STS

Scope includes Science, Technology and Safety

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CONTENTS

1 Editorial

2 News & comment

3 Electrical equipment testing

4 Superwool 607

6 CE Marking and product safety

7 Radford Labpacks, Liquid nitrogen transport, Traffic light LEDs.

8 Microscopes

10 Control at S1/S2

12 Buffers

13 Power supplies

14 LED array

15 UV LEDs

16 Technical tip, Trade News, Addresses.

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Interesting times?

In occasional episodes of self-delusion any of us may see ourselves as polymath when *dilettante* or *amateur* might be nearer the mark.

For instance, I recall my own fairly disastrous dabblings, some years ago, with Mandarin. I'd had the incredible good fortune to be invited to give a presentation and workshop in Shanghai. Despite weeks of lessons I never got beyond the usual "hello", "goodbye" and some rather inane other stuff about the weather. What is, however, fascinating about the chinese language is its sheer economy. There are no verbs as such, the verb being implied, and thus no tenses. Present, past and future are indicated by the use of time words in constructions such as: "Yesterday work very hard". Chinese, is therefore somewhat unusual, but not unique, in often gaining something in the translation. Turning it into conventional English means providing verbs, tenses and other syntactical paraphenalia, of which chinese folk seem to have no need.

There have been recent moves here to do away with grammatical luxuries, like the apostrophe, on the grounds that hardly anybody knows how to use them. Things became even more ludicrous when it was suggested that the comma also was a minor and unnecessary feature of modern English. Then I heard a vote of thanks which illustrated the continuing need for our wee, punctuating friend:

"*I have to say to M. . . . that she has been a rock, star and a real friend to this community*".

Which brings us back to the Chinese. There is a proverb or saying, purportedly of chinese origin, which folk are fond of spouting, often in a political context:

"*May you live in interesting times*"

Here, I'm convinced, something was lost and not gained, in the translation. That something is a comma. I'm sure it should read :

"*May you live, in interesting times*"

Well, these are certainly interesting times for science and technology education. For the first time in over two decades it looks as though the need for science and technology based skills is better appreciated in practice by government and business. There is even a distinct whiff of money in the air. It is amazing what an educational feeding frenzy the odour of funding may trigger. Who and what then emerges from around the periphery becomes a fascinating study.

Don't get me wrong, I'm not complaining ("for once" I hear you say). Overall this is a good sign. Having quietly campaigned, as one only of many in Scottish science and technology circles, for a Science Strategy, extra funding for science based education and much else besides, I'm extremely pleased to see inertia at last overcome and the bandwagons rolling. Nonetheless this is the most dangerous, and therefore especially interesting, phase. Having got things going and the key issues taken more seriously, none of us are keen to be flattened by a fleet of new projects and initiatives. This is especially so if they are to be driven by dabblers with little or no practical experience or first hand knowledge of school science and techology.

There are some very useful initiatives underway. But, lately, I've lost count of invitations to consultation sessions, conferences and strategic workshops that I can't spare the time to attend. Should these be but signs of heightened interest then fine. Should they, however, result merely in a diversion of funds which, by rights, should go directly to schools and colleges then we all have every right to get somewhat tetchy.

So, if we want to live well in these particularly interesting times we all best ensure that our voices as teachers and technicians are clearly heard. We can do that both individually and collectively through professional associations like the ASE, IoB, IoP, RSC and the TTA. We've had the waggons in a circle for years. We'd best not get trampled to death now by the cavalry.

ASE Scotland programme

The Association for Science Education Scotland has published its programme of meetings for the 2002-03 session. This contains details of meetings which have been organised by the various sections in the Forth Valley, Grampian, Tayside and Fife and in the West of Scotland. Borders section had still to confirm its programme at the time of writing. These section programmes have a good variety of activities from pre-primary right through to Higher Still.

A downloadable version (a *pdf* file) of the programme is available on the ASE Scotland website at:

www.asescotland.org.uk

An advance notice of the 2003 annual meeting in Aberdeen is also posted on the site with much other useful stuff besides.

ISE 5-14 project

The Improving Science Education 5-14 (ISE 5-14) project has been established as a partnership between the Scottish Executive Education Department (SEED); the Scottish Science Advisory Group (SSAG) representing Local Authorities, LT Scotland and SSERC. The overall objective is to address the relevant priorities identified within the HMI report on *Improving Science 5-14* (1999) and in the *Science Strategy for Scotland* (2001).

With the appointment of a Project Director, Bill Fleming, and of three Development Officers - Peter Gorrie, Janette Keane and Neil Taylor - we are also moving on to a new phase of on-line support for 5-14 Science Education. The Science Online Support Network (SOLSN) site has been re-named and will be used to support the project, eventually contributing to the NGfL. This is but one of a range of resources which will spin-off from ISE 5-14. For further detail please see issue 26 of SSERC's 5-14 Science and Technology News or visit our website.

Accounts Commission on PPP

In its report on Public and Private Partnerships [1] the Accounts Commission has stated that :

". . there is a case for centrally led research on best practice in specifying school requirements in Scotland".

The full report runs to some 90 odd pages but there is an 8 page Executive Summary There are three paragraphs (12,13 and 14) in that summary which are particularly germane to some of the problems we have noted, particularly in the context of facilities for science and technology education.

In essence, the report says that national, best practice, guidelines about what makes for a well-designed school are needed. While there has been some informal sharing of good practice between councils, overall there is insufficient guidance in areas such as what constitutes acceptable standards for room sizes, heating, lighting and other technical factors that affect the learning environment.

They go on to say that :

"For various reasons, not least the significant financial support it provides for school projects, the Scottish Executive is well placed to lead this initiative in partnership with councils."

Certainly, the existence of consistent technical and environmental output requirements would have done much to avoid the sorts of problems we observed in some early PFI schools projects. In our view, such technical specifications would be particularly welcome for specialised learning and teaching areas such as those for the practical subjects.

The architects and buildings branch of the DfES south of the border has published much useful guidance on such matters. Since education is a devolved matter, the DfES's writ doesn't run here. Its advice thus has no official currency. It would, however, provide an excellent starting point from which to develop specifically Scottish guidance.

HSE and risk management

We've noticed recently an increased willingness on the part of Health and Safety Executive Inspectors to serve Improvement Notices on Scottish education authorities and their schools. There is little evidence of an increase in unannounced routine visits to schools. The HSE is as stretched for staff as ever.

Where visits result from incidents and injuries, however, the inspectors seem less patient than once they were when it emerges that staff have been insufficiently trained or informed on health and safety matters. In particular, they have been unhappy about poor risk assessment procedures and their management.

We've published a fair amount in these pages on managing risk assessments in science and technology departments [2]. In particular we've stressed that a risk assessment is a process, not a thing or just a piece of paper. We've also stressed that the key outcomes of any such assessment are the preventive and protective measures that minimise risks and consequences.

Huge tomes of material safety data sheets (MSDSs) or similar information sitting on a shelf somewhere, unread and unused can be of much use as a chocolate fireguard. All the documentation in the world won't protect a department from the wrath of the HSE, especially if things should go pear-shaped, unless staff have been aware of those preventive and protective measures and know how to implement them in practice.

The simple way to ensure this is to transfer the key information on such measures to documentation which will be referred to continually at the point of use. Another way, and one often appropriate in science and technology is by the provision of simple, in-house, practical training by more experienced and knowledgeable staff [e.g. for science see ref. 3].

Bob finds use for comb

The talents of Bob Kibble, lecturer in science education at the University of Edinburgh and immediate past chair of ASE Scotland, are both numerous and legendary. He now has yet another claim to fame having won the the 6th World Paper and Comb Championships held in Stonehaven this Summer. The good news is that he's agreed to defend his title next year. The bad news? He'll now have buy a comb so he can start practising.

* * *

References

1. *Taking the Initiative : Using PFI contracts to renew council schools.* Audit Review,Audit Scotland for the Accounts Commission, June 2002. Can be downloaded from : www.audit-scotland.gov.uk

2 *Managing Risk Assessment*, Safety Notes, Bulletin 193, SSERC, 1998.

3. *Safe and Exciting Science*, an in-school, in-service pack, ASE , 1999, ISBN 0 86357 295 2.

* * *

Electrical equipment testing

The IEE have revised their code of practice for the in-service inspection and testing of electrical equipment.

Why should electrical equipment be taken out of service while still in working order for a safety examination and tests? Twenty years ago, few of us did that. If it worked, it worked. If it was broken, or dangerous, it was laid aside and fixed. Since then the technician service has moved from reactive to proactive servicing. Are schools any safer for it?

We would like to read, in plain English, from the most significant professional body of electrical experts in the UK of their reasoning for a programme of continual in-service inspection and testing (I&T). We imagine also that there are lots of technicians, bogged down with vast itineraries, seeking reassurance that their efforts are worthwhile. Unsatisfactorily, the IEE don't offer such an explanation. Instead they rely on formulaic reasoning.

> "*Every employer shall ensure that work equipment is so constructed or adapted as to be suitable for the purpose for which it is used or provided.*" (PUWER Regulation 4(1))

A battery of legislation is shown to the reader. It is a pity they don't offer a pragmatic explanation for what is, unquestionably, a time-consuming business.

Enough of the carping! Accepting, as we do, that in-service I&T is necessary, this revised code of practice from the IEE is informative. Gone are the simplistic rules – the earth resistance shall not exceed 0.1 Ω when tested at 25 A; the insulation resistance shall exceed 2 MΩ when tested at 500 V dc – to be replaced by conditional guidance. We now have recognition that different sorts of equipment need different types of tests. The problem with simplistic rules was that they continually caught you out with anomalies. It led to failing equipment that shouldn't have been failed and applying tests inappropriately, sometimes to the detriment of the apparatus under test. So even although this revised code is more complex than any other guidance hitherto offered, it is more useful because it responds to many of the problems we meet and provides routes for sorting those that are strange.

Four types of tests are distinguished:

- type tests, to be applied by test labs (usually destructive to equipment),
- production tests, to be applied in manufacture,
- in-service inspection and tests, to be carried out by the user,
- after repair tests.

There are 3 categories of I&T: user checks, a formal visual inspection, and a combined I&T, the last two to be carried out by trained personnel. The frequency of these should depend on the type of equipment to be looked at, whether hand-held, kettle, ICT, or whatever. Guidance for the schools' sector remains unchanged (see SSERC website).

As part of the combined I&T, the following 3 tests should be carried out, although there is a strong warning not to carry out the insulation resistance test if you think it might harm the equipment:

- earth continuity tests,
- insulation resistance testing, or touch current measurement where insulation resistance testing is not appropriate,
- functional checks.

The earth continuity test may be carried out in one of two ways: by applying a test current of either between 20 mA and 200 mA, or at least 1.5 times the fuse rating but not more than 25 A. The pass condition shall be an earth resistance no greater than $(0.1 + R)\ \Omega$ where R is the resistance of the protective conductor of the supply cord, which depends on the length and cross-sectional area.

The insulation resistance test voltage is 500 V dc. Pass conditions are lower than in type tests, being 1.0 MΩ and 2.0 MΩ for Class I and Class II equipment respectively. Exceptionally the limit for Class I heating equipment rated ≥ 3 kW is 0.3 MΩ.

For some types of equipment, the insulation resistance test is not appropriate:

- heating equipment that does not meet the insulation test pass mark, and
- ICT equipment that does not comply with BS EN 60950 (such a test could damage the equipment).

For these types of equipment, or where an insulation test has given suspect results, a *touch current* should be carried out instead or as well as. *Touch current* is the current that would flow through a human being in contact with an appliance casing to earth. If the appliance has a sound protective earth, touch current would be negligible. It only becomes appreciable where the protective earth conductor is broken, or absent as in Class II appliances, and where there is a significant leakage current from the live conductor through the system's insulation to the casing. *Touch current* is not quite the same as *earth leakage current* because the former is obtained with a phantom body's impedence interposed between the casing and earth. We understand that one PAT manufacturer, Megger, treats the two quantities as being the same. Another, Seaward, differentiates between them.

Within the appendices is a long section on production testing so as to help the reader come to a sound judgement when handling a difficulty.

Whereas there can never be a definitive text on electrical testing, this revised code of practice is near to being the last word. Copies are available from IEE, BSI and elsewhere.

Reference

1 *Code of Practice for In-service Inspection and Testing of Electrical Equipment* 2nd edition The Institution of Electrical Engineers (IEE) 2001 ISBN 0 85296 776 4

Superwool 607

A recently developed ceramic fibre - Superwool 607 - has been shown to be free of carcinogenic properties. Tests in our laboratory show that this material, both in the form of wool and paper, is suitable for a wide range of techniques for heating metals and their oxides, etc. Current ceramic fibre paper and wools should be substituted with Superwool products when they become available to schools.

In *Bulletins 187* and *189* (1996) [1, 2] we reported on the hazards of thermal insulating ceramic wools, various rockwools and glass wools which had been in use for some time. Our advice in 1996 was to avoid, if at all possible, the use of the ceramic fibres available at that time as the then recent research had shown ceramic fibres and rockwools to be carcinogenic to animals and possibly to humans[1] .

We have therefore been advising you to substitute ceramic fibre wool by other materials wherever possible and, if there were to be no alternative for a particular application, to use it carefully [3]. Recently we have been investigating the suitability of the recently developed Superwool 607, both in the form of wool and 'paper', for several standard procedures. Here are our findings.

What is different about Superwool 607?

The last generation of refractory ceramic fibres, which were presented by the insulation material industry in the 1970s as the safe alternative to asbestos, were high in alumina and silica, but with only traces of alkaline earth metals. Their range of diameters of 1 to 3 µm overlapped with that of blue asbestos (Crocidolite). Having the high alumina content resulted in a material with a high continuous working temperature, but also conferred on the fibres a long biopersistance. This means they survive for a long time in lung fluid, thus enabling lung diseases, including tumour formation, to occur. It is believed by some that even if there were a large deposition of fibres of the typical dimensions of asbestos (diameter < 1 µm, length > 5 µm and aspect ratio 3:1) in the lungs, then a high solubility can prevent the onset of respiratory disease.[2] This is because the fibres would have a low biopersistance.

Later research on ceramic fibres found ways of making them more soluble. Omitting the alumina and increasing the alkali content increases the solubility of the fibres, but at the expense of some lowering of the useful working temperature.

Constituent	Percentage composition
SiO_2	60-70%
CaO + MgO	25-40%
Al_2O_3	< 0.2%
$Na_2O + K_2O$	trace

Table 1 *Percentage composition of Superwool.*

[1] International Agency for Research on Cancer (IARC) categorised these as Category 2B "possibly carcinogenic to humans on the basis of limited evidence in both animal experiments and human exposure".

Superwool 607 within the above compositions (Table 1) has a working temperature in the region of 1100 °C combined with a low biopersistance and hence a predicted very low incidence of lung disease. This has been confirmed by animal experiments. It is worthwhile comparing the rate of dissolution of asbestiform minerals and other man-made mineral fibres (Table 2)[3].

In-vivo inhalation investigations also showed the Superwool fibres to have a low biopersistance and an absence of fibrosis or tumour formation.

Material	Solubility rate constant ($ng\ cm^{-3}\ h^{-1}$)	
	MMTC results (21d flow through tests)	Typical value ranges from other studies
Erionite	-	0.002
Crocidolite (Blue asbestos)	-	0.1 to 0.2
Chrysotile (White asbestos)	-	0.05
Glasswool(1)	-	15 to 33
Glasswool(2)	98	80 to 150
Mineral wool	-	250 to 450
607-0	190	185
Superwool 607 Spun	609	-
Superwool 612 Spun	50 to 75	-

Table 2 *Solubility rate constants comparing Superwool 607 with some other MMVFs (Glass wools) and natural mineral fibres.*

MMTC (Manville Mountain Technical Centre) sold off its interests in this field to the Morgan Crucible Company (now Thermal Ceramics UK).

Applications of Superwool 607

Wool

This is very suitable for use as follows:

(i) Loose plugs in the mouth of test tubes and flasks to keep 'spitting' crystals from being ejected (eg, when heating potassium manganate(VII)) or trapping mists and other aerosols. For many applications cotton wool is still better and cheaper, but would of course be most unsuitable where strong oxidising agents were present. In such cases, always use non-oxidisable materials such as a glass wool or Superwool (Fig. 1).

[2] Pott, F. *Testing the carcinogenicity of fibers in laboratory animals: results and conclusions.* In Warheit, D.B. (ed.): *Fiber Toxicology***.** San Diego: Academic Press 1993.

[3] *Development of a soluble high temperature insulation fibre* an original paper by Alexander, I.C. and Jubb, G.A. of Morgan Materials Technology Ltd, Stourport-on-Severn (UK), published in *Glastech.Ber.Glass Sci. Technol. 70 (1997) No 12.*

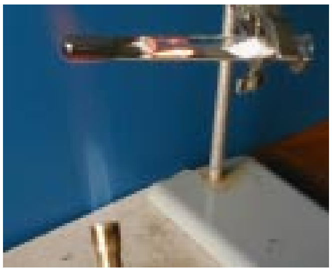

Figure 1 *Potassium permanganate being heated to drive off oxygen; iron is reacting on the other side of a plug of Superwool.*

(ii) 'Reservoirs' or separators in Arculus small scale methods. We still find that scrunched up filter paper holds a greater volume of liquid, but where the use of paper is inadvisable - with oxidising agents or some corrosives - Superwool is preferable.

(iii) A thermal insulator for aiding the ignition of calcium held in tongs.

Superwool 607 paper

The paper can be used for all the applications for which Mackechnie fibre paper (a refractory ceramic fibre) or asbestos paper were used in the past. It is available in various thicknesses and we would recommend the 2 mm size.

Like the previous papers the material contains an organic binder, usually an acrylate latex, which burns off on the first occasion the paper is heated. Acrylates are known sensitisers. The binder must be burned off in a fume cupboard before using Superwool paper in the open laboratory, for reactions of powders, etc. Unfortunately this leaves the paper a bit less pliable and more prone to break up if handled roughly. Yet it is manageable. The whole operation can also be carried out in a fume cupboard. Like Achilles' heel the small area of paper gripped by the jaws of the tongs is not freed of the binder by roasting. The tongs will have to be moved to one side and that part of the paper reheated.

Figure 2 *Metal oxide and carbon being heated on a square of Superwool.*

The reduction of the oxides of copper and lead with charcoal and of copper(II) oxide with zinc may be done with 2 cm squares cut off with scissors (Fig. 2). These should be pre-roasted to remove the acrylate binder and then held with tongs above a bunsen. Alternatively these mixtures of metal oxides and carbon or other reductant should be heated from above at one end. Once the reaction starts the burner should be removed allowing the reaction to spread along the length of the mixture. If you want to heat from the top, first apply a gentle flame, or heat from below, either way sintering the surface a little. Otherwise, a roaring bunsen flame on top can scatter the powder.

Reductions were also tried using a 'vee' made by folding a short strip of paper (Fig. 3). This works well, but has no great advantage over the wee square.

Figure 3 *Metal oxide and carbon being heated on a vee of Superwool.*

Reactions started much sooner with 1 mm paper, but we found the thinner size to be mechanically weaker. Molten beads of lead wiil fall through it; hence our compromised preference for 2 mm. As a test, lead shot pellets were placed on top of 2 mm paper and heated from below. They did not fully melt to a flowing liquid but held their shape as spheres. These spheres were soft enough to be easily dented with a spatula. This demonstration of the good insulating properties of Superwool 607 paper is not what we want in this particular application.

Ceramic centred gauzes

Another area of possible concern is that of aged ceramic centred gauzes. The material there is made of the older type of refractory ceramic fibre, which is now classed as *Toxic, Category 2 carcinogen by inhalation.* Schools should initiate a rolling programme of replacing any of these which are badly damaged with new stainless steel gauzes without a centre. We hope that some suppliers may start fitting the centres of gauzes with Superwool 607. In the meantime we should turn down the gas a bit.

Another hazard from all ceramic fibres containing silica is that on prolonged heating at high temperatures they undergo a change from amorphous glass to crystalline Mullite or Crystalobite. These are both more toxic than the original fibre. The amount formed will depend on both temperature and time. A rough rule of thumb is that either will be formed if the fibres are heated

- at 1000 °C for years,
- at 1100 °C for months, or
- at 1200 °C for weeks.

Given that a good Bunsen flame might just about reach 1000 °C, there is certainly no problem with the general use of the paper and the fibre wool as they are only heated for about a minute and then in any case disposed of. The centres of ceramic gauzes will be heated for a much longer total time during their lives and might possibly give rise to a small cause for concern. This is another reason for considering their replacement. This type of change induced by strong heating can also happen to Superwool.

Supply

Superwool and the related paper are new products. At the time of preparing this article they do not seem to be available from any educational supplier. Several such companies have been approached by SSERC to ask that they stock these materials.

Acknowledgement

We are grateful for the advice of Dr H Hickling and John Brinsden of Thermal Ceramics (formerly Morganite, who took over Mackechnie Refractory Fibres Limited, the manufacturers of the first ceramic paper generally used in schools). Thermal Ceramics are the makers of Superwool. We also collaborated with Bob Worley of CLEAPSS School Science Service.

References

1 *Hazards of man-made mineral fibre* Bulletin 187 SSERC 1996.

2 *Tiles: heating metals and oxides* Bulletin 189 SSERC 1996.

3 *Hazardous Chemicals - a manual for science education CD2* SSERC 2001.

A fuller version of this article can be found on our website. It includes the MSDSs for Superwool 607 fibre and Superwool 607 paper.

Summary

Superwool is believed to be free of carcinogenic properties. On the other hand the rockwools and glasswools we presently may use in laboratories are Class 2 carcinogens. Superwool should be substituted in the listed applications in preference to the older varieties such as Kaowool. However there is no reason why you shouldn't go on using platinised Kaowool as a catalyst; once placed in the catalyst chamber on the first occasion of use, it can be kept there and need never be removed thereafter.

Superwool paper is worth trying. It can save you having lots of test tubes with metal oxides fused into the glass.

Both the wool and paper forms of Superwool may have many other applications in thermal insulation.

CE marking and product safety

There is much confusion on CE marking. Its purpose is to facilitate the free movement of goods within the EU. It is a symbol for trade and traders. Strictly speaking, it is not a quality or safety mark for consumers.

There are 21 product directives, only a few of which are relevant to us (Table 1). These direct how the public interest should be looked after. For many products, based on in-house testing, which may or may not have been checked by an independent body, the manufacturer can declare that their product complies with a directive.

A CE mark is not a guarantee that a product meets essential safety or performance standards. To get such a guarantee, the consumer should look for the licence mark from an independent test house. The BSI *Kitemark* and *GS* stamp from the German-based RWTUV are examples. Under these schemes, not only does the licensing agency scrutinize the original product and its design, but furthermore it continually selects production samples at random for repeat testing.

Product Directive group	Self-declared compliance by manufacturer	Compliance checks by independent test-house
Electrical	All products	None required
Machinery	Some machine types	Other machine types
Pressure	Extra-small systems	Most types of pressure system
Personal protective equipment (PPE)	PPE of simple design	PPE of complex design

Table 1 *Product groups used in science and technology education whose products require to be CE marked.*

CE-marked pressure equipment

One of the last product directives to take effect is the one on pressure equipment. As from May this year pressure equipment cannot legally be traded in the EC unless bearing the required CE marks. Therefore when you go to buy an autoclave, pressure cooker or steam engine, check before you buy that it carries CE marking. Hearing from BSI that, as of this midsummer, 60% of manufacturers had still not certified their products, we have done some asking around. Dixons' hope to have their autoclaves in compliance by the end of the year. But Prestige Medical are ahead of them – all of their autoclaves are CE-marked.

If pressure equipment bears the CE mark then you can be reasonably assured that it is safe by meeting essential safety requirements on design, manufacture and testing. Very small pressure systems such as model steam engines can be self-assessed for compliance by the manufacturer. No checks by other competent bodies are needed. With larger systems such as autoclaves, an independent agency such as BSI must check the checks the maker has made.

Product safety

Legally, there are duties on several parties to ensure that equipment you work with is safe. The manufacturer, importer and supplier are all bound to ensure that equipment they design, make or supply is safe for its intended purpose. After purchase the employer then becomes responsible for equipment safety. The CE marking scheme gives the customer a certain amount of assurance. For instance it should indicate with which product standards a product is purported to comply. For better assurance, employers, as both customers and dutyholders, should look for independent verification .

SSERC is an independent test-house for laboratory equipment. We conduct a restricted range of type tests, limited by our small facilities. We are funded largely by grants from Scottish councils and never take payment from manufacturers whose products we test. For information on longer term product performance, including defects, we rely on reports from schools.

Radford Labpacks

In 1996, every council and independent school were written to by the Centre to notify them of our concerns with these obsolete power supplies. The issues are complex. There had been many models produced. Some model types were believed to have several versions. Some of these had dangerous features, or systems which, in the event of a fault, could lead to danger. Many units had been modified by schools and there is a history for some modifications causing electric shocks. Taking these factors into consideration, we recommended in 1996 that certain models should be withdrawn from service forthwith and disposed of. All others should be phased out over a 3 year period.

We now understand through the Scottish Technicians' Advisory Group that some schools still have Radfords in service. If so, they should be disposed of and replaced with modern units of safe design.

Liquid nitrogen transport

In light of new information, safety guidance offered by us in Bulletin 190 [1] on transporting liquid nitrogen (LN) by road has been reappraised. Recent advice from BOC and HSE is that "you should always assume that there is a possibility of the largest container of nitrogen falling over and releasing its entire contents over a short period of time." If 2 litres of LN were to be suddenly released in a car the oxygen concentration could fall to 10%, causing mental failure and unconsciousness. Even if the oxygen concentration dropped by a few percent only, co-ordination, perception and judgement could all be impaired.

This presumably is why recent recommendations from the British Compressed Gases Association [2] include "Dewars shall not be transported by car". The Association advise transporting LN on a flat-back vehicle. We therefore warn you not to carry LN by car, minibus or van, but to use either a flat-back truck or trailer. We are sorry for those of you who use the stuff if that makes life awkward and trust you accept the explanation.

The maximum quantity of LN to be brought into a school is 2 litres. LN must be stored in a proper cryogenic flask that permits venting. An ordinary vacuum flask is not suitable. A suitable container is the Air Liquide product *GT2* (BDH, 327/1003/00, £317.48). At second best and of a lower standard you could use the 2 litre Nalgene flask from BDH (236/1950/02) at £92.02.

References

1. *Liquid Nitrogen* Bulletin 190 SSERC 1997.
2. *The safe use of liquid nitrogen dewars up to 50 litres BCGA Code of Practice* CP30 British Compressed Gases Association 2000.

Traffic light LEDs

One of the staple projects in school technology is making a set of model traffic lights out of LEDs controlled by digital logic. This technology has moved on now from the design bench to the street, where we find those stunningly luminous and brilliantly coloured LED traffic light signals.

Colour, luminous intensity and the way the lights are distributed all contribute to the correct recognition of traffic signals. The colours must be sufficiently distinct such that one signal is never confused for another.

Because red colours are at one edge of the eye's photopic response, a red signal has to be sufficiently far from that edge to be clearly visible, but not so far that it might then be confused with amber.

LEDs that have been specifically designed for use in traffic signals are now becoming available from general distributors (Table 1). If you are running them off a 5 V supply, we suggest that the series resistor value should be either 150 Ω or 180 Ω.

Colour	Wavelength (nm)	Spectral half-width (nm)	Luminous intensity (mcd)	Viewing angle (deg)	Type	Order code	Price (£)
Bluish-green	502	35	1000-1500	23	HLMP-CE23	362-5280	0.75
Amber	590	17	1000-3700	30	HLMP-EL33--QT000	302-7600	0.27
Red	630	17	1650-6300	30	HLMP-ED3-3-SV000	332-4448	0.26

Table 1

Traffic signal LEDs stocked by Farnell. They are supplied in packs of 5.

Microscope specifications

The key principles underpinning SSERC's specifications for educational microscopes are explained. Parts of these notes may be of some application in Scottish courses which require basic knowledge of the effective use of an optical microscope. The SSERC specifications are summarised.

There is now at least a promise of some increased funding for science teaching equipment in schools. Against that background, in the last issue we indicated that we had again been testing educational microscopes. It is some years since we last published such information and many teachers may never have seen specifications to guide any intended purchases.

Our specifications have a long provenance, being based on the work of the old ASE Apparatus Committee and that of the various Nuffield Science Education projects. Whilst they have been 'tweaked' over the years to reflect improvements in apparatus, and accessories such as illuminators, camera adaptors and video, at their core they have proved remarkably durable. The key principles[1] are few and fairly simple.

Most importantly, the specifications are differentiated by age and stage (Table 1 opposite). This is because optical quality (particularly *resolution* of the required detail) is the critical factor. The opposite argument is also often heard - that the younger the pupil the less the important is the quality of the optics. The 'cheaper' the instrument the better. Nothing could be more misguided. It shows a fundamental misunderstanding of the nature of optical instruments.

Optical quality

The image formed by such an instrument is never simply a 'picture' of the object under examination. Rather, it is what has been elegantly described elsewhere as an *optical transform*[2]. What a teacher or pupil sees at the eyepiece of a conventional microscope, or on the screen of a video microscope, is the sum total of what the specimen and system have done to the light which enters that system. Light which leaves the specimen carries information about its detailed structure. The eye detects, and the brain interprets, any changes in the light brought about by the effects of such 'structure' largely from what is, essentially, a complex of interference patterns.

The specimen may:

- *absorb some of the light, reducing its amplitude and thus intensity or it may selectively absorb certain wavelengths so changing the colour;*
- *refract or reflect it, so that some light which may otherwise have entered the objective no longer does, or so that some enters which otherwise would not;*
- *scatter or diffract it, with similar effects to above,*
- *change its phase, or plane of polarisation, so that with special optics changes in intensity may be observed.*

All optical microscopes, even the best and most expensive, have a limited capacity to capture structural information about the specimen as carried by the light entering and passing through the system.

Consider the following limitations:

Illumination

The system can only affect the light available at the specimen. Whatever system of illumination is used, be it a mirror or a built-in illuminator, there are limits to the accuracy with which the area of the specimen under examination can be fully and properly illuminated. Light from outwith the area of interest carries no information about that area's underlying structure. Instead it may introduce spurious information. It may also reduce contrast and so increase 'glare'. Lens coatings, condensers and aperture controls such as disc or iris diaphragms provide only partial solutions to such problems.

Resolution

Resolution is the ability of the system to distinguish between small, separate, yet closely spaced objects and so determine highly detailed structures. This is largely dependent on the numerical aperture - roughly equivalent to the light gathering capability - of objectives. The specimen emits light in all directions. Only a proportion of that light can ever enter the objective. The remainder, including the information it carries, is 'lost' to the optical system. Numerical aperture is a trigonometric value related to the angle of the solid cone of light which can enter the objective. Magnification in the absence of resolution is useless and is rightly known as "empty magnification".

Aberrations and other defects

The optical system is never perfect. It may itself introduce spurious information to the final image. Glass bends light of different wavelengths differently. Images may thereby be spuriously coloured or tinged. Remember prisms and spectra? In addition, lenses are spherical and images may well be curved rather than flat. They may also be distorted. Circular objects or apertures may appear as elliptical images. Squares may appear as barrel or pincushion shapes.

Microscope lenses thus have to be made up from different kinds of glass in an attempt to correct for these unfortunate tendencies. The processes of such correction are imperfect and even in the best of instruments there are residual defects.

Key principles

All of the factors listed above support the fundamental rules, for specifying features of educational instruments, which are:

The less experienced the user the less able they are to distinguish between 'genuine' features in an image and the spurious detail which may result from defects in the system or its use.

Therefore : the younger the pupil the better the basic optical quality of the instrument which is to be specified.

Where economic or educational considerations rule out the purchase of more expensive instruments to obtain such optical quality then any savings are best made by simplification. Costs may be lowered, for example, by simplifying the mechanics and controls or in altering the number and type of objectives and eyepieces.

Footnotes

1. These were best defined by Colin Weatherly, one time Assistant Director at SSERC but now probably best known for his proseltysing on critical thinking in learning and teaching. Like all good principles they are elegantly simple.
2. In papers supporting the Royal Microscopical Society's course : *The Principles of Optical Microscopy*.

Age and stage	Optical Features	Mechanical Features and Illumination	Comments
Primary 1 to 7 (Years 1 to 7) Science in Environmental Studies 5-14	Simple hand lenses (x6 to x10) or single fixed magnification objective (x20) in a stand resembling a 'proper' compound microscope. Simple stereomicroscopes or video microscopes can also be useful for three dimensional speci-mens examined with incident light (e.g so called'minibeasts').	Manual focus by distance adjustment (hand lens) or single coarse focus control. Illumination by diffuse daylight or battery powered illuminator (modified torch types)	Young pupils have problems with 'proper' compound microscopes because of twin difficulties - dealing with lateral and vertical inversion and an inability to interpret three dimensional structures from two-dimensional sections (needed for work with transmitted light). Such difficulties are best avoided unless such an instrument is used for teacher demonstration work. Inexpensive video microscopes may have limited resolution and a time lag between focusing and the result appearing on screen - best restricted to use with simple, three dimensional specimens.
Secondary 1 to 4 (Years 8 to 10) Standard Grade or Access/Interm-ediate 1	Magnification x200 (but up to x400 with a fine focus see next column). Provided by three objectives x4 or 5 , x10,and x20 (preferably) or x40 on a triple nosepiece and a x10 widefield eyepiece. Objective numerical apertures : 0.10 for x4 or 5 ; 0.25 for x10 and 0.40 for x20. Where x40 is fitted it should have a numerical aperture of 0.65.	Single coarse focus by rack and pinion, or similar, moving stage or body tube. Stop(s) fitted to the mechanism. If a x40 objective is fitted rather than x20 then a fine focus must be present, preferably a screw and lever mechanism. Mirror, sub-stage illuminator or built-in. Removal of stage clips, eyepieces, mirrors etc requiring the use of a tool.	So that pupils may relate parts of a specimen to the whole, a suitable low-power objective (x4 or x5) is a necessity. Magnification of x200 is adequate for first examination level although it's on the limit for some demanding specimens commonly specified in syllabuses (red blood cells, chloroplasts and mitotic figures). As the magnification or power of an objective increases then its depth of focus and working distance decrease. It is nigh on impossible to properly use a x40 objective without a fine focus mechanism.
Secondary 4/5 to 6 (Years 11/12 to 13) Intermediate 2, Higher and Advanced Higher	Normal working magnification x400 and up to x900 or x1000 where a focusing sub-stage condenser is fitted and an oil , or water, immersion objective is available. With a simple fixed condenser lens in a stage aperture the resolution of even a x40 objective will be less than optimal. Objective combinations on a triple or quadruple nosepiece of x4 or 5 NA 0.10; x10 NA 0.25, x40 NA 0.65. all to at least achromat standard. Flatter field types to the DIN standard are optional but preferred. A x10 eyepiece, widefield type - but a graticule on the field stop must be in focus.	Both coarse and fine focus mechanisms required. The former preferably by rack and pinion moving either the stage or the body tube, the latter by screw and lever or a variant thereof. Where a focusing condenser is fitted the focus mechanism should be by rack and pinion but a helical or spiral mount will do. Removable parts to be secured by means requiring the use of a tool except the eyepiece which may be 'held'. Illumination may be by mirror and bench lamp but preferably will be built in and low voltage from an integral transformer.	The recent trend has been not to fit a proper focusing condenser but use a fixed condenser lens in the stage with a sub-stage disc diaphragm. This has been defended on the grounds of simplicity of use and of cost. There is a price to be paid for such simplicity. With a fixed condenser, a x40 objective can't be fully lit. Resolution suffers. Without a focusing condenser immersion lenses cannot be used. For courses such as Biotechnology at Intermediate 2 and Higher or the Biotechnology option at Advanced Higher the work will be restricted if students do not have access to immer-sion lenses for the examination of bacteria. Similarly widefield eyepieces with no field stop for an eyepiece micrometer make for difficulty in quantitative micros-copy at this level.
Advanced Higher at secondary and in FE for use a demonstration instrument.	As for the highest spec above with focusing condenser etc but also with a double eyepiece tube (also known as a 'tutor' tube) which will accept a camera either conventional or, preferably, digital and possibly video.	As above but with the addition of a mechanical stage to increase ease of use in quantitave work and in demonstrating specific features to students.	Although this specification is for a demonstration instrument on a one per department basis, it would also be the ideal instrument where significant numbers of students are studying biology courses at the Higher and Advanced Higher levels. Phase contrast would be a useful feature but phase instruments are now hard to source at reasonable prices. We are working on this problem.

Table 1 Outline specifications for optical microscopes for use in Scottish biology and biotechnology courses.

Test reports

Our test reports are sent to the manufacturer or supplier in draft form for comment before they are finalised. Such reports should appear fairly soon in summary form, hopefully in the next issue of the Bulletin and on the members' section of our website. It is likely that the web version of the summary will be accompanied by a fuller version of Table 1 above and descrip-tions of our test procedures.

Test procedures

SSERC's tests are designed to evaluate the extent to which the specifications outlined in Table 1 are met. Optics are examined to assess critical aspects such as resolution, acceptable levels of common defects etc. The mechanics are also examined to assess quality of fit and finish, and suitably robust construction to ensure reliability and longevity. Our sister organisation CLEAPSS has also been testing microscopes and we'll take account of their results.

Control at S1/S2 with small models and a PIC

Control is one of the elements generally missing from 5-14 in primary schools but could and should be addressed at S1/S2. With progression to Standard Grade and Intermediate levels in mind we offer the following ideas which we believe are fun, informative and inexpensive.

The first is control of traffic lights using a home-made model – the ubiquitous school project. The second is control of three washing machine models: two home-made and the third a store-bought toy. All of them make use of a Project Board from Revolution Education.

The Project Board contains a PIC microcontroller; either one of 1684s or 16627s would do (Table 1). We have chosen the 16627 because of ease of use when applying analogue inputs. When buying the chip you are also supplied with the project board, a download cable and software, all for the serfly sum of £12.61. Programming the models is straightforward and should be within the capabilities of most S1/S2 pupils. The circuit can be as simple or as complicated as needed to match the capabablities of the child.

Chip features	PIC16F84A	PIC16F627
Analogue inputs	0	2
Digital inpits	4	4
Digital outputs	8	8
Sound output	1	1

Table 1 *Features on 2 PIC microcontrollers.*

Essentially, each model causes lights or motors to go on or off in sequence responding to switched inputs and a control program.

Traffic Lights

At its simplest, the circuit for the traffic lights' model is a set of three lamps in parallel. Photographs (Fig's 1, 2) give an idea on how the model was manufactured from odds and ends of 25 mm cable trunking, 3 coloured bulbs (red green and yellow) and a terminal block. We used bulbs rather than LEDs to simplify the wiring; there is no need for resistors.

To allow some progression we also made a couple of models with an extra lamp on the side to act as 'Green Man' signals for a pedestrian crossing. With an input as well as outputs, programming becomes more interesting and challenging. We will not offer any programming notes for this model.

Figure 1 *Model traffic lights, completed model.*

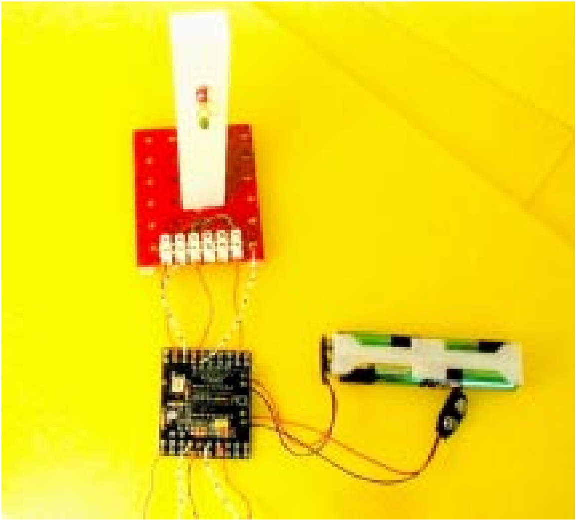

Figure 2 *Fitment of bulbs and holders in model traffic lights.*

Washing Machine

The models illustrated (Fig's 3, 4) were constructed for an in-service on programming and control. Using one's imagination, it can be seen that the example shown in Figure 3 can represent either a washing machine or a microwave. As usual, many of the components in the models can be purchased from the SSERC surplus list. A parts list is given on our web site. The parts were mounted on perforated plastic sheet on the underside of which had been glued a pair of wooden battens of 10 mm cross-section.

The toy Hotpoint Washing Machine from Casdon (Fig. 5) was bought from Argos. When used along with the home-built models, the home-built versions become understandable.

For the toy washing machine we originally used the circuit supplied with the store-bought machine. It has a chip that gives the sound of the drum filling with water. However we

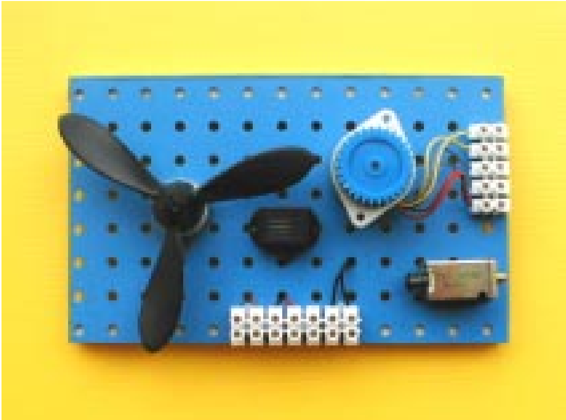

Figure 3 *Model washing machine or microwave.*

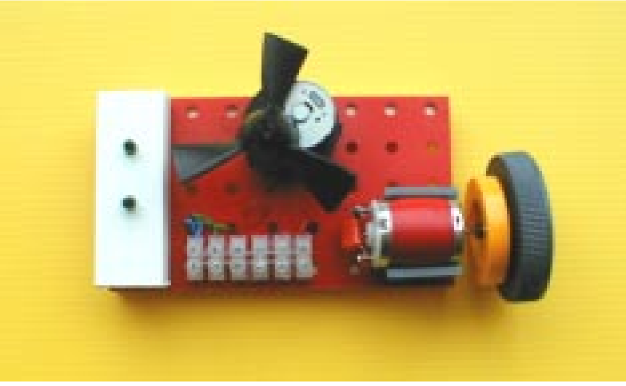

Figure 4 *Model washing machine.*

Figure 5

Hotpoint washing machine, toy from Casdon, with PIC controller on top panel.

decided that this may cause too many problems for pupils because tracks have to be cut and others have to be linked. We thus discarded the toy's own circuit and replaced it with our own.

At the centre of the circuitry on top of the toy (Fig. 6) is the PIC microcontroller in its Project Board. Terminal blocks on either side handle inputs and outputs. The large terminal block on the top rear of the toy washing machine connects control lines between the toy and Project Board. Two battery packs are needed – one pack supplies the Project Board. The other powers components in the toy.

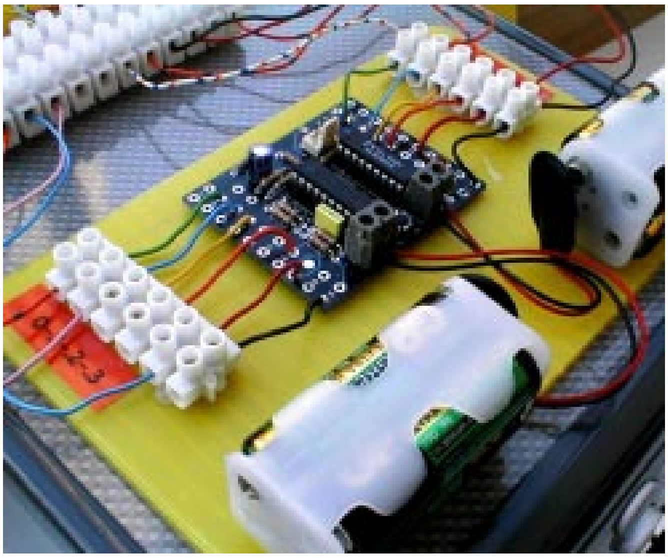

Figure 6 *Close-up view of PIC microconroller on top panel of toy washine machine.*

There are two real switches on the model, a push-button switch on the front panel marked *POWER* and a microswitch on the door. Also there are three pretence switches, *FILL*, *WASH*, and *ECO WASH*, and four LED indicators, *SPIN*, *WASH*, *FILL*, and *POWER*. Last and not least, the clothes' drum is turned by a motor.

Having discarded the toy's own control circuitry, we had to construct a substitute circuit of our own to connect the switches, LEDs and motor to the Project Board (Fig. 7). On a separate board we placed a thermistor voltage divider circuit. This can be handed out to certain pupils as an extra item once you judge they are ready to handle an analogue input.

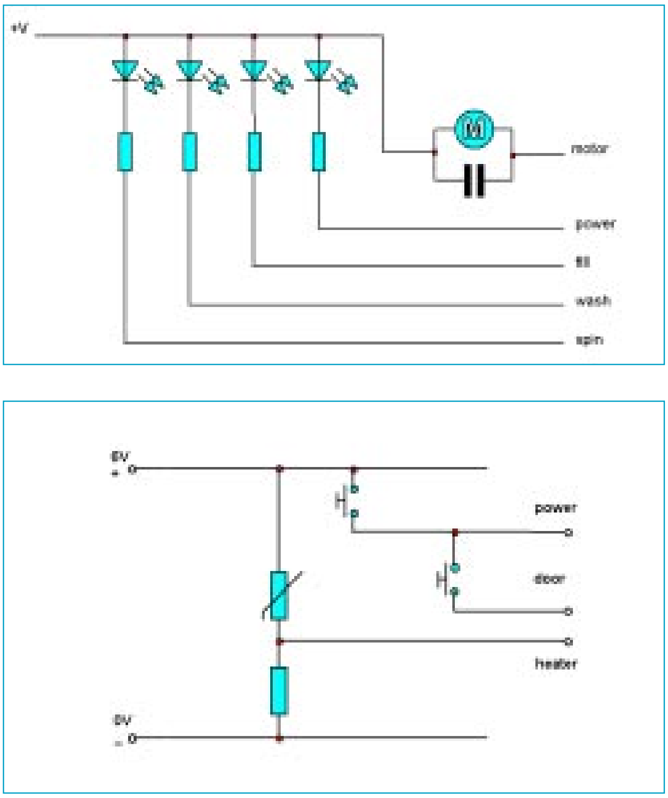

Figure 7 *Home-built circuits for input (top) and output devices (below).*

A list of parts is shown (Table 3). Perhaps the hardest bit of this exercise may be scrounging the £20 from petty cash needed to buy the washing machine toy from Argos!

Part	Detail	Order code	Supplier	Price
Coloured bulbs, pack of 10	Red Yellow Green	203.014 203.036 203.058	Opitec	£1.15
Bulb holder, pack of 10		200.075	Opitec	£0.70
PIC Project Board	PICAXE-18 Starter Pack	AXE002	Revolution	£12.61
(Toy) Hotpoint Electronic Washer		351/5712	Argos	£19.99

Table 2 *Toy washing machine parts.*

Program

Programming could start simply with 1 input and 5 outputs.

Input	*POWER ON* button
Outputs	*POWER ON* LED
	FILLS LED
	WASH LED
	SPIN LED
	Motor

Thereafter pupils could progress to handling 2 digital inputs, making use of the micro-switch on the door, then adding an analogue input with the thermistor circuit.

Programming is straightforward. We suggest *symbols* are used to make the program easier to follow, for example:

```
symbol red = 7          ' POWER ON LED on
symbol green1 = 6       ' FILL LED on
symbol green2 = 5       ' WASH LED on, drum spins slowly
symbol green3 = 4       ' SPIN LED on, drum spins fast
symbol counter = b1     ' variable for motor wash and LED flash before opening door
```

The program below was used for the thermistor input. Others are of course possible.

```
heat:  readadc 1,b0           ' reads the analogue signal to variable b0
       if b0 > 64 then wash   ' if variable greater than 64 goto wash
       if b0 <65 then heat    ' if variable less than 65 goto heat
       pause 500
```

Comment

We believe that attempting the above exercises will match several of the Attainment Targets in the 5-14 section on Information and Communications Technology within the Science and Technology part of Environmental Studies.

Should anyone feel that a copy of our simple washing machine program would be useful, please contact SSERC or e-mail tsa@sserc.org.uk. If you have experience of this toy washing machine used with Basic Stamp or a PIC we would be pleased to hear from you.

Buffers

During recent trials of pH meters, we inadvertently discovered that the pH 12 buffer solution we had purchased from Scientific and Chemical Supplies Ltd (SCS) was outwith specification. We measured the pH of the solution with six different meters and obtained consistently readings of 10.5.

The offending buffer solution, which we received during May this year, is the SCS, General Purpose Reagent, pH 12 buffer solution:

Batch numbers 030010-2 026020

We contacted SCS who, after an investigation, confirmed that there was a problem. They also informed us that the affected buffers had been withdrawn and that their supplier was now looking into the matter.

With this in mind, we felt it appropriate to remind members that DIY alternatives to commercial buffers are cheap and easy to prepare. In Bulletin 163, DIY buffers were compared to commercially available solutions. This article concludes that DIY buffers provide a cheap and reliable option that, for many school applications, do not even require to be accurately prepared. Table 1 below gives the results of both accurate and rough preparations of some DIY buffers.

If stored in sealed polythene or glass containers these DIY buffers can be kept for a number of months. However, unlike their commercial kin, which contain fungicides, they will eventually go mouldy. Our advice is to make up fresh solutions as and when required rather than make up large quantities for storage.

Safety

When making up these buffer solutions wear appropriate PPE and avoid raising dust. Of the chemicals listed below the most hazardous are:

Potassium trihydrogen dioxalate (potassium tetraoxalate) – Xn, harmful by ingestion, inhalation or skin contact. Avoid raising dust, wear gloves and eye protection.

Calcium hydroxide – C, corrosive, avoid contact with skin and eyes. Wear gloves and eye protection.

Chemical	Molecular weight	Molarity (M)	Accurate preparation (g/100 cm³)	pH	Rough preparation (spats/100 cm³)	pH
Potassium trihydrogen dioxalate	254.19	0.05	1.27	1.92	2	1.92
Potassium hydrogen phthalate	204.22	0.05	1.02	4.01	3	4.01
Potassium dihydrogen orthophosphate with	136.09	0.025	0.34		1	
di-sodium hydrogen orthophosphate	358.14	0.025	0.895		3	
1:1 mix of above 2 solutions				6.86		6.86
di-sodium tetraborate	381.36	0.01	0.38	9.03	5	9.03
Calcium hydroxide	74.1	saturated	0.37	11.45	1	11.45

Table 1

Buffer solution recipes comparing results of accurate and rough preparations.

The spatula used for the rough method was the Nuffield stainless steel type used with the scooped end.

Power supplies

Since we last issued test reports on power supplies in 1996-7, there have been many product changes. Much of the Griffin range has been redesigned, but keeping the same designer and manufacturer. These designs are now sold also by Scientific & Chemical. Philip Harris have totally changed their products. No longer are they made in the old Unilab factory. Manufacturing has been shifted offshore. Irwin have gone out of business, but their power supply business was bought over by Economatics. STE is the new boy on the block and they too have new products on offer.

Where to start? This short report looks at three basic items: two from Economatics and one from STE. Economatics continue to sell their power supplies under the name *Irwin*, taking advantage of the reputation that Irwin power supplies enjoyed.

On safety, each product was tested for evidence of compliance with the relevant standard, BS EN 61010-1. No significant deficiencies were found. Each product is declared to be safe.

The products were also tested for performance seeing whether output voltages agreed with settings and by how much they dropped under loading, checking that the maximum rated output current could be maintained for 1 hour, observing temperature rises from self-heating, testing overcurrent cut-outs, and checking, where provided, voltage limitation devices.

Because the Irwin products have been on the market for a long time, we asked several councils to comment on how well they stood up to use in schools. The replies we got indicated that they stand up well.

Assessment:

A Most suitable for use in Scottish schools and non-advanced FE

B Satisfactory for use in above

C Unsatisfactory

Irwin LV Power Supply EJ1001

Manufacturer and supplier: Economatics Education
Price: £78.95 (special offer at 31/7/02)
Outputs: 2, 4, 6, 8, 12 V ac and dc switched steps (dc full-wave rectified), 5 A max. continuous
Voltage limitation: Between 6 V and 8 V
Electrical protection: Fuse on supply (not accessible); resettable thermal cut-out on outlet
Construction: Robust 2-part enclosure, very convenient for carrying

Comments: Performance is quite good although the dc voltage drop with load is worse than found on some rival products. It is fairly robust, but the voltage limitation mechanism and rotary switch both have inherent weaknesses. However response from users indicates that they stand up well. The price is good.

ASSESSMENT: A

Irwin LV Power Supply EJ0032

Manufacturer and supplier: Economatics Education
Price: £105.95 (special offer at 31/7/02)
Outputs: Continuously variable to 12 V ac and 16 V dc, 8 A max., 5 A continuous
DC smoothing: Effective for small loads only
Voltage limitation: At any value
Electrical protection: Fuse (not accessible): thermal fuse on transformer winding; resettable thermal cut-out (all 3 devices on the supply)
Construction: Robust 2-part enclosure, very convenient for carrying

Comments: Performance is good. It is fairly robust, but the voltage limitation mechanism and rotary transformer both have inherent weaknesses. The latter would be costly to replace. However response from users indicates that they stand up well. The price is good.

ASSESSMENT: A

STE Power Supply EMP 1212TB

Manufacturer: STE UK Ltd.
Supplier: Anderson Scientific
Price: £119.11
Outputs: 2, 4, 6, 8, 12 V ac and dc switched steps (dc full-wave rectified), 5 A max. continuous
Voltage limitation: None on this model
Electrical protection: Fuse on supply (accessible); resettable thermal cut-out on outlet
Construction: Very strong, 2-part, steel enclosure; perhaps too heavy

Comments: Performance is fair. The mean ac voltage is generally too high whereas the mean dc value is too low. Both fall faster with load than on some other similar products. The rotary switch resembles the one on Irwin's EJ1001 – therefore having the same inherent weakness but satisfactory performance. The price is a little high.

ASSESSMENT: B

LED array

We describe the construction with LEDs of an array of optical radiation sources spanning the entire visible spectrum. Some uses are provided.

Light emitting diodes are now made in every colour of the visible spectrum. Some are also made in composite colours, for instance in white and pink. The ones used in our array were chosen because they have relatively narrow bandwidths, some as narrow as 10 nm. They have been selected so that their peak emission wavelengths are uniformly spaced, so far as was possible, across the visible spectrum. Although none of these radiation sources are monochromatic, in effect they can be regarded as sources of pure colours. The whole effect is stunning and quite pretty. It beats fairy lights on the Christmas tree!

The LEDs in our original array illustrated here (Fig 1) were obtained mainly from the Austrian supplier, Roithner. Excepting the UV and deep red LEDs, they are also obtainable elsewhere from companies such as Farnell, Rapid or RS. Our selection criteria were:

- Colour purity,
- Wavelength separation of between 10 nm to 30 nm,
- Range from 400 nm to 700 nm,
- Luminous intensity between 1000 mcd and 2500 mcd (this has to drop off at the limits because of the photopic response of the eye),
- Small viewing angle not above 30°.

Our list (see website, or phone for a copy) is by no means definitive. We have so far been unable to find suitably bright emitters in some hues of orange and yellow.

Published LED wavelengths are nominally peak values at specified currents, but are inexact. The actual peak emission can shift by some 20 nm with current.

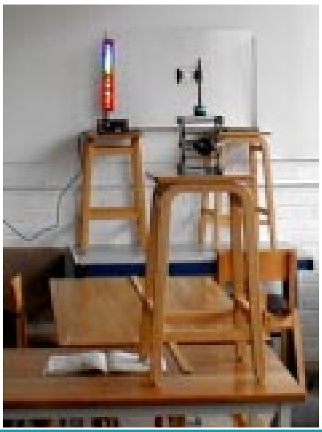

Figure 1

Figure 2
LED array spectra, 2 orders shown.

The peak colour perceived by the eye shifts from the actual peak towards the green part of the spectrum where the eye is most sensitive.

Each LED was supplied with a forward current of 10 mA from a 5 V regulated supply. Current is set by a resistor or pair of resistors in series with the LED. The LEDs and their series resistors were wired in parallel across the supply.

Stripboard was used to support the LEDs and connect the series resistors. Three strips 30 mm wide were cut from a standard sheet 118 mm broad. These three strips were mounted end to end on a supporting base material measuring 400 x 60 mm. Many types of insulating sheet material would suffice for the base. In our model we used a perforated plastic sheet. The overall length of stripboard holding the array was about 350 mm. The 15 LEDs were uniformly spaced 9 holes apart on the 0.1″ matrix. The array was supported with a laboratory stand.

Risk assessment

The first and last sources in the array are apparent emitters of violet and deep red radiation, but mainly emit ultraviolet and infrared radiation respectively, which are both hazardous. The risks can be minimized by:

- Not permitting close-up viewing,
- Limiting the exposure period,
- Shielding the ultraviolet LED with a UV-blocking filter.

It is perhaps not feasible to block ultraviolet radiation entirely with a filter while at the same time transmitting violet light. The suggested filter is in the form of a roll of film supplied by Edmund Scientific (E39-426, £10.03). This material allows less than 10% transmission below 390 nm, but may transmit nearly half of the radiation at 400 nm, the nominal upper edge of the UV waveband. Thus the filter reduces rather than eliminates the risk.

Hazard warning notices should be attached to the array beside both of the hazardous LEDs. These would reinforce oral warnings to keep a safe distance and limit the period of viewing.

Viewing through a diffraction grating

It is recommended that the LED array should be set up vertically with a black wall as the backdrop. Set up a diffraction grating (300 lines per mm, lines vertical) exactly 2 metres in front of the array. The height of the grating should be arranged for comfortable viewing and should be level with the mid point of the array. Set up an A1-sized screen with one edge immediately behind the array, the plane of the screen being at right angles to the line between the array and the grating. The screen should have a set of vertical lines ruled on it 10 cm apart, the overall separation being at least 80 cm. When the array is looked at through the grating, two or more diffraction orders will be seen with each source. Each order fans out from violet to red, the smallest fringe separation occurring at the violet end (Fig. 2). The bandwidths of the sources vary and generally appear to extend across 50 nm at least.

Wavelength can be estimated as follows: The angle θ subtended by the first order fringe at the grating can be derived from trigonometry. If the fringe displacement is x and the grating is 2 m from the source, then $\tan \theta = x/2$. The wavelength can then be derived from $\lambda = d \sin \theta$ where d is the grating spacing.

Experimenting with UV LEDs

Because a LED is a point source, UV LEDs can be used quite easily in optical experiments. By detecting the radiation with fluorescence, the wave nature can be demonstrated and wavelength can be measured with precision.

"In the way that these things do", UV LEDs "are bound to become much cheaper". Since writing that in the last issue, they have indeed. We have found a UK stockist, Marl, selling UV LEDs at prices lower than Roithner's. SSERC has bought in stocks of these for sale to schools. We offer two types (Table 1) with peak wavelengths at 400 nm and 370 nm. The former emits a mixture of UV and violet radiation. The latter emits UV only. Each LED should be mounted on a small piece of stripboard with a120 Ω series resistor for supply at 5 V. A reverse biased diode should be connected in parallel across the LED preventing it being destroyed by wrong polarity. This LED circuit should be recessed within a film canister (Fig. 1), to which a hazard warning sign is attached. This lets the user handle the LED, while warning that the radiation is dangerous.

Figure 1 *370 nm UV LED in its film canister housing.*

LED	Peak wave-length (nm)	Spectral halfwidth (nm)	Viewing angle (deg)	Luminous intensity or optical power	Emission	SSERC stock number	Price £
L-7113U-VC	400	20	20	160 mcd	Violet and UV	891	1.50
260018	370	12	10	0.75 mW	UV only	892	11.00

Table 1 *UV LEDs for sale through SSERC with wiring instructions, hazard sign and 3 sq in UV filter.*

Experiments

Detection by fluorescence: The following materials exhibit fluorescence: anthracine, bank notes, highlighter pen ink, vaseline, washing powder and some types of paper. A useful exercise would be to find out which white materials make suitable screens for optical experiments with UV radiation. Shine each LED on different potential screens such as a painted matt white surface, filter paper and photocopying paper. We find that only the last of these fluoresces. In fact it fluoresces strongly. By irradiating the 400 nm LED on filter and photocopying paper in turn, you can differentiate between the violet radiation, which is scattered off both papers, and ultraviolet, which fluoresces on just one of the papers.

Wave properties: Invisible radiation from the 370 nm LED can be shown to behave like a wave. In each of the following, use a piece of white photocopying paper as your detector:

Reflection: Irradiate a silvered metal surface and plane glass surface, detecting the reflections with paper. It should be apparent that as the angle of reflection is increased, the relative amount of reflected radiation increases also.

Refraction: Direct the radiation at a spherical lens and show that it can be focused to produce a sharp image of the emitter. Use the lens to collimate the radiation, direct at a prism and show that radiation emerging from the prism can be brought to a focus with a second lens.

Diffraction: Requires a diffraction grating rather than a single slit.

Interference: Fringes can be produced with difficulty using a multiple slit and 2 lenses.

Polarization: Effect not seen because all types of polarizer we tried totally absorb UV.

Wavelength measurement: Focus the radiation on a screen using a converging lens such that the lens-to-screen distance is 300 mm exact. Place a diffraction grating (80 lines/mm) next to the lens creating a set of interference fringes on the screen. You should be able to see 4 orders on either side of zero.

Wavelength can be estimated as follows. The angle θ subtended by the nth order fringe at the grating can be derived from trigonometry. If the fringe displacement is x and the grating is 300 mm from the source, then $\tan\theta = x/0.300$, giving you the values of θ and $\sin\theta$. If values of $\sin\theta$ are then plotted against n, wave-length can be derived from the gradient (λ/d) where d is the grating spacing.

The method is generally applicable for all LEDs. The dominant wavelength can thus be found to considerable precision (Fig. 2).

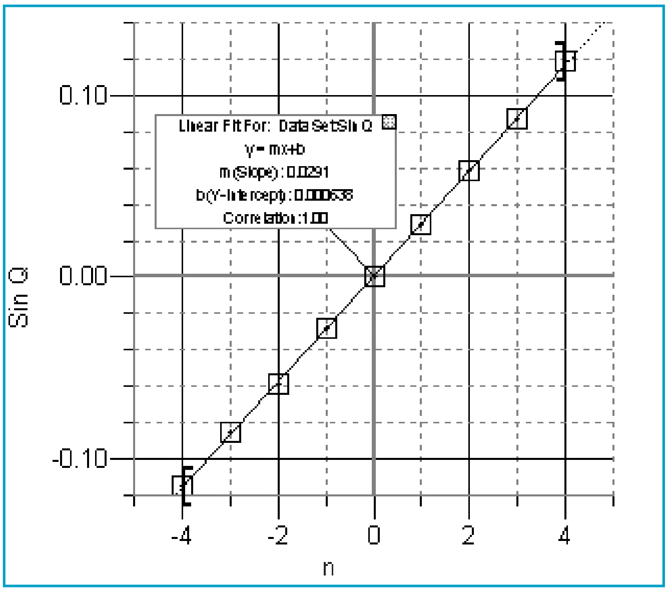

Figure 2

Graph of sin θ versus n for 4 diffraction orders on either side of zero.

Using the gradient, the derived value of wavelength is 364 ± 4 nm.

Technical tip

Popping *Alba* files into *Excel*

Several teachers have asked how files from the *Alba* datalogger can be exported to *Excel* or other packages; here is the method:

With *Alba* opened and the Table window active, go to the drop-down menu under *File* and select *Export Table*.

Save the file, giving it a name; note that it is saved as a text file.

Go into *Excel* and select *Open* from the File Menu.

Change the file type to *Text Files* and navigate to the file you want to import. The Text Import Wizard now takes over and you are presented with three windows in sequence. Accept the default on each:

Step 1: select *Delimited*
Step 2: select *Tab*
Step 3: select *General*

The data streams in - but that's not quite it – the data streams into a phantom *Excel* spreadsheet (for want of a proper, technical description) floating ethereally over your, as yet empty, *Excel* spreadsheet underneath. This data should then be copied to the desktop (using *Edit* and *Copy*) and pasted into the real, underlying, *Excel* workbook, whence it can be saved as an *Excel* file.

Alba data can also be exported as a text file to other packages.

Trade News

Solar Science Set

In the photo opposite is a product for showing energy transfers recently developed by a startup company Solar and Wind Applications. The S^3 as it is called features:

2 inputs:	Solar power	battery of 3 solar cells
	Wind power	computer fan, operating in reverse to generate electricity
8 outputs:	Rechargable battery	
	Capacitors to show charge storage	
	LED torch, set of 4 white LEDs	
	Digital voltmeter	
	Digital thermometer	
	Voice recorder with speaker	
	Sound effects machine with piezo output	
	Metal detector	

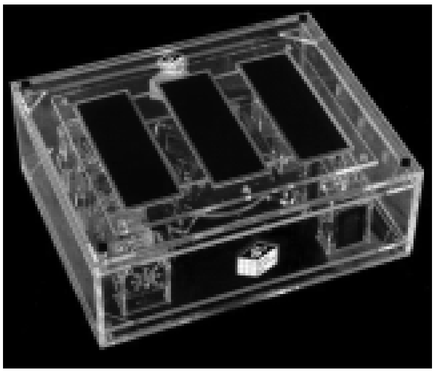

Figure 1 *The Perspex case of the Solar Science Set with its 3 solar panels on the lid and showing 4 output devices down the left hand side.*

Costing £350, this looks like an attractive kit for demonstrations of energy transfer, solar and wind power generation, and low power applications of electricity with elementary science classes.

Alpha Boards

These are now being manufactured by Tech Lab who also supply all spares for the boards. Unilab continue to market the boards. Reg Jones at one time of E&L Boards runs Tech Lab Ltd (see Address List).

Glasgow physics website

Glasgow University Physics Department have ceated a section for teachers attached to their website. You can enter this section directly from:

http://www.physics.gla.ac.uk/teachers/

Worth looking to see what's on offer!

Addresses

Anderson Scientific Ltd., Luzon House, Main Road, Cardross, Dunbartonshire, G82 5PX. T: 01389 841220, F: 01389 849180, W: www.andersonscientific-tech.com

Argos, W: www.argos.co.uk

ASE Booksales, College Lane, Hatfield, Hertfordshire, AL10 9AA. T: 01707 283000, F: 01707 266532, W: www.ase.org.uk

British Standards Institution (BSI), Chiswick High Road, London, W4 4AL. T: 020 8996 9001, F: 020 8996 7001, W: www.bsi.org.uk

The Design and Technology Association (DATA), 16 Wellesbourne House, Walton Road, Wellesbourne, Warwickshire, CV 35 9JB. T: 01789 470007, F: 01789 841955, E: data@data.org.uk

DfEE Publications, PO Box 5050, Sherwood Park, Annesley, Notts., NG15 0DJ. T: 0845 60 222 60, W: www.dfee.gov.uk

djb microtech, Delfie House, 1 Delfie Drive, Greenock, PA16 9EN. T/F: 01475 786540, W: www.djb.co.uk

Economatics (Education) Ltd., Epic House, Darnall Road, Sheffield S9 5AA. T: 0114 281 3311, F: 0114 243 9306, W: www.economatics.co.uk/education/

Edmund Scientific Ltd., 1 Tudor House, Lysander Close, Clifto Moor, York, YO30 4XB. T: 01904 691 469, F: 01904 691 569, W: www.edsci.com

Farnell, Canal Road, Leeds, LS12 2TU. T: 0870 1200 200, F: 0870 1200 201, W: www.farnell.com/uk

Griffin & George, Bishop Meadow Road, Loughborough, Leicestershire, LE11 5RG. T: 01509 233344, F: 01509 231893, E: griffin@fisher.co.uk

Philip Harris Education:

E6 North Caldeen Road, Calder Street, Coatbridge, Lanarkshire, ML5 4EF. T: 01236 437716, F: 01236 435183.

Novara House, Excelsior Road, Ashby Business Park, Ashby-de-la-Zouch, Leicestershire, LE65 1NG. T: 0870 6000193, F: 0800 7310003, W: www.philipharris.co.uk/education

HSE Books, PO Box 1999, Sudbury, Suffolk, CO10 2WA. T: 01787 881165, F: 01787 313995.

IEE, PO Box 96. Stevenage, SG1 2SD. T: 01438 767 328, F: 01438 742 792, E: sales@iee.org.uk

Instruments Direct Limited, Unit 14, Worton Road, Isleworth, Middlesex, TW7 6ER. T: 0208 560 5678, F: 0208 232 8669, W: www.InstrumentsDirect.co.uk/pasco

Learning and Teaching Scotland, 74 Victoria Crescent Road, Glasgow G12 9JN T: 0141 337 5000, F: 0141 337 5050 and at

Gardyne Road, Broughty Ferry, Dundee, DD5 1NY. T: 01382 443600, F: 01382 443645.

Marl Optosource Ltd., Ulverston, Cumbria, LA12 7RY. T: 01229 582430, F: 01229 580012, E: SaleOpto@optosource.com

Opitec Educational Materials Ltd., 7 West Road, Woolston, Southampton, SO19 9AH. T: 02380446515, W: www.opitec.co.uk

PASCO - see Instruments Direct

Revolution Education Ltd, 4 Old Dairy Business Centre, Melcombe Road, Bath, BA2 3LR. T: 01225 340563, W: www.revolution-education.co.uk

Shaw Scientific Ltd., Greenhills Industrial Estate, Walkinstons, Dublin 12. T: 00353 1 450 4077.

Solar and Wind Applications Ltd., Hannah Research Park, Ayr, KA6 5HL. T: 01292 674033, F: 01292 674133, W: www.solarwindapplications.com

Tech Lab Ltd, LLAY, Wrexham, Flintshire LL12 0PJ T: 01978 853555