

STS

Scope includes
Science,
Technology
and Safety

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One of the better ideas for a Scottish millennium project was for the compilation of a Fourth Statistical Account of Scotland, the third such having been issued over fifty years past. Publication of the fourth is now underway. The following report is taken from the chapter for the Parish of Gladsmuir in the First Account¹. As with most such entries, it was written by the parish minister, a Reverend Mr George Hamilton. It reads:

"Miscellaneous Observations - On the 21st of July 1789, a thunder storm began in the north, and came gradually nearer, having circled round by the west. The school, where above 70 children were then assembled, unfortunately stood in its way. The thunder burst upon the house, and seemed at first to have levelled it with the ground. The walls were rent, the windows shattered, and the roof demolished. A thick darkness, caused by the smoke and dust, for a while concealed the extent of the mischief; when it subsided, the neighbours, who first entered, anxious for the fate of their children, had reason to fear the worst; for few signs of life appeared, the whole crowd of little ones, either stunned or terrified, lay stretched upon the ground, beneath the tables or benches where they sat. Many were quite senseless, but afterwards recovered. Two boys were killed outright, and the master, with many others, much injured.

The present incumbent was not then minister of Gladsmuir, but he has since been at pains to obtain information as to all the particulars of so uncommon an event. The following, amongst others, is singular: Two boys, who were in a separate apartment in the west end of the school, (the thunder came from the west) declared that they saw a ball of fire, which hovered for a few instants over their heads.

There was a sky light in this part of the house; but it was through the tiles, or rather within the roof, as the boys imagined, that the glare of this meteor was seen. They had no apprehension of danger; but were still gazing at it, when it burst with the fatal explosion.

Accidents like this, however, but rarely occur,"

Comment: How up-to-date this account of a natural phenomenon is. It is succinct to the point of sparse. There are no adjectives or adverbs of emphasis, or of melodramatic effect. Nor is there any mention of the supernatural. The usage of the word "meteor" was correct in the 18th century. It then meant any atmospheric phenomenon. This usage continues to this day in the word 'meteorology', whose scope now includes most things atmospheric.

And then there is the conclusion, "Accidents like this, however, but rarely occur". There was nothing more that the man need have said. Firstly he called the event an 'accident', which today we take to mean an unforeseen course of events leading to misfortune wherein blame cannot be attributed². It meets this description. Secondly, there is the reassurance that the accident is unlikely to reoccur. Thirdly, there is the acceptance that the event was natural. If we consider the widespread belief, in times previous, in unnatural events such as those associated with witchcraft, and the re-emergence of such beliefs today, this acceptance is remarkable.

Some presumptions about the educational background of the Revd. Mr George Hamilton are reasonable. He would probably have been an Edinburgh graduate and if so, from the reports of others, would have been strongly influenced by the then Principal, William Robertson (also one time minister at Gladsmuir Kirk). Robertson is renowned as the father of historical writings. A friend of both Adam Smith and David Hume, he was one of the leaders of the Scottish Enlightenment. Hamilton was of his time. He would have had a Scottish education. His report on the storm is a testament to that. We owe it to our children to continue such a tradition of sound education, one grounded in common-sense philosophy and founded on reason.

Footnotes:

1. *First Statistical Account of Scotland, Volume II, The Lothians (1791-1799)*, in the chapter on the Parish of Gladsmuir.
2. Less blame being something we all may wish for in these litigious days.

Science 2020

We were only able to attend the formal sessions on the first day of this recent Scottish three day science (education?) fest. We had a continued presence, though, by way of an exhibition stand shared with SAPS and the recently formed SIBE (Scottish Institute for Biotechnology Education). Thus it was that at the end of each day we could pose that key, Elaine C. Smith, question - "How was it for you, better than a Curly Wurly?" Classroom practitioners were somewhat thin on the ground but one or two were tracked down and so quizzed.

The consensus seemed to be that the programme was a bit over-loaded with 'informal' science education which in turn led to a shortage of time to discuss the issues properly and report the results to the main sessions. There was also a feeling that not enough had been made of home based talents. On the positive side, several respondents suggested that it would be worth doing again, if only to prove that Scottish educationalists can sometimes get it right.

Oops! Nearly forgot, Nicol Stephen the Depute Education Minister also announced ten million pounds worth of Science Strategy funding for education over the next three years - which was nice.

Science Strategy Funding

At the *Science 2020* Conference (March 5th to 7th) more additional funding for school science was announced by Nicol Stephen MSP the Scottish Executive Depute Education Minister. A total of ten million pounds will be distributed over the next three financial years.

The distribution will again be made via the Scottish Local Authorities but will be 'tapered', with five million this coming financial year (2003-04), three million the year after and two million the year after that. The pattern of that distribution will, however, be similar to that of previous years. Knowledge of that earlier pattern or formula makes it a relatively simple arithmetic matter to estimate the various individual Councils' apportionments. Figures based on such calculations are tabulated at the head of the next column. Note that these are not the official SEED figures.

Stirling Biology Meeting

The programme for the 8th Institute of Biology Scottish Biology Teachers' meeting ("Taking Biology Forward"), in Stirling on the 3rd of June, has now been

COUNCIL	ALLOCATION
Aberdeen City	£162,080
Aberdeenshire	£292,126
Angus	£120,350
Argyll & Bute	£106,588
Clackmannanshire	£47,410
Dumf. & Galloway	£179,346
Dundee City	£126,392
East Ayrshire	£121,263
East Dunbartonshire	£115,785
East Lothian	£90,155
East Renfrewshire	£97,010
Edinburgh City of	£307,830
Eilean Siar (W.Isles)	£40,570
Falkirk	£132,385
Fife	£338,240
Glasgow City	£469,065
Highland	£267,340
Inverclyde	£79,545
Midlothian	£83,480
Moray	£97,790
North Ayrshire	£137,165
North Lanarkshire	£318,020
Orkney Islands	£29,332
Perth & Kinross	£140,370
Renfrewshire	£165,965
Scottish Borders	£123,320
Shetland Islands	£35,905
South Ayrshire	£110,685
South Lanarkshire	£299,545
Stirling	£90,435
West Dunbartonshire	£92,845
West Lothian	£161,635
TOTAL	£5,000,000*

*Distribution based on the agreed weighted formula with any error in the total due to roundings or other minor factors.

TABLE 1 Apportionment of additional funds for science education 2003-04

issued to schools and others. If you have yet to see one, an electronic version (pdf format) can be downloaded from the "Events" section of the SSERC website.

The programme looks good (as always) with a keynote address from Prof. Wilson Sibbett, Chair of the Scottish Science Advisory Committee followed by a good mix of other speakers and topics.

For registration contact Peter Anderson (see address list for details).

Chemistry : The Vital Element

The RSC/St Andrews and RSE 7th National Conference for Chemistry teachers will be held in the School of Chemistry at St Andrews University on Friday 30th May. The programme has now gone out to schools and further details are available from, and registration with, Dr Nigel Botting - see address list, back page.

IOP Stirling Meeting

Some further information has been released about the IOP Stirling meeting on Wednesday 4 June 2003. Details should be in schools by the end of March. Topics for the day will include: science policy in Scotland; improving science education 5-14; embedding assessment in learning and teaching; Intermediate 1 as an alternative to Standard Grade science and teaching physics with digital content. See :

www.scotland.iop.org

Exhibition: SSERC hopes to organise an exhibition of physics apparatus for the IOP Stirling Meeting. This will feature a large selection of new apparatus. Wherever possible, the apparatus will be set up in a working context, letting visitors see its performance for themselves.

Human genome chemistry

To mark the 2001 publication of a draft that described the complete chemical makeup of human genes - the human genome as it is often called - the Royal Society of Chemistry (RSC) have published an attractive 48 page booklet outlining the chemical science behind the discovery. The book should interest students and their teachers at post-16 level biology and chemistry. A copy has been circulated to every UK school. If you missed out, extra copies are available from the RSC at £6.50 (members), or £8 (schools).

Chemistry and the human genome Royal Society of Chemistry 2002 ISBN 0 85404 396 9

DNA Anniversary

In turn, SSERC has posted up some key links to websites which have sections celebrating the 50th Anniversary of the discovery of the structure of DNA.

See the SSERC "Events" section at:

www.sserc.org.uk

More Frost on datalogging

Roger Frost has updated his book *Data logging in Practice*, telling you what's worth doing and, just as usefully, what's not worth the candle. Most of us, I guess, will turn to Roger's book to look for experiments on a specific topic we plan to teach. With around 120 experiments in Biology, Chemistry and Physics, this is the most useful compendium we know of in using sensors and dataloggers. Suppliers include ASE Booksales (£17.50).

Roger Frost *Data logging in Practice* IT in Science 2002 ISBN 0 9520257 4 4

UV source: Model risk assessment

The risk assessment on a small, hand-held ultraviolet lamp provides a model on which to assess other lamps.

The optical source is a hand-held UV lamp from Maplin (order code ZC10L) (Fig. 1), supplied by a 6 V battery, with 4 W tube (order code CR48C) (134 mm long by 15 mm diameter), emitting mainly UVA radiation centred between 350 to 360 nm, extending into visible violet radiation.



Figure 1 Hand-held UV lamp from Maplin.

Risks:

1. UVA radiation if incident on the skin is probably carcinogenic to humans (Group 2A carcinogen, i.e. there is limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals).
2. Some people have skin which is extra-sensitive to UV. This condition can be from genetic factors, or brought on by medication or cosmetic applications.
3. If incident on the eye, the cornea transmits UVA. The lens absorbs strongly, allowing the rest (about 1%) to reach the retina. There is a risk of cataract formation. Chronic exposure prematurely ages the lens. The retina can be damaged by violet or blue radiation (380 to 550 nm) producing lesions. The threshold for this effect,

called 'blue-light photoreinitis' depends jointly on light intensity and exposure period.

Risk assessment:

There are no legal limits controlling exposures to UV radiation, whether in the workplace, or elsewhere. There are however action levels for UV radiation from the Proposed CEC Physical Agents Directive; they are tabulated below. In the absence of legal limits, these are considered to be the *de facto* limits to apply. Halve the values for children.

The lamp's input power from a 6 V supply is 2.1 W. Assuming 60% efficiency and treating the source as being a rectangular surface 134 mm x 15 mm, the radiant exitance is 600 W m⁻².

At the distance of closest viewing (150 mm) the irradiance on the eye would be about 7 W m⁻². Direct viewing for 12 min would exceed the EC Action Level. Because the risk of photoreinitis is a threshold effect, brief exposures of the eye to the lamp's radiation are unlikely to be harmful.

To find the effective irradiance on the skin, the radiant power is reduced by a factor of 0.0002 from 1.2 W to 0.24 mW to adjust for the effect of UVA on the skin. The EC Action Level for skin would be exceeded in 2 min were the lamp in contact with the skin, and in 3 hr at a distance of 150 mm.

We conclude that it is reasonably foreseeable that either action level would be broken from use by children. Therefore they should not work with the lamp unless there are engineering controls limiting irradiation of the skin. The light box described on page 7 of this issue reduces irradiation to a very low level. Children can use this light box quite safely with supervision.

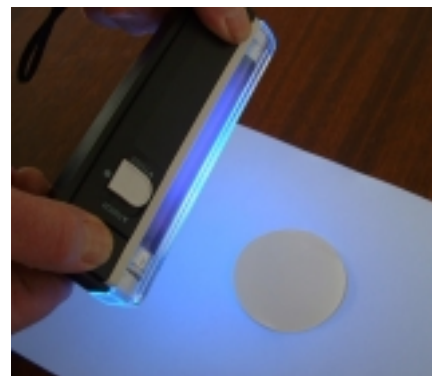


Figure 2 Lamp can safely be hand-held by a responsible person. In this example, the lamp is pointing away from the user at 2 types of paper: a circular sheet of filter paper lying on top of an A4 sheet of photocopying paper. The latter fluoresces strongly.

Considering use by a responsible person, where we presume that no one is directly irradiated except for some occasional, brief handling of specimens at a distance of about 6" (150 mm) from the source, no engineered controls would be needed. The risks are negligible.

It follows that teacher demonstrations with the lamp are OK (Fig. 2) provided that no one is directly irradiated except for hands and that exposures to the hand are reduced as far as practicable.

Details of this risk assessment, with measurements, evidence, assumptions and calculations, are being placed on our website. We are grateful to NRPB for checking and commenting on the assessment.

Other lamps

Risk assessments on other UV lamps will be placed on our website.

Wavelength (nm)	Action level	Protection
180-400 (UVR)	15 J m ⁻² effective (8 h)	Skin (and eye below 315 nm)
315-400 (UVA)	5 x 10 ³ J m ⁻² (8 h)	Eye

Table 1 Action levels for UV radiation from the Proposed CEC Physical Agents Directive.

Metalworking fluids revisited

Following our mention of new guidance on metalworking fluids by the HSE in the last issue we understand from CLEAPSS that the HSE took a pretty cautious line. The main fear is that cutting oils might become contaminated with used lubricating oils and only then might therefore pose a cancer risk.

Electrical safety: Working with HT supplies

The likelihood of being hurt by an electric shock depends on the magnitude of the current the energy source can deliver as well as voltage, capacitance and environmental conditions. The HT power supply is capable of delivering a fatal shock. Special precautions are required to prevent harm.

The risk of harm from an electric current flowing through the body depends on many factors [1] including:

- Magnitude of current
- Current path
- Duration
- Environmental conditions
- Nature of current (ac or dc, frequency)

Some of these factors are inter-related. For instance current magnitude depends, to a certain extent, on the path taken by the current through the human body, skin contact area, tightness of grip, dryness of skin, cuts, etc. Physiological harm is unlikely if current doesn't exceed the values in Zone 2 of Table 1. However, to be completely safe, electrical systems should be engineered such that bodily currents cannot exceed the values in Zone 1.

In normal, indoors, dry conditions, provided that voltage levels don't exceed 33 V ac rms, or 70 V dc (ripple-free), any current that the human body might conduct should lie safely inside Zone 1, but in wet conditions these voltages should not be considered safe (Table 2).

The term 'hazardous live' is useful for denoting an electrical system whose voltage levels exceed 33 V ac rms, or 70 V dc (ripple-free), and are capable of delivering a current in excess of 0.5 mA ac rms, or 2 mA dc (ripple-free) respectively. Some high voltage power supplies don't fall into the hazardous live regime because their outputs are current limited.

Educational power supplies are generally classified as LT, HT, or EHT, depending on their voltage outputs and whether or not they are current limited (Table 3). In normal, dry conditions, the output from an LT supply would not be hazardous live – not unless it was stepped up by a transformer, or by some other inductive means. The outputs from some EHT supplies are current limited at 2 mA dc – they, too, would not be hazardous live. Other EHT supplies are current limited at 3 mA or more, 5 mA being the upper limit. Whilst these outputs are hazardous live, they are only just over the Zone 2 lower boundary. They are unlikely to harm anyone from a shock.

Zone	Physiological effect	Current	
		ac (or dc unsmoothed)	dc (ripple-free)
1	Usually no reaction effects	<0.5 mA	<2 mA
2	Usually no harmful physiological effects	<10 mA	<30 mA
3	Likelihood of muscular contractions	<30 mA	<120 mA
4	Probability of ventricular fibrillation	>30 mA	>120 mA

Table 1 The 4 zones of risk for a current path from the left hand to feet for a duration of 10 s or more. Some zone limits extend to higher values for shorter periods of current-flow.

Environmental condition	Safe limits for steady-state voltage	
	ac (or dc unsmoothed)	dc (ripple-free)
Normal, dry conditions	33 V rms	70 V
Wet conditions	16 V rms	35 V
Immersed condition	0 V	0 V

Table 2 The steady-state voltage limits for safe working dependent on environmental conditions. The ac frequency range holds for 15 Hz to 100 Hz.

Power supply type	Voltage output	Current output	Hazard
LT (Low Tension)	33 V maximum	Unlimited Unlikely to exceed 10 A	Generally no risk of electric shock except in applications with inductors. Risk of burns or fire.
HT (High Tension)	Generally 400 V maximum	Unlimited Maximum values typically lie between 80 mA and 400 mA	Hazardous live. Risk of electrocution
EHT (Extra High Tension)	5 kV	5 mA absolute limit Typical maxima are 2 mA or 3 mA	Either outwith, or just inside, the hazardous live regime. Risk of harm is unlikely.

Table 3 Power supplies are classified by their electrical outputs and the hazards presented.

The only power supply type that clearly presents a risk of electrocution is the HT power supply. These have quite limited application:

Subject Application requiring an HT supply

Biology Electrophoresis, DNA separation and protein analysis

Chemistry Electrophoresis
Excitation voltages of argon and xenon with thyatron valves

Physics Teltron Fine Beam tube
Teltron Critical Potentials tube
Neon lamp excitation

Control measures

If working with an HT supply, or indeed hazardous live in general, the following control measures should be taken, where appropriate:

Engineered:

- Shrouded socket outlets on HT supplies
- Shrouded terminals on apparatus
- Enclosure of HT conductors in apparatus
- Leads with shrouded connectors
- Meters with minimalist features

Administrative:

- Warning notice on HT power supply
- Pupils under 16 years or S5 must not work with HT circuits
- Instruction given to senior students on HT working arrangements
- Warning notice placed beside HT circuit

Until very recently, it was common to find that unshrouded socket outlets had been fitted to HT or EHT power supplies (Fig. 1). Either these should be replaced with shrouded sockets, or converted by overfitting with a 4 mm shrouded socket adaptor (Figs. 2 and 3). The latter is easier to accomplish and does not require opening the apparatus and making internal changes.

Socket adaptors are available from Farnell (type MC, 462-858, £2.75 for 2 with allen key) and Rapid Electronics (type PJP, 17-1605 at 60p, allen key also needed).

An electrophoresis kit recently brought out by Griffin shows the danger that can occur with unshrouded HT connectors. The apparatus (Fig. 4) has guarded but unshrouded sockets accessed through



Figure 1 An example of an HT power supply with unshrouded 4 mm socket outlets.



Figure 2 Showing fitment of 4 mm shrouded connectors over unshrouded socket outlets.



Figure 3 4 mm shrouded connectors. The Allen key is used to turn a screw in the base of the socket, which tightens the fitment.



Figure 4 Plugging into the Griffin electrophoresis kit.

holes in a clear, acrylic, top panel. Although this design prevents the operator from touching the conducting part of the 4 mm plug while it is being inserted or removed, it does not prevent contact at other times. The system is not fail-safe. It is therefore dangerous.

Teltron tubes

Teltron tube electrodes were originally unshrouded. Connecting plugs to these could be dangerous (Fig. 5).



Figure 5 Presenting a stackable, unshrouded, 4 mm plug to an unshrouded electrode on a Teltron tube.

Teltron have overcome this danger by engineering a clear plastic collar to fit over the electrode. The user connects to this electrode with an in-line, 4 mm, free-socket outlet¹ (Fig. 6).



Figure 6 A Teltron electrode protected with its shroud, with a connecting lead through an in-line, 4 mm, free-socket outlet.

Teltron supply shrouds to cover electrodes at £2.50 for a pack of 6. They also supply a red-coloured lead, 75 cm long, with an unshrouded plug at one end and a free-socket at the other (part no. 2500/1, price £6.97). For orders from Scottish schools for this part number, they will include 2 shrouds per lead at no extra charge.

¹ As an aside, if 2 or more connectors were to be stacked together at a Teltron tube electrode, the torque on the electrode can be excessive, leading to breakage. Any stacking of conductors should be done at the power supply.

However this lead would be safe only with a Teltron power supply. With other makes of power supply, the power supply end of the lead should be terminated with a stackable, shrouded plug. Free-sockets are stocked also by Farnell (496-110) at £2.94 and Rapid (17-2460) at £1.40.

Until fairly recently, the operating instructions issued by Teltron have not mentioned earthing in the text, nor drawn any connection to earth in circuit diagrams. However the Nuffield Physics Guide suggests earthing some point in the circuit, adding that where the electron beam is used after it has passed through the anode, it is best to earth the anode. No doubt some users will earth their circuits, perhaps making an arbitrary choice on whether to earth the anode or cathode. In their revised operating instructions, issued within the last decade, Teltron recommend earthing the anode in most instances. If this is done, then both the cathode and heating coils sit at negative, hazardous voltages. This means that the 6.3 V heater supply terminals on the power supply and at the rear of the tube also have to be protected with 4 mm shrouded connectors (Fig. 7).

We summarize by stating that every Teltron connector and every socket outlet on an HT, and also, preferably, EHT, supply should be protected with shrouded connectors.

If the EHT positive outlet is earthed, as both Nuffield and Teltron suggest, then a potential difference of at least 5 kV can develop across the heater supply's isolating transformer, putting its insulation under stress. Some models mark the 6.3 V supply 'Insulated for EHT'; or words to that effect. A check through product



Figure 7 Teltron tube rear sockets adapted for shrouded connectors. In this example, because of insufficient clearance, only 2 sockets can be protected. The red adaptor should be repositioned according to needs.

catalogues from the 1980s and 90s confirmed that this specification is widespread.

We do find that the insulation of 4 mm sockets can fail if one of the EHT terminals is earthed. Breakdown is announced by a zitting sound typical of a high voltage discharge and either the collapse or limitation of voltage. If this happens, the system fails to a safe condition: it is not dangerous. If it occurs during a demonstration, limit the EHT voltage to 3 or 4 kV. Afterwards, the sockets should be replaced with best quality new ones, but because they are rated to 1000 V only (continuous operation), or 6 kV (50 μ s), they can be expected to break down eventually.

Meters

When meters are used in HT circuits, the meter should have shrouded sockets and a suitable voltage rating. The standard design of digital multimeter, even although it may be rated to 1000 V dc or 750 V ac, is quite unsuited for use in circuits at hazardous live because the user has too many selections to make. Most of us make mistakes with multimeters. If current were to be selected instead of voltage and if an incorrect pair of sockets were to be used, then the user is in danger. Unlikely though such a combination of errors may seem, the frequency of complaints we get from schools on the incidence of blown multimeter fuses shows that these mistakes happen often enough – if safely, because of low voltages (see page 15).

High voltages up to 600 V can be measured safely with a digital multimeter with minimalist features, like the one shown (Fig. 8). These features are:

- 2 sockets, and not more
- shrouded sockets
- high input impedance for each type of measurement (voltage, resistance and continuity)
- no low impedance input (no facility for measuring current)
- autoranging, which minimizes switch settings
- very few switch settings
- enhanced electrical insulation

Related to the meter is the GS38 lead set¹:

- shrouded connectors
- robust, flexible, well-insulated leads

¹ So named after its specification in the HSE Guidance Note GS38 'Electrical test equipment for use by electricians'.



Figure 8 Electrician's digital meter, to show its minimalist features.

- HBC fuses and/or current limitation
- finger barrier preventing fingers slipping on to live conductors
- minimum of exposed metal at tips

Suitable, minimalist meters for measuring up to 300 V and 600 V are the Fluke 7-300 and 7-600, available from Farnell, Rapid and RS. The Farnell prices at £44 and £56 are the lowest (stock items 768-765 and 768-777). A GS38 lead set from Farnell (676-421) costs £31.90.

If there is a need to measure current at hazardous live, then either modify an analogue ammeter by fitting shrouded sockets and, if necessary, closing the back, or assemble your own meter by getting a moving coil meter from Rapid, fitting it to an enclosure and adding shrouded sockets.

Risk assessment and summary

Where your risk assessment indicates that conductors might be at hazardous live, then the range of control measures listed above should be applied as appropriate. Please always look for an engineered solution: administrative control measures are not fail-safe because they depend on human behaviour.

The results of any risk assessment and the actual controls that should be devised are going to depend on the peculiarities of the apparatus to be used. We have given you some examples above to follow: wiring Teltron tubes and working with meters. Directly instructive also are our arrangements for powering a neon lamp, to be found in the article on flashguns in this issue (pages 9-10).

Reference

- 1 Preventing electric shock Bulletin 173 SSERC 1992

Ultraviolet lightbox

We describe the design and construction of an ultraviolet lightbox allowing children to observe fluorescence in reasonable safety.

The design is for the Maplin UV lamp reported on on page 3. It may not be safe with other lamps. Details are shown in the illustrations (Figures 1-4).

The overall dimensions are:

- Width = 240 mm
- Depth = 230 mm
- Height = 180 mm

The panels are 6 mm MDF, but plywood would also suffice. These are held together with an inner framework of 10 mm square battens pinned and glued. There is a stouter batten, 40 x 15 mm, at the top rear for additional strength, which provides a lip for carrying. The removable top panel, 227 x 145 mm, rests on horizontal rails 110 mm above the box floor. Two home-made brackets made of folded aluminium sheet hold the ultraviolet lamp. Clearance between floor and lamp is about 55 mm. A block mounted on top serves as a lifting handle. There is a 70 mm gap between top and front panels through which the box floor can be viewed. The front panel, 214 x 185 mm, slides in grooves rebated into battens down either side of the box front. All surfaces have been painted with matt black to reduce direct reflections.

The design allows the top panel to be removed to operate the lamp (Fig. 1). By raising the front panel, the student can access the box floor to place or rearrange specimens in the UV radiation (Fig. 3). These can be viewed for fluorescence through the gap between the top and front panels (Fig. 4). The design prevents any direct viewing of the lamp except when it is removed to switch on or off. Because of the matt black interior, fluorescence can be clearly seen even when the lightbox is used in subdued daylight (Fig. 4).

A stronger, and therefore longer-lasting, box should result if the front panel were fixed in place instead of having it slide up and down. We understand that UV lightboxes with fixed front panels are available from Schools' Laboratory Equipment at £12.50.

With such a lightbox, ultraviolet fluorescence can be safely viewed from a variety of specimens (Table 1).



Figure 1 Lightbox interior with front panel removed and lid upturned showing Maplin lamp secured with aluminium brackets.

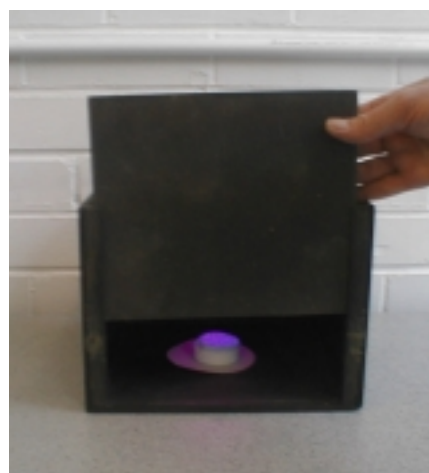


Figure 3 By lifting the front panel, specimens can be placed or rearranged in the radiation.



Figure 2 Front panel removed showing a fluorescing specimen (washing powder tablet).



Figure 4 The proper viewing position showing the specimen through the gap between the top and front panels.

Sample type	Fluorescing specimens
Biological samples	e.g. transformed <i>E.coli</i> colonies from the Bio-Rad Transformation Kit
Chemical reagents Analytical result	Anthracene ¹ Chromatograms
Geological samples	Calcite Fluorspar
Manufactured articles or substances	Bank notes, postage stamps Highlighter pen ink, security mark Photocopying paper Vaseline Washing powder

Table 1

Examples of fluorescing specimens which can be used with the light box.

¹ Anthracene is a possible carcinogen. It should be kept in a sealed Petridish for viewing fluorescence in UV radiation.

New WPA colorimeter

The recently introduced Colourwave colorimeter from WPA (model CO7500) passes our tests with flying colours.

In the Equipment notes of Bulletin 198, we reviewed colorimeters from Griffin, Philip Harris and WPA, and recommended the WPA CO75 as the *Best buy overall*. Since then, WPA have produced the *Colourwave* CO7500, which they describe as being designed with student users in mind and as a 'natural' successor to the CO75. In this article we review of the CO7500 (priced at £295) and compare it with the CO75 to see if the manufacturer's claims are justified.

Description

The CO7500 (Fig. 1) is smaller, lighter and more modern looking than its predecessor, the CO75. It is well designed, reasonably robust, easy to use and is supplied with a low voltage, external, plug-top, power supply (also available, but not tested, is the CO7500B which can be powered by NiMH batteries or mains electricity).

The instrument case is made of light grey plastic with controls, screen and cuvette socket (with drainage hole) situated in an almost circular panel on the top of the colorimeter.

Eight gelatin filters are supplied (440, 470, 490, 520, 550, 580, 590, 680 nm), fixed in place in a filter wheel which can be turned clockwise or anti-clockwise to alter the wavelength. This makes for easy use and reduces the likelihood of the filters being damaged or lost.

The cuvette holder accepts either 10 mm pathlength cuvettes or 16 mm diameter test-tubes.

A drainage hole is provided in the base. The colorimeter is supplied with a set of



Figure 1 WPA CO7500 colorimeter.

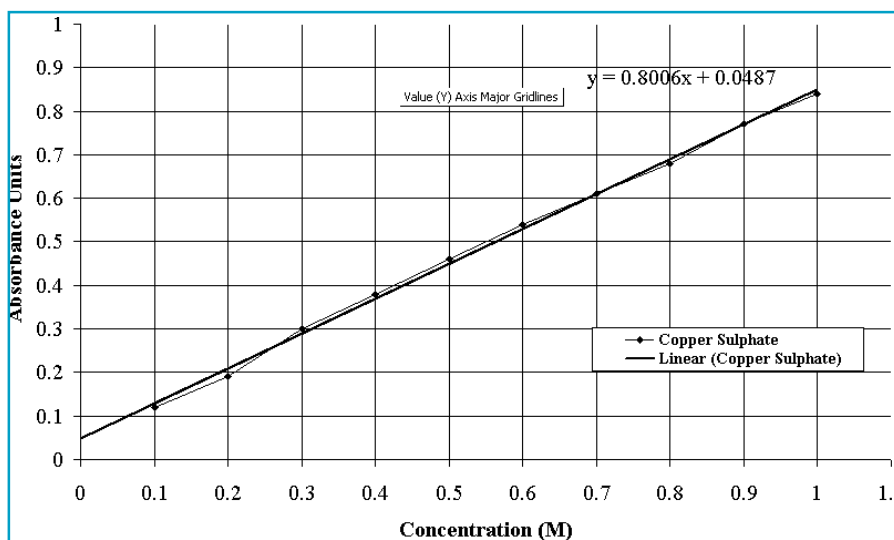


Figure 2 Test results: absorbance versus concentration for copper sulphate.

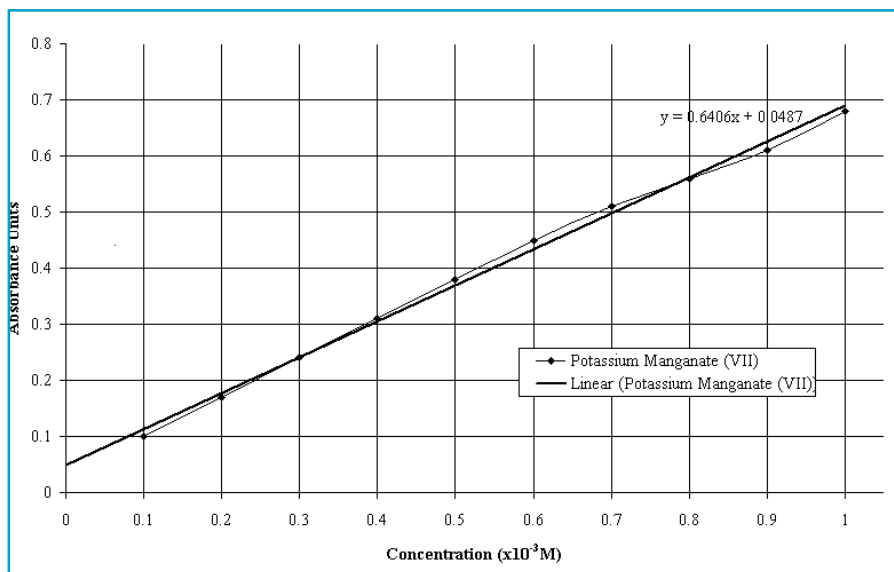


Figure 3 Test results: absorbance versus concentration for potassium manganate(VII).

ten 10 mm square plastic disposable cuvettes. These are for use with aqueous solutions only and are not suitable for use below 300 nm.

Performance

A series of known concentrations of KMnO_4 and CuSO_4 were accurately prepared, their absorbances measured and plotted against concentration. The best straight-line fit in each case was calculated and drawn (Figures 2 and 3). A straight-line, direct relationship between absorbance and concentration should result. Any deviation from a straight line

suggests optical or other defects in the instrument. For this instrument, the maximum errors observed were in the order of 0.02 absorbance units for both the copper sulphate (Fig. 2) and manganate(VII) (Fig. 3) tests.

The control panel is well organised and the transmission mode and automatic zero adjustment are features not found on the previous model. This instrument can easily perform all the basic functions required of a school colorimeter. Our only minor concern with the CO7500 is the possibility of liquid accumulating in the

recessed display and wavelength indicator areas of the instrument.

A comparative performance against its predecessor, the CO75, shows that the CO7500 scores at least as well on all counts (Table 1). Our overall assessment is A – most satisfactory for use in Scottish courses.

Conclusions

So is the CO7500, as the manufacturer claims, the 'natural' successor to the CO75? Well certainly its ease of use, smaller footprint, extra features and equivalent price to its predecessor makes it difficult to disagree. As part of the test programme, we field tested this instrument with a group of PGCE students on a practical training course and both the trainers and students found it simple to use and were more than happy with the results obtained.

Colorimeter	Design	Operation	Performance	Electrical Safety	Assessment
CO7500	A	A	A	A	A
CO75*	A	A	A	A	A

Table 1 Colorimeter assessment summary.

The ABC rating in general stands for: A Good B Fair C Poor

*from Bulletin 198

The CO7500 is an easy to use instrument, which should be more than able to perform the tasks required of a school or college laboratory colorimeter. It is well-designed and suitably robust, giving a very good performance in all the tests we subjected it to. At £295 it represents good value for money and appears to us to be a worthy successor to the CO75.

Suppliers include Griffin and Scientific & Chemical (S&C) as well as the manufacturer, Biochrom (WPA were taken over by Biochrom, who continue to use the name 'WPA' as a trade mark on scientific instruments).

Uses of capacitors: the photographic flash

Activity 14: HG Physics: Electricity and Electronics: Student Material

This note offers corrections to the information and instructions, and guidance on how the activity can be done safely.

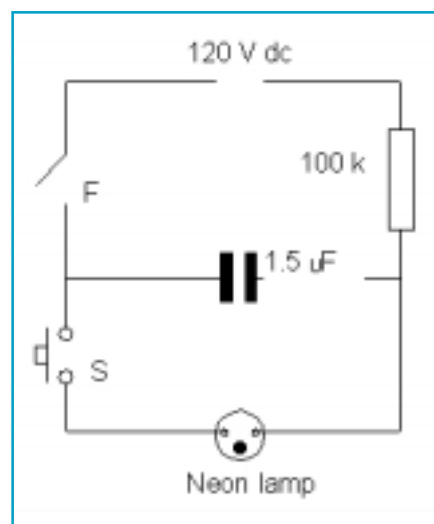


Figure 1 Original model photographic flash circuit from HSDU Student Material.

At the core of this activity, there is a circuit diagram (Fig. 1) purporting to model a photographic flash. But as with any model, only certain parts are analogous to the real thing. The neon lamp models the xenon tube. The capacitor stands for itself. The 120 V dc power supply stands for the low voltage battery. Herein the model breaks down and becomes nonsensical. Given an HT supply in the circuit, you

don't need the capacitor to light the neon. Furthermore, with a time constant of 0.15 s, the capacitor charges rather faster than in any flashgun we have encountered.

In an actual flashgun, the energy source is typically a 6 V battery. This drives an electronic oscillator which, because of an inductor in its circuit, generates a high voltage and causes a large value capacitor to charge up, its final voltage being nearly 300 V. There is an audible note rising in pitch to 10 kHz or more from the oscillator during the charging period. When the capacitor is fully charged, a neon indicator lights. When the camera shutter is depressed, the capacitor discharges through the xenon tube, which flashes brilliantly. In one flashgun we have dismantled, the capacitor value is 320 μF, with a rating of 350 V.

Turning to Activity 14, some sense of the model can be found if the following sequence is used:

1. Close Switch *F*, letting the capacitor charge up.
2. Open Switch *F*, disconnecting the HT supply.
3. Close Switch *S*. The capacitor discharges through the neon, causing it to light up for about 0.2 s.

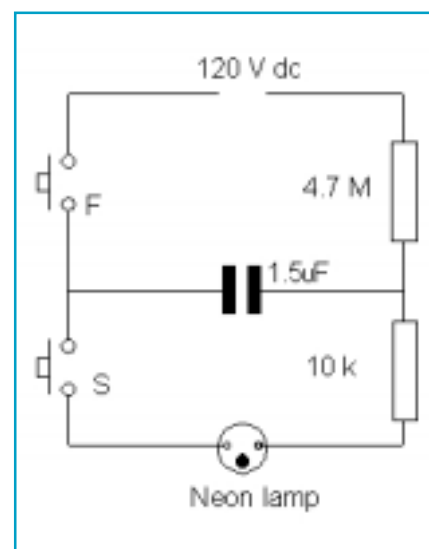


Figure 2 Modified model photographic flash circuit.

We have made three changes to the circuit, the amended one being shown in Figure 2.

Firstly, because the striking voltage of a neon lamp is around 90 V, a 10 kΩ resistor should be connected in series with the lamp protecting it from overvoltage and overcurrent. Without this series resistor,

the neon emits pale violet radiation instead of its usual orange-red coloration when lit, indicating that it was under stress.

Secondly, the value of the resistor bearing the charging current has been changed from 100 k Ω to 4.7 M Ω , raising the time constant of the charge cycle to 7 s, which you may feel is a more realistic value.

Thirdly, switch *F* should be a momentary action type so that it is open when the capacitor is discharged through the neon.

Finally, for added value, if both switches are held down, the neon flashes continually with a period of about 2.3 s at a 120 V supply voltage. The circuit oscillates.

Safety

As discussed in the *Safety Notes* section of this issue, the energy source, an HT power supply, is capable of delivering current at high voltage sufficient to cause



Figure 3 Finished circuit appearance.

Part	Specification	Supplier	Part no.	Price
Enclosure	High impact resistant polystyrene case, height > 40 mm	Farnell	279-195	£8.68
Switch	SPNO momentary. Voltage rating: > 250 V	Farnell	519-327 (Red) 519-352 (Yellow)	£4.27
Neon	Clear bezel. Voltage rating: 100-130 V ac. With integral series resistor	Farnell	140-012	£1.41
Capacitor	Non-polarized, polypropylene. Voltage rating: 250 V ac. 1.5 microfarad	Farnell	303-9274	£1.11
Resistor	4.7 Megohm, ¼ W 10 kilohm (included with neon)			
4 mm Shrouded Socket	Screwmount	Farnell	462-883 (Red) 462-895 (Black)	£4.96 (pack of 5)
4 mm Shrouded Plug	Stackable	Farnell	269-396 (Red) 269-402 (Black)	£8.56 (pack of 5)

Table 1 Parts list for model photographic flash circuit.

electrocution. To prevent danger, the circuit must be enclosed within an adequate box, designed to Class 2 standard of construction. Terminals on the box and power supply must be shrouded. Leads must be fitted with shrouded plugs. Suggested parts are given in Table 1. Its finished appearance can be seen in our photograph (Fig. 3).

If the apparatus is built with these components to Class 2 standard of construction, then it should be adequately safe for senior pupils to work with under

instruction and supervision. Students should be told of the risks of working with unshrouded connectors. The circuit can withstand an overvoltage of 350 V, or reverse polarity. Should the charged capacitor be discharged across a student, the 4.7 M Ω resistor limits the current to a very low value.

Anyone servicing the circuit should be aware that the pd across the capacitor is about 70 V after the neon has struck. The capacitor should be discharged safely before being touched.

Composition of inspired and expired air

A simple experiment to investigate the amounts of oxygen and carbon dioxide in inspired (i.e. atmospheric) air is described in this article.

We pointed out in Bulletin 202 that CASE materials¹ do not mention that alkaline pyrogallol is hazardous. Below is a method whereby this reagent can be handled safely by pupils in S1 or S2 to investigate respiration. Other curricular contexts include Photosynthesis (Standard Grade Biology) and analyses of air samples of expired air before and after exercise.

¹ CASE Activity 14, *Combinations*, Teacher's Guide.

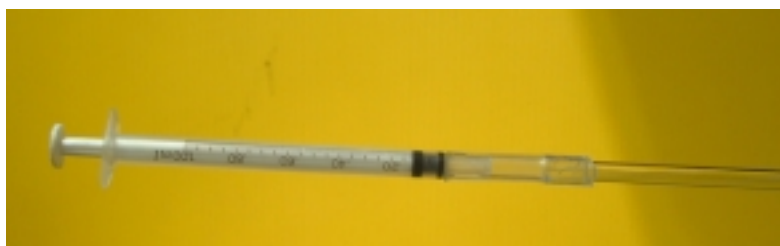


Figure 1 Capillary tube, syringe and connecting PVC tubing.

Method

The system consists of a straight 30 cm capillary tube, 1 mm bore, 1 ml syringe and small piece of PVC tubing about 3 cm long, and can be seen in the photograph at the foot of the preceding page (Fig 1).

A sample of air is drawn into the capillary tube by means of the syringe. The volume of air is noted. Potassium hydroxide is then introduced into the tube absorbing any carbon dioxide present and causing a decrease in the volume of air. This new volume is noted. Aqueous pyrogallol then drawn into the tube is made alkaline and absorbs any oxygen present, causing the air column in the capillary tube to decrease in volume once more. This new volume is noted. From these results the percentage of carbon dioxide and oxygen in the air sample can be calculated.

Materials required

Apparatus: 1 cm³ syringe; capillary tubing, 30 cm length, 1 mm bore
PVC tubing, 3 cm approx.

4 McCartney or Universal bottles

Materials: 4M KOH *Corrosive*

25% w:v Benzene-1,2,3,-triol (pyrogallol, pyrogallic acid) *Harmful*

1M Hydrochloric acid *Irritant*

Food colouring

Propanone *Highly Flammable*

Procedure

Wear eye protection and pvc gloves.

- 1) Ensure apparatus solutions and samples are at room temperature.
- 2) Fit the capillary tubing, PVC tubing and syringe as in the photograph (Fig. 1).
- 3) Label four bottles appropriately with water, potassium hydroxide, pyrogallol and dilute hydrochloric acid (Fig. 2).
- 4) Using the syringe carefully draw a column of water about 5 cm in length into the tube (Fig. 3).



Figure 2 Bottled reagents.



Figure 3 Apparatus set up ready to draw in or expel liquid reagents.

- 5) Remove the tube from the water and draw about 10 cm of air into the tube. Wait for at least one minute. Do not handle the part of the tube where the air is located.
- 6) Expel all but about 1 cm³ from the end of the tube and then draw 4M KOH into the tube. Keeping the end of the tube in the hydroxide solution carefully shuttle the hydroxide up and down the capillary about six times to allow the air sample to come in contact with the hydroxide. Wait for a minute and re-measure the length of the air column. The decrease should be negligible and difficult to measure.
- 7) Expel all but the last 5 cm³ of the hydroxide and draw in pyrogallol. Keeping the end of the tube in the pyrogallol shuttle slowly back and forward as before but never expel the last 5 cm³ of the hydroxide. The pyrogallol will react with the potassium hydroxide in the tube

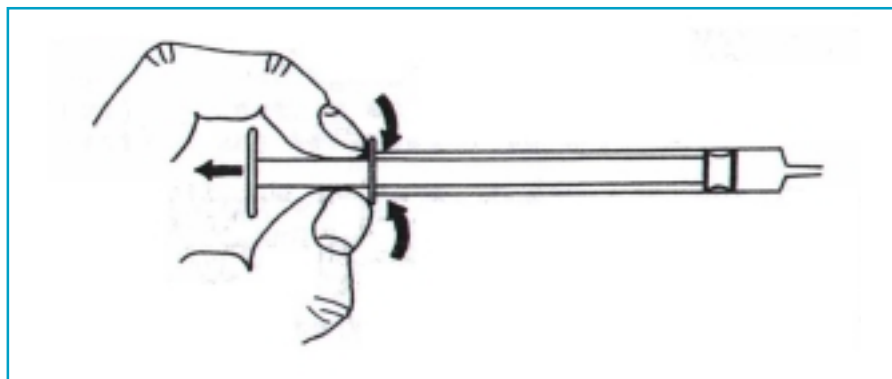


Figure 4 Showing syringe with recommended grip.

forming pyrogallate, which will absorb oxygen from the air sample. After a minute measure the length of the air column.

- 8) At least three samples of air should be analysed and the average taken.

Calculations

$$\text{Percentage of CO}_2 \text{ in the air sample} = 100(a - b)/a$$

$$\text{Percentage of O}_2 \text{ in the air sample} = 100(b - c)/a$$

a = original length before KOH was admitted

b = new length after KOH admitted

c = new length after pyrogallol admitted

Tips

- a) Cleaning capillary after use:

Rinsing is carried out by drawing the liquid into and out of the tubing by means of a syringe:

- 1) Rinse tube in cold water.
- 2) Rinse tube in dilute sulphuric acid.
- 3) Rinse again in cold water.
- 4) Rinse in hot water containing detergent such as Decon 75 or Byprox.
- 5) Rinse again in cold water.
- 6) Rinse in propanone.
- 7) Hang vertically to dry.

- b) Manipulation of syringe: Many people – particularly young pupils – find it difficult to move the syringe plunger sufficiently delicately to prevent the gas bubble either from disappearing into the syringe barrel or from being ejected from the open end of the tubing. To overcome this problem the grip shown in the diagram (Fig. 4) is recommended.

If the finger and thumb are squeezed inwards, in the direction indicated by the curved arrows, the plunger is pulled gently outwards and is under complete control. For movement in opposite direction the plunger is pushed in, using the finger and thumb as stops against the top of the barrel. In both cases, extended movement in one direction will require adjustment of the position of the finger and thumb on the plunger from time to time.

- c) A small amount of food colouring in the water can help with the capillary measurements.
- d) An easy way to measure readings is to mark the capillary tube with a marker pen, lie it on a piece of graph paper and count boxes or squares to the nearest millimetre.

Advantages

- a) Small amounts of reagents are used.
- b) Pyrogallol and potassium hydroxide are mixed *in situ* in the middle of the assay. There is therefore no need to store alkaline pyrogallol under liquid paraffin to exclude air (see Bulletin 202).

Reference

- 1 *CASE Materials, Safety Notes, Bulletin 202, SSERC, 2001.*

Constant humidity solutions

Methods for setting the relative humidity of air, required in SAPS 'ELISA' and Botrytis protocol, and other applications.

We have sometimes been asked for ways of providing atmospheres of known humidities for a variety of applications such as the SAPS 'ELISA' and *Botrytis* protocol. These can be obtained by having the airspace enclosed above solutions of known concentrations of a variety of solutes. This can be arranged in two ways, by having either (i) a range of saturated solutions of different solutes (Table 1) or (ii) a range of different concentrations of the same solute (Table 2 shows this for three solutes).

As the mole ratio of a solute increases, that of the water decreases and there will

be a lowering of the vapour pressure of the solution. The vapour pressure of a solvent or solution can be thought of as a measure of the escaping tendency of its solvent molecules. Thinking of this another way, if there are fewer water molecules in the solution then there will be fewer escaping from the liquid phase into the air above and they will contribute less to total pressure of that airspace, making it drier. It might be expected that this relative lowering of vapour pressure would be directly proportional to the molality as per Raoult's Law. This would only be the case at very dilute solutions where solutions behave ideally. However, even at the high concentrations used, it can be seen to be very roughly true.

Several of the substances listed in Table 1 are dangerous to the environment and there will obviously be a disposal problem afterwards, especially if they have been used on a largish scale. Unless really necessary it might be a good idea to especially avoid the use of those marked with an asterisk. Consult the SSERC *HazChemManual* for disposal methods if

required. The nitrite can be converted to harmless nitrogen gas. Alternatively the salts can be recovered by evaporation for use again.

Saturated solution	Relative humidity (%)
Lead(II) nitrate *	98
Sodium carbonate-10-water	92
Potassium chloride	86
Ammonium sulphate	80
Sodium chloride	76
Sodium nitrite *	65
Ammonium nitrate	63
Calcium nitrate-4-water	55
Potassium thiocyanate	47
Zinc nitrate-6-water *	42
Calcium chloride-6-water	35
Potassium ethanoate	20
Lithium chloride-1-water	15

Table 1 Relative Humidity in air above the following saturated solutions in a closed vessel at 20 °C.

Relative humidity (%)	Sulphuric acid	Sodium hydroxide	Calcium chloride
100	0.00	0.00	0.00
95	11.02	5.54	9.33
90	17.91	9.83	14.95
85	22.88	13.32	19.03
80	26.79	16.10	22.25
75	30.14	18.60	24.95
70	33.09	20.80	27.40
65	35.80	22.80	29.64
60	38.35	24.66	31.73
55	40.75	26.42	33.71
50	43.10	28.15	35.64
45	45.41	28.15	37.61
40	47.71	31.58	39.62
35	50.04	33.38	41.83
30	52.45	35.29	44.36
25	55.01	37.45	-
20	57.76	40.00	-
15	60.80	43.32	-
10	64.45	47.97	-
5	69.44	-	-

Table 2 Relative humidity above three aqueous solutions at 25 °C. Concentrations are expressed as percentages of anhydrous salt in solution by weight.

Finding Planck's constant with LEDs

A value for Planck's constant can be found by plotting the forward voltage across a series of LEDs versus the frequency of radiation. Though simple in execution, the method is flawed.

Theory and method

Let V be the forward voltage across a LED that is emitting radiation and e be the electronic charge. The method presumes that if work eV is put into an atom causing an electron to jump from its valence to conduction band then when the electron returns to the valence band energy is emitted in the form of a photon whose energy is hf where h is Planck's constant and f is the frequency of radiation emitted. The experimenter measures the forward voltage across a set of different coloured LEDs. By plotting a graph of forward voltage against frequency it should turn out if this simple model is correct that the relationship is linear. The gradient then should be h/e . If the value of e is known, the value of h can be derived.

The method can be tried out with apparatus supplied from Lascells (*Photon Energy Array*) or Philip Harris (*Planck Experiment*), or home-made circuits. The applied voltage is controlled by a pot across a 5 V supply. There should be a resistor and possibly also an ammeter in series with the LED. Forward voltage should be measured with a multimeter directly across the LED.

The size of the forward voltage is dependent on the forward current. At its threshold, when a LED is only just emitting light, V might be around 1.5 V at 0.1 mA. Then when the current is increased to 20 mA, V might have risen to 1.8 V. Which value should you take? Or should you use a sub-threshold voltage at 1 μ A, or 1 nA? One common method is to measure V for 2 or 3 high current values, lets say 10 mA and 15 mA, fit a straight line through an I - V plot and extrapolate back to the voltage axis. The value of V to use is the point on the axis cut by this line, which is effectively a tangent to the I - V plot.

Results

The experiment has been tried out with apparatus from Lascells and Harris, and with home-made arrays of LEDs. Three ways of getting forward voltage have been tried:

- Tangent method whereby a tangent fitted to the V - I curve at high current values is extrapolated to cut the voltage axis as already described.

- Switch-on voltage method where the LED just starts emitting light.
- Constant current method where all the LEDs are driven at the same current and the resulting forward voltage is used in the analysis.

None of the ways gives good results. Two graphs are shown for illustration: the tangent method with the Lascells kit (Fig. 1) and the constant current way with home-made circuits (Fig. 2). The following patterns emerged:

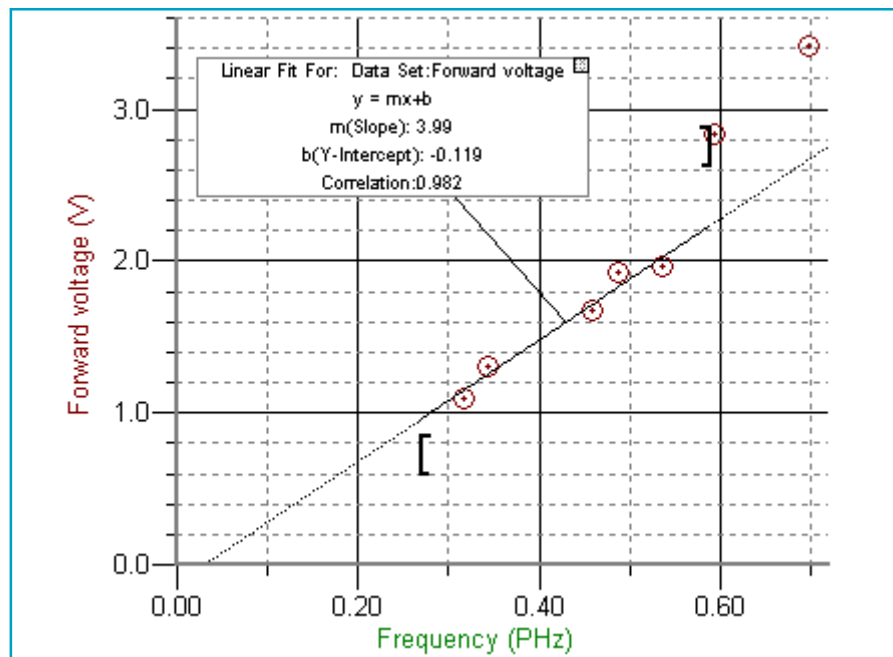


Figure 1 V - f graphed data from a Lascells Photon Energy Array. Forward voltages obtained by the tangent method. Note discontinuity at 550 nm.

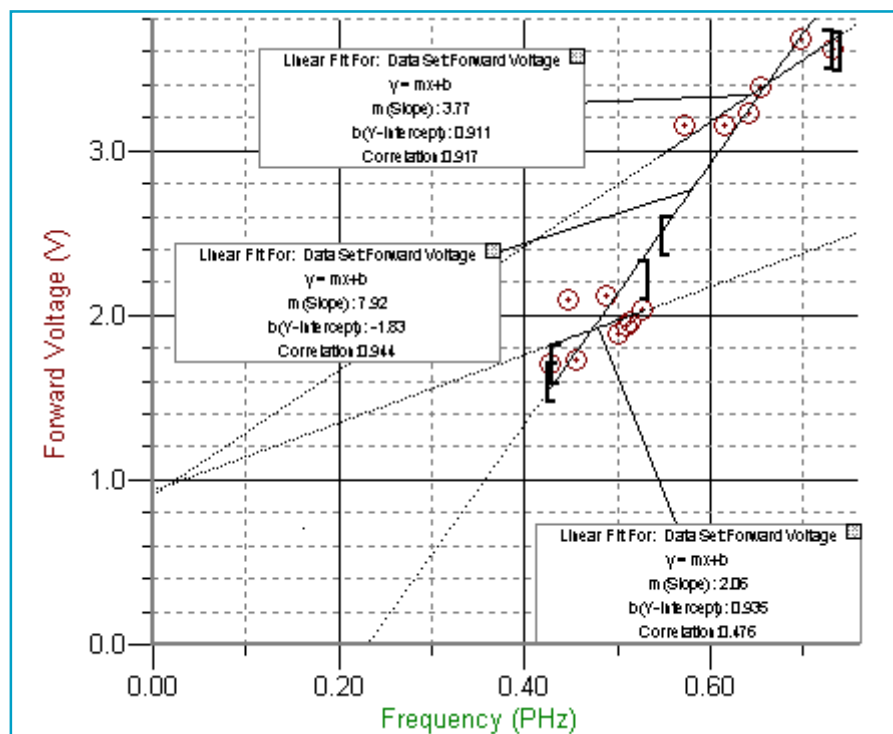


Figure 2 V - f graphed data from a home-made LED array. Forward voltages obtained by the constant current (10 mA) method. Note discontinuity at 550 nm.

Apparatus	Method	LED set	Value of h derived from gradient ($\times 10^{-34}$ J s)
Lascells Photon Energy Array (Fig. 1)	Tangent	All LEDs	9.5
		Infrared to yellow-green	6.4
Home-made array (Fig. 2)	Constant current	All LEDs	12
		Red to yellow-green	3.3
		Green to violet	6.0

Table 1 Values of Planck's constant from different methods and sets of LEDs.

- There is a discontinuity between yellow-green and mid green colours (i.e. between GaAs and GaN LEDs).
- On either side of the discontinuity, the results are scattered about linear lines from whose gradients a value of Planck's constant to within the right order of magnitude can be derived (Table 1).
- There is less scattering if the tangent method is used.

Discussion

Both pedagogically and physically, as a method for investigating the relationship between photon energy and frequency, there is disagreement. We have one correspondent¹ who believes that the method is "simple" and "easily understood". However we know of another physics teacher² who is concerned that the method is in the "realm" of "cookbook" physics. The reader is left to form his or her own opinion on the aptness of the method. Those who tried the experiment at last year's Physics Summer School did seem favourably impressed.

In our opinion the method is flawed. The underlying physics is more complicated than the simple model presents – namely that electrons are pumped directly from the valence to conduction band, then jumping cleanly back, with resulting photon emission. In practice there are lots of electron traps lurking under the conduction band. Similarly there are lots of hole traps lurking just above the valence band. Photon emission tends to be associated with electrons jumping from trap to trap rather than band to band. Therefore the photon energy is a little less in practice than it might be had

there been a clean transition (Fig. 3). We understand also that there is disagreement amongst GaN scientists as to how GaN LEDs work.

Another pedagogical difficulty is the method¹ used to measure forward voltage. LEDs conduct current for all values of forward voltage. Simply, since the emission of light is part of the phenomenon being investigated, voltage values below that needed to cause emission should be discounted. This then leaves three methods at least (Table 2).

Although the method is flawed, lying as it does on unsound foundations, only partially understood, it will be appealing to many teachers because it is simple to carry out, uses inexpensive components and can yield a result fairly close to Planck's constant. So for those of you who want to use this experiment, we suggest that you treat the theory as follows.

Let E_{input} = Electrical energy given to atom = eV
 Let E_{output} = Radiant energy released by atom = hf

E_{output} should not be equated with E_{input} ; the underlying physics would not seem to support that identity. Thus $hf \neq eV$.

E_{output} is generally a little lower than E_{input} , so we can write:

Method used to measure forward voltage	Advantages	Disadvantages
Minimum voltage needed to cause emission	Simple procedure	Inefficiency of eye at detecting optical radiation at the extremes of the spectrum
Tangent to an I - V curve method	Method seems to give the correct result for h for GaAs or GaN LEDs, but not both together	Lengthy procedure, which makes no physical sense
Constant current method	Simple procedure	Claimed to make physical sense, but theory lies outwith school science

Table 2 Comments on different methods for measuring the forward voltage of a LED.

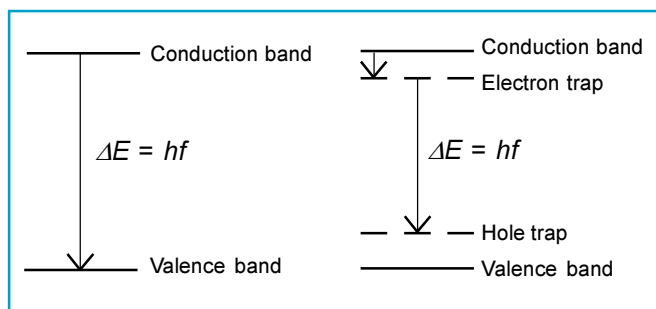


Figure 3 Photon emission from a LED tends to be from electron trap to hole trap rather than from conduction band to valence band.

$$\begin{aligned} E_{input} &\geq E_{output} \\ \Rightarrow eV &\geq hf \\ \Rightarrow V &\geq (h/e)f \end{aligned}$$

Although the relationship between V and f is an inequality, it turns out that a graph of a set of ordered pairs of V versus f obtained from different coloured LEDs has a linear dependence, albeit with a lot of scatter (Figs. 1 and 2). The gradient tends to lie within 50% of the accepted value of h/e , from which a rough value for Planck's constant can be derived.

Wavelength measurement

The mean wavelength of LED radiation can be determined quite easily with a diffraction grating – see 'LED arrays' and 'UV LED experiments' in Bulletin 206

Because the radiation has a bandwidth of 20 nm typically, there is uncertainty as to what wavelength value to take.

Acknowledgement

We are grateful to Les Haworth (Edinburgh University), David Cook-Martin (Philip Harris) and John Whitehead (Lascells) for corresponding on this experiment, and Carol Trager-Cowan (Strathclyde University) for a discussion.

¹ John Whitehead, Lascells, private correspondence.

² D F Holcombe, letter to 'The Physics Teacher', Vol. 35, April 1997.

¹ R Morehouse, Answer to Question #53, *Measuring Planck's constant by means of an LED*, Am. J. Phys., Vol. 66, No. 1, January 1998.

Apparatus review

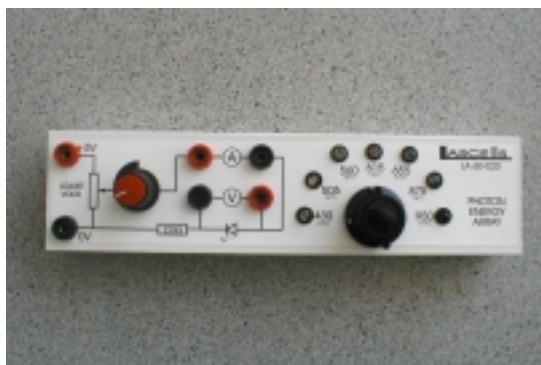
Photon Energy Array, Lascells

Manufacturer and supplier: Lascells

Order code: 920-119

Price: £36.75

Description: The circuit has been assembled on simple plastic trunking, open underneath. There is an array of 7 LEDs of which 2 are infrared emitters and 2 emit short wave radiation below the 550 nm discontinuity. The circuit has a pot for varying the forward voltage and a fixed value series resistor for overcurrent protection. Socket outlets permit the measurement of current and voltage with external meters. A separate power supply is also needed.



Performance: If the tangent method is used to obtain forward voltage and if data from the blue and violet LEDs are discounted, then you get a reasonably linear V - f graph. From such a graph we obtained a value for h that agreed with the accepted value.

ASSESSMENT: B

Planck's Constant Experiment, Philip Harris

Manufacturer and supplier: Philip Harris

Product code: B5G60709

Price: £84.46

Description: This apparatus is self-contained, having its own battery supply and LCD voltmeter. Housed in a sturdy, injection moulded, plastic case, it resembles a hand-held instrument. The array of 5 visible LEDs includes one blue emitter below the 550 nm discontinuity. Controls include a wavelength setting switch and voltage adjustment pot. There is no provision for measuring current. This prevents the measurement of forward voltage by the tangent method.



Performance: If either a full brightness or threshold method is used with the 4 LEDs from red to yellow-green, we get a value of h of $(3 \pm 1) \times 10^{-34}$ J s – half the accepted value.

ASSESSMENT: B

The ABC rating in general stands for:

A	Good
B	Fair
C	Poor

Technical Tips

Yeast Glucose Agar

The bare ingredients you will need to grow a yeast glucose agar culture are listed below.

- Glucose 20 g
- Yeast Extract 10 g
- Agar 15 g
- Dist Water 1 L

Note that no bacto-peptone is needed. The yeast will grow without it.

Bacto-peptone

Bacteriological peptone is sometimes incorporated into the above yeast recipe. However as we have said, you do not need to include it. Few companies supply bacto-peptone; one that does is Blades Biological (cat no. MED 165, 50 g, £7.15)

Rapid 318 fuse marking

This popular multimeter has the wrong fuse type embossed on the back of the enclosure, where it says that the fuse type is "200 mA". It should read "2 A". Legend on both the front panel exterior and on the printed circuit screenprint by the fuseholder correctly states "2 A".

Multimeters fusing

Schools sometimes complain about the nuisance caused by multimeter fuses blowing.

Multimeters generally have 2 fuses: a low value fuse protecting its low current ranges, and a 10 A fuse protecting the 10 A circuit. Children are unlikely to be able to blow the 10 A fuse.

Fusing is the correct and only feasible form of protection to your multimeter from mistakes or abuse. The common mistake that causes the low value fuse to be blown is when someone tries to measure voltage with one of the test leads connected to the socket marked "A". Because the multimeter then short circuits the power source, there will be a massive over-current rupturing the fuse. There is no way of protecting a fuse from this mistake. It protects the multimeter from being destroyed. You just have to accept this.

Your only means for reducing nuisance fusing is by information, instruction, training and supervision of the youngsters. This has to be overt, systematic and continual. If done sensitively, it should be possible to get the children on your side trying to reduce the frequency. Apart from

the (odd?) reprobate, it is not in the child's interest to have work inconvenienced by inoperable meters. If fusing is endemic in your department, explain the problem to the pupils. Show them how careless usage will blow a fuse. Show them how awkward it is to replace the fuse. Get a pupil to replace a fuse with others watching.

HT transmission line models

Since publishing details of 2 model HT lines in Bulletin 158, the accepted ac voltage to which uninsulated conductors may be taken safely is 33 V rms. Therefore the 50 V model transmission line should not be constructed.

The other model, which stepped up from 2.5 V to 20 V, presents no risk of harm. Indeed you could safely turn up the input voltage from the published value of 2.48 V ac to around 3.0 V ac. If so increased, the HT line would have a potential difference across it of about 30 V, causing the 2.5 V MES lamps to shine more brightly than in the original model.

The 20 VA, 240 V to 12 V transformer from RS (207-144) we specified in Bulletin 158 has been replaced by stock item 805-063 at £4.58.

Trade news

New from DJB

New apparatus for studying ray optics has been developed by DJB. The *RayZer Lightbox* contains 3 laser diode modules with integral optics producing 3 parallel lines of radiation across a white baseboard (47x29 cm), switchable down to one line. The lasers are Class 2; each has a power of under 1 mW. The radiation wavelength is 650 nm. The laser unit is permanently attached to the baseboard, thereby fully meeting the safety requirement that any laser must be securely clamped. This apparatus is safe for use by children under supervision at S3 and above. The price of £66.50 includes a plugtop power supply.

Also just out is a *bioreactor vessel* with a control unit which is compatible with the ALBA datalogger. See the "Latest News" section of the DJB website.

CAX 2000 Teltron tubes

Teltron have developed a new range of vacuum tubes, called *CAX 2000*, to match their classical ones. Whereas the classical range had been designed for demonstration, the CAX 2000 series may be used by students, being "simple, safe and reliable in use" according to Teltron. The new apparatus is said to yield more precise experimental results compared with the classical series. Prices of the CAX 2000 items tend to be 10% to 30% lower than classical ones.

Smart UV products

New UV products from Teaching Resources at Middlesex University are based on a UV LED (98p) emitting a mixture of visible purple and UV radiation. They include a UV adhesives kit (£14.40) utilising the technology dentists use and photochromic pigments (from £1.16) with which fluorescent graphics can be created on paper, plastics, metals or fabrics.

PASCO energy transfer apparatus

At last the inventive minds of the PASCO team have got around to designing a range of energy transfer apparatus. Whilst we have not tested nor seen any of this stuff yet, descriptions indicate another thoughtfully produced apparatus set. The key component is a low friction, efficient tachogenerator – the basis for many SSERC experiments between 10 and 15 years ago. Applications include water, wind and solar power. There are opportunities for monitoring with dataloggers and sensors.

PASCO USB/serial converter

Following our note in Bulletin 207 of a USB/serial converter from Pasco (CL-6759) at £110, we had a message from Boroughmuir High School saying that these devices are available from many local computer shops at a much lower cost. For instance the Belkin USB serial adapter (F5U103) costs typically around £50. We understand that Boroughmuir obtained their adapter from Micro Warehouse, getting an educational discount. They report that it works fine with all of their Pasco 500 interfaces.

Chladni's plates' omission

Our Trade News article on Chladni's plates in the last issue omitted to point out the considerable differences between the hand bowed kit from Malin Starrett (Experience of Experimenting) and the less expensive plates that fit on vibration generators. This might have suggested that these products are equivalent. They are not. The plate which is energized by bowing was designed to help pupils learn the manual skills needed for good experimenting. It would therefore offer richer educational experiences than the other types of plates.

RS Components Limited, PO Box 99, Corby, Northamptonshire, NN17 9RS. T: 01536 201234, F: 01536 405678, W: rswwww.com

Schools Laboratory Equipment, 1 Loch Place, South Queensferry, EH30 9NG. T: 0131 331 1955, F: 0131 319 1607, E: Schools_Lab@compuserve.com

SAPS Biotechnology Scotland Project, Institute of Cell and Molecular Biology, Univ. of Edinburgh, Darwin Building, King's Buildings, Mayfield Road, Edinburgh, EH9 3JR. T: 0131 650 7124, W: www.saps.plantsci.cam.ac.uk

AND AT: Quest Biotech Laboratory, Dollar Academy, Dollar, FK14 7DU. T: 01259 743753.

Scientific & Chemical Supplies Limited, Carlton House, Livingstone Road, Bilston, West Midlands, WV14 0QZ. T: 01902 402402, F: 01902 402343, W: www.scichem.co.uk

Technology Supplies Limited (Lascells), Phoenix House, Tern Hill, Market Drayton, Shropshire, TF9 3PX. T: 01630 637 300, F: 01630 637 302, W: www.technologysupplies.co.uk

Teltron Limited, Unit 14, 98 Victoria Road, London, NW10 6NB. T: 020 8453 1224, F: 020 8963 0310.

University of Edinburgh (Chemistry Summer School): Julie Urquart, St Mary's Land, Moray House Institute, Holyrood Road, Edinburgh, EH8 8AQ.

WPA - see Biochrom.

Addresses

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

Biochrom (WPA), 22 Cambridge Science Park, Milton Road, Cambridge, CB4 0FJ. T: 01223 423723.

Bio-Rad Laboratories: T: 0800 181134, W: www.bio-rad.com

Blades Biological, Cowden, Edenbridge, Kent, TN8 7DX. T: 01342 850242, F: 01342 850924, E: info@blades-bio.co.uk

Chemistry Teachers' Meeting: c/o Dr Nigel Botting, School of Chemistry, University of St Andrews, St Andrews, Fife KY16 9ST. E: npb@st-andrews.ac.uk T: 01334 463856 F: 01334 463808 Mark enquiries "CONFERENCE"

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

Experience of Experimenting (Malin Starrett), Unit a28, Valley Business Centre, 67 Church Road, Newtownabbey, Co. Antrim, BT36 7LS. T: 028 90552721.

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, Findel House, Excelsior Road, Ashby Park, Ashby-de-la-Zouch, Leicestershire, LE65 1NG. T: 0845 120 4520, F: 01530 419 492, W: www.philipharris.co.uk/education

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

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

IoB Teachers' Meeting: c/o Peter Anderson, E: Peter.Anderson@fife.gov.uk T: 01592 414676

IoP Stirling Education Meeting: c/o Peter Ball E: peter.ball@iop.org, T: 01383 853207 F: 01383 852856.

Lascells - see Technology Supplies Limited.

Maplin Electronics, Freepost NEA9433, Barnsley, S73 0BR. T: 0870 264 6000, F: 0870 264 6001, W: www.maplin.co.uk

Micro Warehouse, Stuart Road, Manorpark Industrial Estate, Runcorn, Cheshire, WA7 9TH. W: www.microwarehouse.co.uk

Middlesex University, Teaching Resources Ltd, Unit 10, The IO Centre, Lea Road, Waltham Cross, Hertfordshire, EN9 1AS. T: 01992 716052, F: 01992 719474, W: www.mutr.co.uk

PASCO - see Instruments Direct

Rapid Electronics Limited, Severalls Lane, Colchester, Essex, CO4 5JS. T: 01206 751166, F: 01206 751188, W: www.rapidelectronics.co.uk

Royal Society of Chemistry (Sales Department), Thomas Graham House, Science Park, Milton Rd., Cambridge, CB4 0WF. T: 01223 432360.