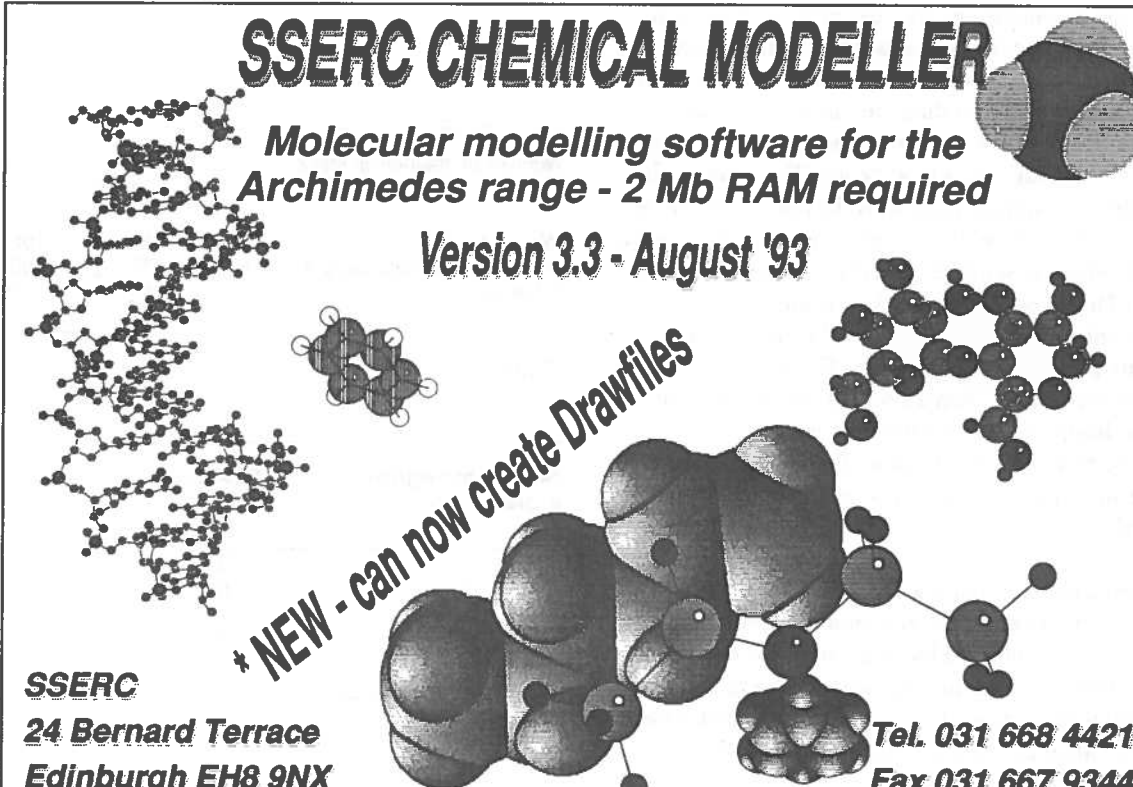
Molecular modelling software for the Archimedes range - 2 Mb RAM required

Version 3.3 - August '93

*** NEW - can now create Drawfiles**

SSERC
24 Bernard Terrace
Edinburgh EH8 9NX

Tel. 031 668 4421
Fax 031 667 9344



Technical Tips

Fun with neodymium : Lenz's Law and Newton 3

If you drop a neodymium magnet down a copper tube, it gently floats to earth, as in a fairy glide, tinkling each time it touches the not quite vertical tube. That it takes this hunk of alloyed iron 10 s to fall 2 m is astonishing. The music it makes is magical.

Neodymium magnets are extraordinarily strong. The remarkable retarding effect is due to eddy currents induced in the tube. By Lenz's Law the magnetic field set up by eddy currents exerts an upward force on the falling magnet. If, as surely happens, terminal velocity is reached, this upward force should be equal in magnitude to the magnet's own weight.

To verify this hypothesis, we dropped stacks of neodymium magnets down a 2 m length of 22 mm o.d. copper tube. Neodymium magnets are stocked in Surplus (item no. 771). They are disk shaped, with a diameter of 13.5 mm. Copper tube is readily available from plumbers' merchants, or from DIY stores. When buying tube, see that it can roll freely over the flat surface of the shop floor, which is a check for straightness of length and roundness of cross-section.

The tube should be set up exactly vertical on the pan of an electronic balance (Fig. 1). We placed a polystyrene block between the metal pan and tube to prevent the magnet from sticking to the pan and to prevent parts of the balance from becoming magnetized. A large cork would also do here. To keep the tube upright, it should be threaded through a 25 mm diameter hole in a wooden board. This lies flat on a wooden stool seat, standing on top of, and at the edge of, a workbench. The balance sits on the floor. The support point must be above the centre of gravity of the tube. With our set up, it was 1.5 m above floor level, which is satisfactory. It is critical that the tube is vertical. This is easily achieved by positioning the wooden board such that the tube has almost no bias towards any part of the 25 mm hole. The weight of the tube is now recorded. When a stack of four neodymium magnets is dropped down the tube the weight will be found to rise to a new steady value. Because the tube is exactly vertical, no tinkling will be heard. The fairy glide is now a whisper.

To weigh a magnet, place a cardboard tube at least 30 cm long - or any other suitable non-magnetic object - on the balance pan, tare the balance, place the magnet on top of the tube, and measure the weight. The tube length ensures that there will not be a significant magnetic force between the magnet and magnetic materials in the balance.

The difference in weights has been found to exactly equal the weight of the stack of magnets (Table 1). We therefore have an example of Newton's Third Law of Motion with the upward force on the freely falling magnet stack being equal in magnitude to the downward force exerted on the tube.

Multivariable investigation

You may wonder why stacks of magnets are used in this experiment? By doing so, we maximize the descent time (Table 2), giving plenty of time to read the balance. Also, the weight is sufficiently large with respect to the balance's readability that weight can be read to a precision of 1% or better.

The magnitude of the upward force depends on both the field strength and speed of the falling magnet. Another variable controlling terminal velocity is the magnet stack mass. These interdependent factors result in the time of fall having a maximum value of about 10 s. A fuller investigation beckons!

Number of magnets in stack	4	8
Weight of stack of magnets	14.6 g	29.1 g
Weight of tube	1063.1 g	1063.1 g
Weight of tube and falling magnets	1077.7 g	1092.3 g
Difference	14.6 g	29.2 g

Table 1

Number of magnets in stack	Time of fall (s)
1	3.1
2	5.6
4	9.0
8	7.3
12	5.1

Table 2

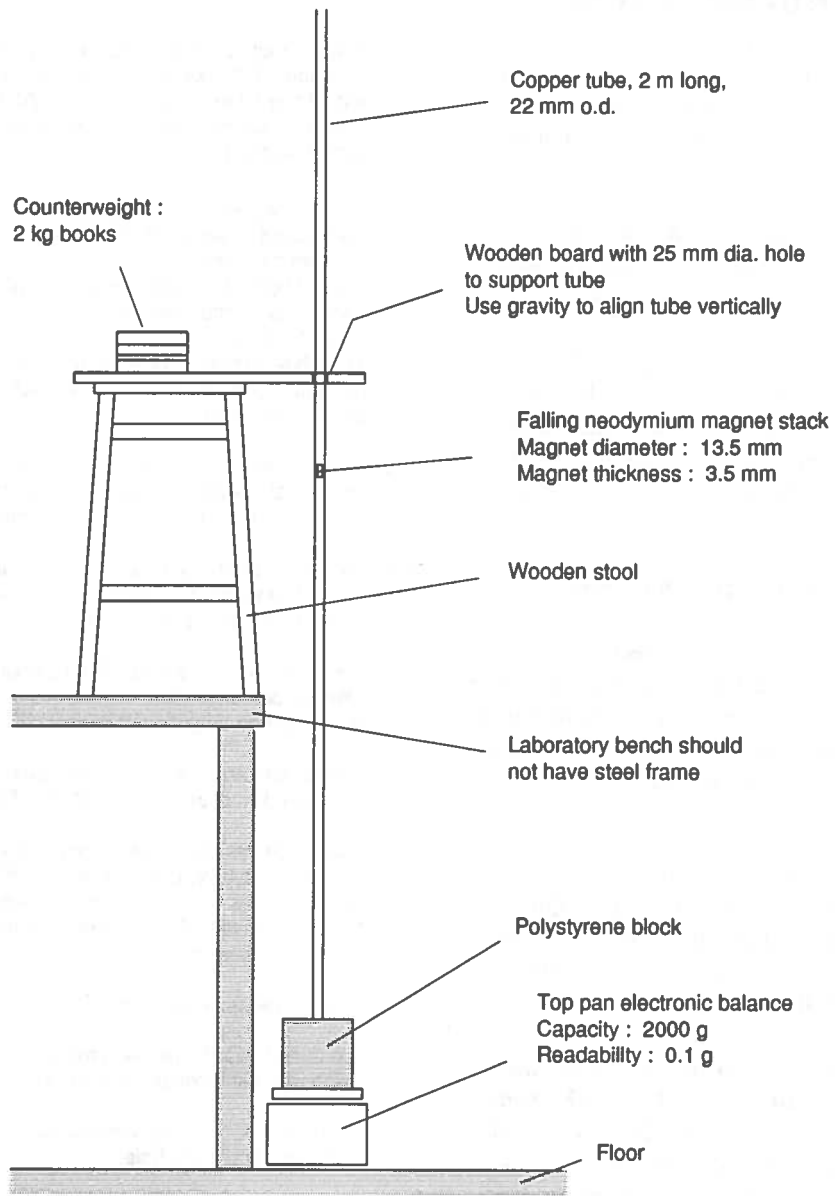


Fig. 1 Experimental set-up

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 VAT 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.

Ballot : Bausch and Lomb spectrophotometers

We have recently acquired a stock of second hand Bausch and Lomb Spectronic 20 spectrophotometers. The current value of the present model of this instrument new is £880. We are selling these by ballot at a nominal price of £10 each, which covers our overheads in making the instruments serviceable.

The spectrophotometer runs off a 110 V a.c. supply, not included in this offer. The cost of buying a suitable 110 V supply with safety earth conductor is £49.99, plus £4 delivery. We shall fit the spectrophotometer with a 3 pin 110 V plug to IP44 BS4343 standard.

There are an Operator's Manual and an Educational Manual available from the Bausch and Lomb UK agents costing £7.20 and £20.80 respectively. The Educational Manual describes the basic principles of spectrophotometry and contains descriptions of ten experiments ranging from Beer's Law to reaction kinetics. It also includes a teacher's supplement to aid in preparing the experiments.

Entry to the ballot should be made in writing, addressed to the Director. The ballot will be drawn on St Andrew's Day, Tuesday the 30th November - in time for despatch by Christmas.

Specification :

Wavelength range: 340 nm to 950 nm

Wavelength accuracy: ±2.5 nm

Stray radiant energy: less than 0.5% T with appropriate filter

Power requirements: 110 V a.c., 50 Hz, 50 W

Dimensions: 405 mm W x 330 mm D x 205 mm H

Weight: 12 kg

Display: 100 mm analogue meter with mirrored scale

Photometric range: 0% to 100% T, 0 to 2.0 A

Controls: Only three:

wavelength selection

power/zeroing

transmittance/absorbance

Motors

- | | | |
|----------------------------|---|-------|
| 591 | Stepper motor, 4 phase, 12-14 V d.c., 400 mA, 27.5 Ω, step angle 7.5°, powerful motor with 15 mm x 6 mm dia. output shaft. Dimensions 40 mm x 70 mm dia. on 70 mm square mounting plate with fixing holes at 56 mm centres. Circuit diagram supplied. | £4.50 |
| 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 |
| 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 |
| 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 |
| 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 |

746	4 mm push-in fitting, with adaptor for pressure gauge (stock item 715).	£1.60	724	Dual in line (DIL) sockets, 8 way	5p
			760	14 way	7p
			776	16 way	8p
313	Thermostat, open construction, adjustable, temperature range +10° to +65°C. Rated at 6 A, 250 V, but low voltage switching also possible.	60p	716	3-core cable with heat resisting silicone rubber insulation, 0.75 mm ² conductors, can be used to re-wire soldering irons as per Safety Notes, Bulletin 166. Per metre.	£1.35
165	Bimetallic strip, length 10 cm; high expansivity metal: Ni/Cr/Fe - 22/3/75 low expansivity metal: Ni/Fe - 36/64 (invar)	15p	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
166	Ditto, but 30 cm length.	40p	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
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	763	Sign "DANGER, Electric shock risk" to BS spec., rigid plastic, 200 x 150 mm.	£2.70
419	Humidity switch, operates by contraction or expansion of membrane. Suitable for greenhouse or similar control project. Rated 3.75 A, 240 V.	75p	764	Sign "DANGER, Laser hazard" to BS spec., rigid plastic, 200 x 150 mm.	£2.70
753	Submersible pump, 6 V to 12 V d.c., 8 litres/min., 0.6 bar, dry operation protected.	£4.55	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
371	Ferrite rod aerial, two coils MW and LW, dimensions 140 mm x 10 mm dia.	85p	731	Re-usable cable ties, length 90 mm, width 2 mm, 50 per pack.	12p
758	Loudspeaker, 8 Ω, 0.5 W, 66 mm dia.	50p	612	Beaker tongs, metal, not crucible type, but kind which grasps the beaker edge with formed jaws.	£1.20
771	Neodymium magnet, 13.5 mm dia. x 3.5 mm thick.	£1.30	752	Shandon chromatography solvent trough.	£1.00
645	Ceramic magnets	7p	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
745	Sub-miniature microphone insert (ex James Bond?), dia. 9 mm, overall depth 5 mm, solder pad connections.	40p	Components - resistors		
723	Microswitch, miniature, SPDT, lever operated.	40p	328	Potentiometer, wire wound, 15 Ω, lin., 36 mm dia.	30p
740	Microswitch, miniature, SPDT, button operated.	25p	737	Ditto, 22 Ω, lin., 36 mm dia.	30p
353	Reed switch, SPST, 80 mm long overall, fits RS reed operating coil Type 1.	30p	329	Ditto, 33 Ω, lin., 36 mm dia.	30p
354	Reed switch, SPST, 46 mm long overall, fits RS reed operating coil Type 3.	10p	330	Ditto, 50 Ω, lin., 40 mm dia.	30p
738	Relay, 6 V coil, DPDT, contacts rated 3 A, 24 V d.c. or 110 V a.c.	75p	331	Ditto, 100 Ω, lin., 36 mm dia.	30p
774	Solenoid, 12 V, stroke length 30 mm, spring not provided	£2.25	421	DIL resistor networks, following values available: 62R, 100R, 1K0, 1K2, 6K8, 10K, 20K, 150K. Per 10.	30p
742	Key switch, 8 pole changeover.	40p	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
382	Wafer switch, rotary, 6 pole, 8 way.	70p	BP100	Precision Helipot, Beckman, mainly 10 turn.	10p-50p
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 batteryholder.	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			

Components - capacitors

695	Capacitors, tantalum, 4.7 μ F 35 V, 15 μ F 10 V, 47 μ F 6.3 V.	1p
696	Capacitors, polycarbonate, 10 nF, 47 nF, 220 nF, 680 nF, 1 μ F, 2.2 μ F.	2p
697	Capacitor, polyester, 15 nF 63 V.	1p
698	Capacitors, electrolytic, 1 μ F 25 V, 2.2 μ F 63 V, 10 μ F 35 V.	1p
358	Capacitor, electrolytic, 28 μ F, 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
726	MC74HC02N quad 2-input NOR gates.	5p
725	MC74HC139N dual 2 to 4 line decoders/multiplexers	5p
699	MC14015BCP dual 4-stage shift register.	5p
711	Voltage regulator, 6.2 V, 100 mA, pre-cut leads.	10p

Sensors

615	Thermocouple wire, Type K, 0.5 mm dia., 1 m of each type supplied: Chromel (Ni Cr) and Alumel (Ni Al); for making thermocouples, see Bulletins 158 and 165.	£2.20
640	Disk thermistor, resistance of 15 k Ω 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 $\pm 0.2^\circ\text{C}$, 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 $>14 \mu\text{m}$, 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, $\frac{1}{4}$ 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.

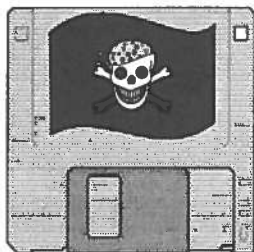
Glassware

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
665	Flat bottom round flask, 800 ml.	50p
747	Quickfit vented receiver, 10 ml.	20p
775	Glass volumetric bulb pipette, 25 cm ³	50p
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 Keisgelguhr 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



*Have you handed over your pieces
of eight for our software treasure?
A word in your shell-like*



Introduction

OK, so everyone's done it at some time or another - copied, pirated, paunched software that is. The tradition, if it can be called that, goes back to the good (bad?) old days when it was as easy(!) as copying an audio cassette tape-to-tape. As often as not the copy would have some glitch right at the end of a Spectrum program which took 10 minutes to load - the dreaded **R Tape loading error 0,1**. Ears became attuned to the littlest nuances of pitch and beep as the program sung to the computer and you knew with a degree of certainty whether a program would load (or not). Nowadays we are LED-flicker watchers and disc drive-chatter listeners and often anticipate errors before the fateful error message is reported by the computer.

The software around at present is much faster, more sophisticated, versatile and easier to use than in the past. Consequently, the number of person-hours required to develop an application, which will stand up to the competition in the software marketplace, is much greater. Here we make a plea to teachers to think twice about ripping-off our and anybody else's software. We outline the Copyright Law and how it affects educational establishments in general.

The Law

The copyright law is clear. The copyright holder is given certain exclusive rights, including the right to make and distribute copies. (The Copyright, Designs & Patents Act 1988.) See also the booklet published by FAST (The Federation Against Software Theft).

Software creates unique problems because it is so easy to duplicate, and the copy is usually as good as the original. This fact, however, does not legitimise piracy. Copyright law makes no distinction between duplicating software for sale or for free distribution. The law protects the exclusive rights of the copyright holder. Unauthorised duplication is a crime and can bring with it unlimited fines and a jail term of up to two years.

Although software is a relatively new type of product its protection is grounded in the long-established rules that govern more familiar media, such as books and films.

Software piracy can often hurt smaller software publishers even more than the larger ones. The industry is filled with new and innovative developers trying to break

into a crowded market. They can only survive if their products are purchased. Each theft makes staying in business that much harder.

Use of software by schools

Educational institutions are not exempt from copyright law. On the contrary, because of their unique position of influence, schools must remain committed to upholding the copyright laws. Just as it is wrong to buy one textbook and photocopy it for use by pupils, it is wrong for a school to duplicate software without authority from the author or his/her agents.

Some teachers claim that software publishers should allow schools to copy programs because it is the only way some schools can afford to provide enough software for their pupils. Software is no different from any other product or service required by a school. Schools purchase books, audio-visual equipment and classroom/laboratory furniture, and they pay a fair price for them. Newer and better software can be developed only if the software development team receives a fair price for its efforts. It can also be said that the more people who buy software the lower the purchase price. In addition, non-legitimate users will have no documentation, customer support and no information about product updates.

SSERC software - the not-so-hard sell

SSERC, as well as selling its software at low prices, offers special sales arrangements to schools and education authorities. If for example around 25 schools arrange to buy software it may be had at a figure approaching 50% of the normal retail price. Any school which buys 5 or more of the *Graphics Libraries* can use the software throughout the school. We are prepared to negotiate with teachers and others with suitable graphics or software in exchange for our software or commission on sales.

A site licence for the *Chemical Modeller* is only 60% more than the cost of a single disc. Users of this software have recently been offered a low-cost update to the latest software and documentation and the opportunity of tapping into a pool of pre-drawn molecular structures. Existing *Graphics Libraries* users can get £3 off the cost of the *SSERC CD-ROM* for every disc previously bought.

So please play fair by us, me hearties, and we can all sail into the sunset with lots of booty and a clear conscience.

Trade News

BEEA Exhibition

The British Educational Equipment Association and the Educational Publishers Council are jointly staging a trade fair in the Scottish Exhibition Centre on Thursday 10th February and Friday 11th February 1994.

Products and services being exhibited will include laboratory and workshop equipment, science and technology resources, books and furniture. A series of special seminars directed at teachers in senior promoted posts is being planned for Thursday 10th February.

Although being held in Glasgow and with support from Strathclyde Regional Council, the event is of national interest and significance. The organisers hope to attract visitors from all over Scotland. You have plenty of advance notice to prepare for a day out at the fair!

We understand that Strathclyde has organised its mid-term holiday to allow schools to take Friday 11th February as an INSET day for the exhibition and that teachers from Strathclyde will be eligible for travelling expenses.

Crotech dual trace oscilloscope

In our oscilloscope test report published in Bulletin 176, the Model 3324 dual trace instrument from Crotech was reported to have two features which presented an unacceptable risk of harm. We are pleased to report that the manufacturers have acted on our findings. Both dangerous features are now eliminated as a result of modifications. The 3324 now has an A (= good) assessment with respect to electrical safety. We also find that the sweep rate performance has been improved to comply with specifications.

Protective equipment

A number of enquiries arising from our microbiology and COSHH training courses have led us to investigate sources of inexpensive lab. coats and gloves. Our initial findings should also be of wider interest.

Laboratory coats

The best we have come up with so far for price is a white cotton drill *warehouse coat* from Haxton and Lang £3.95 plus VAT. Another good source is C.M.T. McLellan of Fife who supply a cotton drill coat for £5.00 and a polyester/cotton mix coat at £5.06. Strathclyde University will sell schools second-hand coats (to Howie specification) at £5 or arrange short term hire at £1.50 per coat including laundry charges.

Gloves

The firm of Haxton and Lang is also a very competitive source of other PPE such as eye protectors and disposable gloves. Their *Pal Vinyl* PVC disposable glove looks a good buy at £4.39 per hundred. Another source of a wide range of glove types are MacKay & Lynn who offer three sizes of PVC glove at £4.00 per 50. A better bargain seems to be their high quality *Micro-touch* gloves with all sizes at £10.35 per 100. Remember however that different gloves may be needed to give protection against different chemicals (see Appendix in SSERC Booklet on COSHH Risk Assessments for Project Work).

Microbiology materials

A number of suppliers seem to have dropped Antibiotic Multi-test Discs from their catalogues. Blades Biological is one specialist firm still offering these at £5.50 for a pack of 10 or £23.50 per 50 (Cat. ref. LZB 185 or LZB 190 respectively). A scan through the latest Blade's catalogue also suggests that they may also be one of the more competitive sources of living microbiological cultures.

Introductions to magnifiers and microscopes

C E Offord have two kits to help the inexperienced person - pupil or teacher - with these instruments. The Offord *Understanding Magnifiers Kit* provides a series of simple hands-on experiments to help children understand how to use magnifiers effectively. There is a single kit (£2.40) and class kit (£18.50) comprising of Fresnel hand lenses, test cards, worksheets and teachers' notes. The Offord *Microscope Specimen Handling Kit* (£6.80) is designed to allow children with no special skills to handle live specimens for themselves. The tools chosen for the kit, if used properly, should allow for gentle handling of small creatures.

Two Related Publications for CSYS Physics

Electromagnetism : Experimental Guide

Prepared by SSERC to supplement the theoretical treatment indicated in the SCCC Teachers' Guide. Price £3.50, including postage.

The Fine Beam Cathode Ray Tube by John Le P Webb

A series of eight articles originally published in *The Physics Teacher* in 1984-5, reproduced by kind permission of the author. Price £3.00, incl. postage.

SSERC, 24 Bernard Terrace, Edinburgh, EH8 9NX;
Tel. 031 668 4421, Fax. 031 667 9344.

BEEA, 20 Beaufort Court, Admirals Way, London
E14 9XL; Tel. 071 537 4997, Fax. 071 537 4846.

Blades Biological, Cowden, Edenbridge, Kent TN8 7DX;
Tel. 0342 850242, Fax. 0342 850924.

CPC, Component House, Faraday Drive, Fulwood,
Preston, Lancs. PR2 4PP. Tel. 0772 654455.

Crotech - see agents - RMR Measurements.

Electrothermal Engineering Limited, 419 Sutton Road,
Southend-on-Sea, Essex, SS2 5PH; Tel.0702 612211
Fax 0702 619888.

Farnell Electronic Components Ltd., Canal Road, Leeds,
LS12 2TU; Tel. 0532 636311, Fax. 0532 633411.

FAST (Federation Against Software Theft) :
2 Lake End Court, Taplow, Maidenhead, Berkshire
SL6 0JQ. Tel. 0628 660377

Philip Harris Education:

2 North Avenue, Clydebank Business Park,
Clydebank, Glasgow G51 2DR; Tel. 041 952 9538;

Lynn Lane, Shenstone, Lichfield, Staffordshire
WS14 0EE; Tel. 0543 480077, Fax. 0543 480068

Haxton & Lang Limited, Gorglen Works, 134 Lower
Millgate, Uddingston, Glasgow G71 7TU;
Tel. 0698 817333, Fax. 0698 816201.

Institute of Biology, 20 Queensberry Place, London,
SW7 2DZ; Tel. 071 581 8333.

Mackay & Lynn Limited, 2 West Bryson Road,
Edinburgh EH11 1EH; Tel. 031 337 9006
Fax 031 346 8948 and at
17-19 Taits Lane, Dundee, DD2 1DZ;
Tel. 0382 645145.

CMT McLellan, Unit 8, Belleknowe Industrial Estate,
Inverkeithing, Fife KY11 1HZ; Tel. 0382 416276.

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

Rapid Electronics Limited, Heckworth Close, Severalls
Industrial Estate, Colchester, Essex CO4 4TB;
Tel. 0206 751166, Fax. 0206 751188.

Ravencourt Limited, Cobbsnook, Newstead, Stamford,
Lincs. PE9 4JJ; Tel. 0780 57370, Fax 0780 55201.

RMR Measurements, 2 MacTaggart Road, Seafar,
Cumbernauld, G67 1JL; Tel. 02367 28170.

RS Components Limited, PO Box 99, Corby,
Northamptonshire, NN17 9RS; Tel. 0536 201201,
Fax. 0536 201501.

SAPS (Science & Plants for Schools), Scottish Office :
The Royal Botanic Garden, Edinburgh EH3 5LR;
Tel. 031 552 7171, Ext. 465, Fax. 031 552 0382.

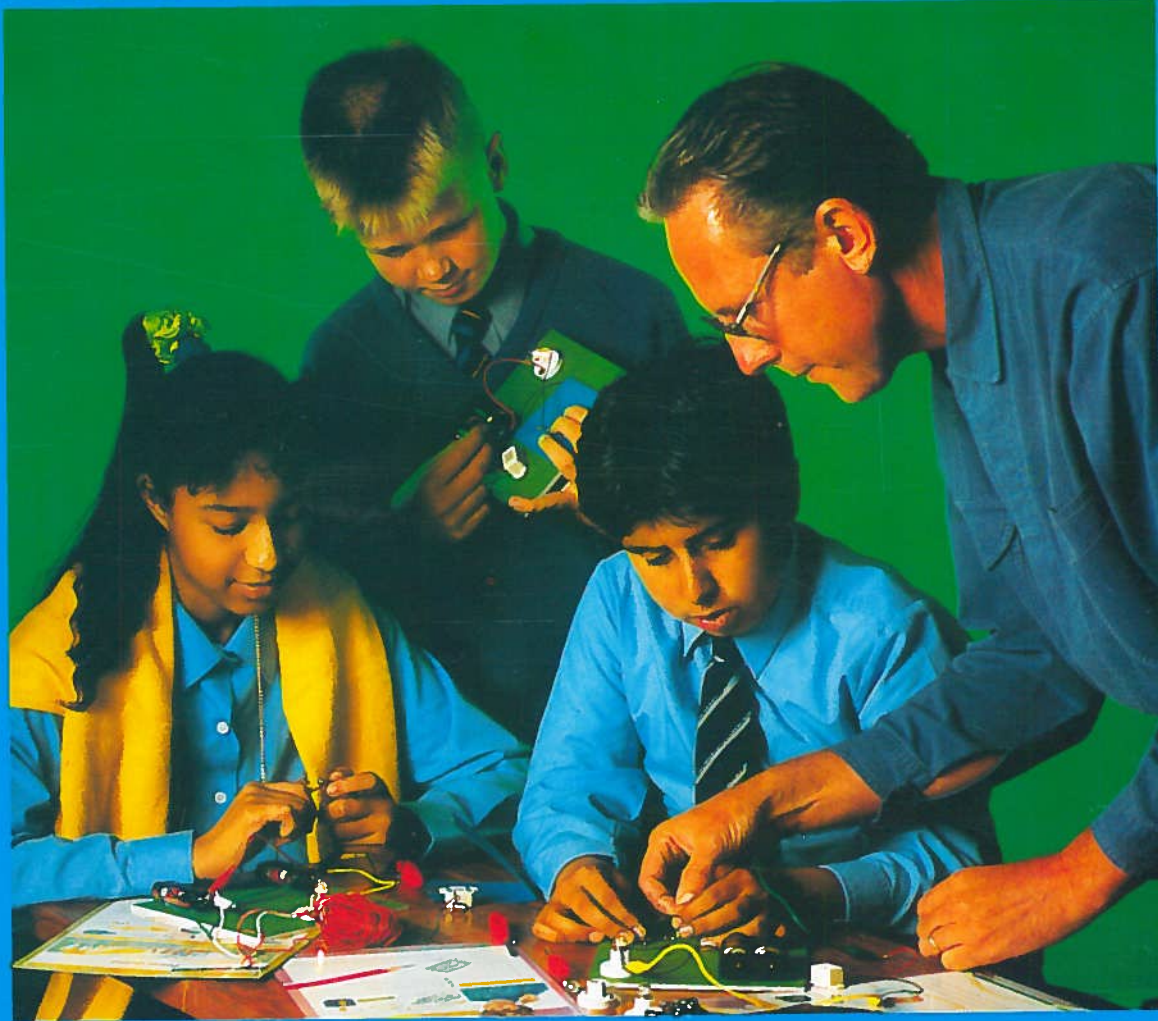
Scottish Consultative Council on the Curriculum, SCCC,
Gardyne Road, Broughty Ferry, Dundee, DD5 1NY;
Tel. 0382 455053, Fax. 0382 455046.

ScottishPower Energy Education Advisors :
East of Scotland - Maria Smith 031 225 2323
West of Scotland - Lesley Brown 0698 281777.

Strathclyde University (Lab. Coat offers) :
Dr.M.Kohn (Microbiological Protection Adviser),
Department of Microbiology, Strathclyde University,
Glasgow. Tel. 041 552 4400, Ext. 2428 05 2063.

Tait Components Limited, 20 Couper Street, Glasgow
G4 0BR; Tel. 041 552 5043, Fax. 041 552 8826.

THE POWER TO LEARN



THE POWER TO TEACH

forging new links

A
POWERFUL
NEW LINK WITH
EDUCATION

Not everyone who benefits from electricity is necessarily a customer - yet. So part of going out into the community involves Energy Education Advisers who work closely with schools and other educational establishments to help young people understand how electricity is made, how to use it safely and efficiently and the environmental implications of energy use in general. Our work here ranges from producing curriculum support materials such as posters, booklets, computer packs and videos to making presentations and running workshops for pupils and teachers.



Maria Smith



Lesley Brown



ScottishPower
It's made for people like you.

Contact Maria Smith on 031 225 2323 or
Lesley Brown on 0698 281777.