

SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



Colorimeter review

Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences

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News and comment	Approved Training Provider status	1
	Support agency ratings	1
	SAPS secondee	1
	Biotechnology summer school	1
	ASE Scotland annual meeting	1
Editorial	That old feng shui factor	2
ICT Notes	ICT needs and science subjects	3
CPD Notes	ICT in the Sciences	5
Equipment Notes	Gas law experiments: Part 2	6
	- STE Jolly's Bulb and Gauge	7
	- Nicholl Absolute Zero Apparatus	8
	- PASCO Pressure Sensor	8
	- PASCO Temperature Sensor	9
	- PASCO Gas Law Experimenter	9
	- PASCO Heat Engine	10
	Practical work with ICT	13
	BASIC Stamp: Part 3	15
	Colorimeter review	20
- Griffin Colorimeter Model 41	22	
- Harris S-Range Colorimeter	24	
- WPA Colorimeter CO75	26	
Biotechnology Notes	SAPS Biotechnology Scotland : Vacancy	19
Technical Notes	Higher Physics: Electricity: Activity 21	28
Odd and ends	New resources and equipment	29
Equipment offers		30

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NEWS AND COMMENT



New Opportunities Fund

partner

Announcement

We are very pleased to announce that SSERC Limited as the Lead Body for a partnership known as the Scottish Science Consortium, has now received formal acceptance of an application for Approved Training Provider status. This approval was made under the arrangements for Information and Communications Technology (ICT) training operated through the New Opportunities Fund scheme. The approved provider status currently enjoyed by the Scottish Consortium only covers subject specific training for secondary science teachers. The training materials and methods we shall employ are based on those used south of the border in a parallel programme by our partners in The Science Consortium. Further details are given on page 5 of this Bulletin issue.

Highly rated

We should like to congratulate a number of science and biology education support agencies on their rankings in the results of a recent survey carried out by Harris Research on behalf of The Wellcome Trust. In this UK wide survey, practising science teachers were contacted and questioned on their awareness of a range of scientific organisations. Their views were also sought on how they rated such organisations. Data was gathered on contact with such organisations and agencies over the previous twelve month period.

We are pleased to report that the Association for Science Education, the National Centre for Biotechnology Education and the Science and Plants for Schools Project, all appeared at or near the top of the table of overall ratings together with the Wellcome Trust itself. This is encouraging for all of us as well as gratifying for them. It is perhaps noteworthy that each of these organisations operates a bottom-up approach to assisting teachers and technicians. They share a reputation for providing relevant and practical advice, information and training all rooted in the curriculum and the day-to-day problems faced by school science departments. The Institute of Biology and the educational arm of the Medical Research Council are obviously also doing the right kinds of things since they too appear well up the rankings.

Also to be congratulated is The Wellcome Trust itself for having the good sense to actively seek the views of practitioners so as to:

“... inform the strategic planning of the Department of Consultation and Education, in particular to identify with which organisations it should be forming strategic liaisons, and to identify effective delivery mechanisms for reaching teachers”

We sense that other agencies may soon follow that sensible lead in beginning to seek regularly, and more importantly act upon, the views and advice of practitioners. Teachers and technicians are well placed to identify problems in science education. They are also not short of the odd suggestion as to sensible solutions for many of them.

SAPS secondee

Given the endorsement of the UK wide project by end-users of its services (column opposite), what better time could there be to advertise for a two year appointment to the Scottish end of SAPS? A copy of the advertisement, for a secondee to take over from Rodger McAndrew, is carried on page 19 of this issue of the Bulletin.

Summer school

The Biotechnology Summer School, 2000, is most definitely a runner. Advance publicity, in the form of a flyer with an outline programme and booking form, has now been distributed by SCCC. The Summer School will run from 26th to the 30th of June. The focus of the week-long event, the third in the series, will be on courses at the Advanced Higher level. As before, the School is being supported by a number of companies and agencies. The University of Edinburgh is again generously hosting the event in the Institute of Cellular and Molecular Biology within the Swann Building. Through the generosity of the various supporters and sponsors the total cost, including accommodation with dinner, bed and breakfast will only be £75 per participant. This represents excellent value at about £15 a day for a high quality, relevant, course of professional development.

A new programme has been developed for the 2000 School. This will focus mainly on the human aspects of biotechnology, particularly human genetics and human therapeutics. A continuing theme of the presentations and practicals will be an examination of the moral, social and ethical issues associated with biotechnology.

ASE Scotland annual meeting

The outline programme and booking forms for this event in March are now available and are enclosed herewith.

* * *

EDITORIAL

That old feng shui factor

“ . . . a woman who, having served her apprenticeship as a hairdresser, now feels qualified to breeze into the nation's living rooms and cover the walls in fuschia. . . .

La McKevitt has a Moonilike conviction that she is right and everyone else is wrong. Having flicked through a few glossy magazines and toyed with Naomi Campbell's locks, she is now on an upward curve that should take her into the salons of the rich and famous, people who think feng shui is the 20th century's answer to Confucius”¹.

Not long back, the most cursory flicks through the, non-glossy, Times Ed Supp Scotland or the letters pages of Education in Science (EiS) seem to have provided sufficient justification for folk to sound the knell for practical work in science. On the one hand, it would appear, the HMI team leader for science had said that it was too expensive and wasteful of resources to justify what pupils got out of it. Practical work, it appeared, was finally dead. Old hands were then doubly shocked to see in the ASE's Education in Science that practical work wasn't needed any more because we could do it all using ICT equipment and simulations. In fact neither is, nor ever is likely to be, the case.

The record will show that I hold no particular brief to defend HMI, especially Dr Jack Jackson who is a big lad and no doubt more than able to look after himself. Nor am I especially suprised that the TESS should cut what he and Professor Wynne Harlen had to say so as to effectively misquote them - thus following the journalistic dictum that the truth should not get in the way of a good story.

What continually disappoints is that multitude of Moonilike, educational McKevitts. There are too many who sieze on particular parts of any research or study merely to hang them on the particular pegs of their own prejudices. They pick out the bits which suit them and ignore the rest. Sometimes they don't even bother to read the other bits before ignoring them. By such means are past recommendations to involve pupils more directly in their own learning turned into an over reliance on resource based methods and death by a thousand worksheets. By identical means is reasonable advice, to include more direct teaching, about to be translated into death by teacher exposition. No more independent pupil activities? Nobody expects the Spanish Exposition!

It is well past the time for us to abandon such shallow debate and all those unnecessary and false antitheses. Such approaches, to what instead should be matters of more serious and wide ranging professional discussion, are not at all productive.

¹ Alan Taylor on interior designers, in *Scotland on Sunday*, 5th December 1999

This obsession with “either,or” assists no one and it may well do serious damage. As always, it's the weans who are the likely victims of the, all too usual, suspects. In the interest of those same pupils and their science practical work, it is instructive to note more fully both the HMI advice and the research review on which it is based. In other words, literally, what do Dr Jackson and Professor Harlen actually have to say and have said in the past on these matters.

“Science practical work is demanding in terms of resources ie time, equipment, technician support and smaller class sizes”.

Yes they do say that and we can hardly deny the overall truth of such a statement even though some of us might wish that it was even more expensive. This means that we shall eventually (now, soon whatever, depending on who is misquoting whom) have to abandon (some, most, all - take yer pick) practical work. No they did not and do not say that, any of it.

The actual arguments are based on a thorough review of the research. What that research suggests is that several of the claims made for the outcomes of many kinds of practical work are at best doubtful. In some cases it is difficult to come to any definite conclusions but in others it is clear that the type of practical work used is not effective in achieving the educational ends claimed for it. Other cases such as investigative work in the right circumstances, for example, hold out the prospect of greater educational benefit than some types of more traditional set piece pupil experiments. In turn, teacher-led demonstrations may, or may not depending on the specific circumstances and purposes of the activity, prove more effective than some pupil practicals.

Therefore the argument before it got hijacked, misinterpreted, and subverted runs thus :

Because practical work is demanding of teachers' and technicians' time as well as of other resources then we need to give far more consideration than we do currently to what kinds of practical work are likely to be effective in meeting the needs of learning and teaching. We need a range of such effective learning and teaching techniques. In order the better to identify these we need to observe and talk to pupils more than many of us do at present. We need to read, think and reflect a bit more before adopting a particular learning strategy.

Most of all we need to stop bleating, McKevitt like, about our so-called professional expertise and pause before we pronounce. This is especially so when, whether as teacher, politician, inspector or adviser, we lie in danger of promoting our own personal equivalent of a fatal penchant for fuschia walls.

* * *

ICT needs and science subjects

A paper from the Higher Still Development Unit is introduced and reprinted.

Background

In Bulletin 195 [1] we announced the publication by the Higher Still Development Unit of a briefing paper for “Senior Managers” on Baseline IT needs for Higher Still courses. We were less than complimentary about a few aspects of that paper. Subsequently an ICT working party was set up by the Scottish Science Advisory Group. They produced a more detailed analysis of the likely needs of science subjects and some Advisory Notes of their own. These were circulated to the directorates in all thirty two Scottish Councils. We were pleased to be able to republish them in Bulletin 196 [2].

Now, science specialists within HSDU have updated relevant parts of the earlier briefing paper and have produced a specific set of notes for the Science Subjects. It is those notes which, with permission, we reprint below. We have made a number of minor amendments so as to suit our house style for the Bulletin.

ICT in Higher Still Science Units and Courses

Summary of baseline IT paper

The baseline IT needs paper commented that Higher Still courses and units can be delivered without significant new IT resources. However, it is recognised that schools and colleges are attempting to make progress in ensuring that science laboratories have contemporary equipment based on microprocessor technology including computers. School and college science laboratories should be equipped with science equipment that reflects current scientific use.

“*Effective teaching and learning - the sciences*” [3] said:

‘In many cases the need for new technology had yet to be fully met in schools. The provision of microcomputers had increased significantly, but few schools had one system per laboratory which would allow teachers to make the computer integral to course work.’

Much of the science equipment in school and college laboratories was purchased during the 1960’s and 70’s and is now reaching the end of its useful life. In many cases much of this equipment has been rendered obsolete as a result of developments in microprocessor technologies.

Over many years in schools, science equipment was linked to the Acorn BBC computer to allow data capture of the measurements and some subsequent analysis of data. The BBC computer was also used for simulations and computer aided demonstrations. The BBC computer series is outdated. Some centres are still using this equipment, but it can produce a very unfavourable reaction in students.

Moving beyond the baseline

Science departments should be replacing equipment that is at or near the end of its useful life and replacing obsolete equipment with its modern microprocessor based equivalents. Increasingly a broader view is being taken of what constitutes ICT, moving beyond computers. In science this constitutes:

- modern instrumentation and equipment some of which is based on microprocessor technology
- sensors and associated software to allow interfacing with the use of ICT for data handling
- computers
- audio-visual equipment.

ICT is an important application of microprocessor technology used by scientists. It is important that students experience the application of microprocessors in ICT and in modern instrumentation and equipment generally.

Using ICT in learning and teaching

In science, ICT should be used at the laboratory bench in practical experimental work, for example in :

1. Data capture

Computers with associated interfacing peripherals should be used to capture experimental data and for control technology. Portable data loggers should be used in certain situations (for example in fieldwork) to capture and store data. In addition the use of ICT enables data to be captured in very short timescales (e.g. charge/discharge p.d.’s across a capacitor in Physics) and over long timescales (e.g. environmental monitoring in Biology). Reference is made to other examples in the Arrangements documents and support materials in Biology, Chemistry and Physics. The plotting of collected experimental data in real time, live to students, has been shown to produce significant improvements in understanding. In this way the use of ICT in school and college science laboratories will parallel current practice in the workplace, both in laboratories and industry.

2. Data analysis

Data is analysed using spreadsheets or in many cases dedicated software. It is important that students be introduced to such data analysis techniques. In science there is an emphasis on such an analysis (e.g. in Advanced Higher investigations). It was a fear that centres may not have suitable equipment that resulted in these aspects being ‘suggested’ rather than ‘mandatory’. (cont./over)

There are several experiments which require a number of graphs to be plotted and, or, readings and uncertainties to be analysed. These should be done using a spreadsheet to allow more time for the interpretation and evaluation aspects. This can help to develop the problem solving Outcome 2 found in all science courses, the performance criteria of which include:

- relevant information is selected and presented in an appropriate format
- information is accurately processed using calculations where appropriate
- conclusions drawn are valid and explanations given are supported by evidence
- predictions and generalisations are based on available evidence.

3. Improving investigational skills

Microprocessor technology should be used to enhance students' skills in scientific investigation and experimental work. Some sensors and other measuring devices which use microprocessor technology may measure with more precision than was possible with conventional equipment. This increases the range of practical work that can be done. The validity of collected readings allows a more meaningful analysis of results in relation to problem solving skills. It also means that experiments can be carried out in a shorter period of time.

4. Improving understanding of subject content

Computers can deepen students' knowledge and understanding of scientific ideas. In Chemistry, modelling software should be used to improve students understanding of molecular structures. Simulation or modelling packages of scientific phenomena should be used to allow students to construct hypotheses and test predictions.

For example, in Physics an important area is the conservation laws where a range of variables can be altered and subsequent analysis displayed. It is desirable that students complete one experiment and the associated analysis. The computer simulation can then be used to alter the variables and allow time for discussion. In Biology, computer simulations of ecosystems can be used to investigate the effect of changes in environmental conditions on populations.

Computers should be used to access scientific knowledge and information on CD ROM or the Internet providing extensive secondary sources of information often enhanced by high quality graphics and commentary to aid understanding. ICT equipment should also be used to present still and moving visual images that demonstrate scientific phenomena in preference to conventional techniques which describe them.

Video cameras linked to computers should be used to view and display microscopic specimens, electronic and optical components, small-scale chemical reactions, animal behaviour etc. allowing data analysis of the captured images. Digital cameras should be used to capture images of projectiles for subsequent analysis.

Advice on hardware and software

Each laboratory should have available :

- a minimum of one computer system with CD drive, modem, Internet link, IR port and printer. In addition there should be a link between the computer system in each laboratory and a link to a central server to allow the most appropriate exchange of data both within the department and within the school or college.
- conveniently accessible to it, a set of six laptop computer systems with data collecting sensors, control interface and relevant software. Alternatively, one Biology, one Chemistry and one Physics laboratory should have a set of six desk top computers equipped with data collecting sensors, control interface and relevant software.
- display screens for demonstration purposes and consider the need for headphones to avoid distracting students engaged on other tasks.

Schools and colleges should have a rolling programme of replacing obsolete equipment with its modern micro-processor based equivalent. As specifications for ICT and associated equipment are constantly improving, current advice should be sought from appropriate sources.

Items considered as 'software' should include stored video images and Internet access as well as CD ROMS and computer programmes or utilities. In principle, software should be interactive. For example, graph plotting and data analysis packages should allow decision making by the students. Simulations should allow the construction of hypotheses and predictions that can subsequently be tested. Advice on the requisite software should be sought from the appropriate sources.

The Higher Still Development Programme intends to provide a series of documents providing more detailed advice on specific uses of ICT in science courses through its published support materials.

References

1. "IT matters too", Bulletin 195, SSERC, Autumn 1998.
2. "SSAG Advisory Notes - ICT in Science Education" Bulletin 196, SSERC, Spring 1999.
3. "Effective Learning and Teaching in Scottish Secondary Schools - The Sciences", SOEID, 1994.

No comment

"Teacher of English (RefENG DUN) Dunbar Grammar School"

East Lothian Council Advertisement, TESS, January, 2000.

Comment

"...for they have seen the future and it is made of MDF, the ideal material for an age in which appearance over substance is all. . ."

Alan Taylor - on interior designers, again (see page 2).

ICT in the Sciences



SSERC is the lead body in a Scottish Science Consortium which has gained Approved Training Provider status for ICT training in secondary science subjects in Scotland. An overview of the New Opportunities Fund scheme is provided and SSERC's role and intentions within those arrangements are outlined.

New Opportunities Fund

Some £230 million of public funds has been assigned for training teachers and librarians in ICT applications over the next three years or so. These monies underpin a training scheme overseen by the Board of the New Opportunities Fund (NOF). Each teacher can opt to undertake such training up to a notional value of £450. Currently the funding does not extend to teachers in independent schools.

Approved Providers

Training can only be provided by bodies and agencies which have gained Approved Provider Status. The Scottish Science Consortium is just one of several such providers which have approval to operate in Scotland. What is a wee bit special about the Scottish Science Consortium is its approved status for subject-specific ICT training in secondary sciences. In theory at least it is for individual teachers to decide whether or not to take up the training and, should they do so, they are then free to choose which provider or providers with which they register. We use "providers" plural because under the NOF rules a teacher is not restricted to the use of only one provider.

Details of all approved providers are circulated to schools by NOF staff in a catalogue. In due course all teachers should have sight of that information. Although the choice of whether or not to take up training, as well as which provider(s) to use, rests with each teacher, under the scheme the funds are administered by each Scottish Unitary Council as the Education Authority. A few Scottish Councils are themselves Approved Providers as well as administrators of NOF funds. Clearly in such cases there is a potential for conflicts of interest and there are rules intended to prevent such problems. SSERC's own position is no exception, since although it is governed by a Private Limited Company, which is also a registered charity, the members of said Company are none other than the thirty two Scottish unitary councils. It is thus obviously not in the long term interests of the Company for SSERC to compete over-aggressively and so discourage collaborative approaches to Scottish ICT training issues.

Partners

The Scottish Science Consortium's approaches to ICT training are modelled on those used by a wider UK Consortium, the partners in which are: *ASE INSET Services; The Centre for Science Education at Sheffield Hallam University; the software company New Media Ltd and the Nuffield Curriculum Projects Centre.*

SSERC is also actively seeking to form sub-partnerships with Scottish Local Authorities who may or may not be approved providers in their own right.

Extent and nature of training

The Scottish Consortium's approval is for science specific ICT training at secondary school level only but this extends across all 32 EA areas on the mainland and in the Northern and Western Isles. Training is offered only in the medium of English (wi' a dod or twa o' Scots an a' nae doot) but tutor support in Scots Gaelic will be provided on request.

Training will be provided through a mix of face-to-face induction and consolidation sessions and distance learning via E-mail, software on CD ROM and a dedicated, password protected website with resources which can be downloaded. Training may last from one term to up to one whole school session. This is at the teacher's discretion. Whilst the Consortium's preference is to train the whole science teaching staff team in any one school, training can be offered to individual teachers. In certain circumstances it may be possible also to train technicians even though their fees cannot be covered by New Opportunities Fund monies.

The course is based on six modules each covering a broad aspect of an overall set of ICT applications in science education:

1. *Finding out about science.*
2. *Collecting and using data.*
3. *Visualising science.*
4. *Handling and interpreting data.*
5. *Modelling in science.*
6. *Communicating science.*

The training is firmly rooted in classroom practice and the application of ICT to learning and teaching in science. Completion is signalled when a range of ICT applications has been used in practical situations.

Enquiries

If you are interested in the possibility of taking up the Scottish Science Consortium training offer then please look out for the NOF catalogue or you can obtain further details directly from SSERC. Please see inside rear cover for our address and other contact details for the Scottish Science Consortium.

* * *

EQUIPMENT NOTES

Gas law experiments: Part 2

Methods and apparatus for showing the pressure-temperature law.

In the last issue we wrote about apparatus and methods for showing Charles' Law. In this issue we'll look at the pressure-temperature one. As before, the devil is in the detail. A slap-dash approach to even what is a well-known and -tried experiment is unlikely to give a good answer. To preface our advice on procedure, we can do no better than restate what has already been written elsewhere [1], "The Nuffield trials revealed that this experiment gives trouble unless these warnings are heeded".

The common mistake of putting the thermometer in the air chamber is discussed. Why this has now become standard practice [2] is odd when authoritative experimental guides [3,4] clearly indicated where the thermometer should be put!

The results were analysed with the method described in the last issue of this journal [5]. Briefly, the data was graphed and checked for linearity. Every data set met with this test. We then fitted the best-fit straight line through the points and extrapolated the line to cut the temperature axis. The goodness of the result was shown by how near to the accepted value of $-273\text{ }^{\circ}\text{C}$ the point of intersection is. A summary of our results is given in Table 1.

General advice

The following guidance applies to all of the methods used in showing the pressure-temperature law:

- Ideally, for best results, dry the air chamber and tubing before use and fill with dry air.
- The entire air chamber must be immersed in the water bath.
- Minimize the water bath volume to avoid spending too much time heating water.
- Use a mercury in glass thermometer, 300 mm long, with a range $0\text{--}100\text{ }^{\circ}\text{C}$, or an accurate electronic temperature sensor.
- The thermometer or sensor must be placed in the water bath – not in the air chamber, as some texts misleadingly instruct (see below).
- Start with the water bath cold and gradually warm it up.
- Maximize the range by starting at roughly $5\text{ }^{\circ}\text{C}$, or just below, and finishing at about $99\text{ }^{\circ}\text{C}$.
- Heat the water bath to raise the temperature by amounts of at least $10\text{ }^{\circ}\text{C}$. By using steps of this size you will get ten or eleven data points, which is ample to establish collinearity. If you are pressed for time, steps of $20\text{ }^{\circ}\text{C}$ will give you six data points, which may be adequate.
- After heating the water bath by roughly the set amount, remove the Bunsen and stir vigorously while the apparatus equilibrates. The waiting period should lie between one and two minutes at temperatures below $70\text{ }^{\circ}\text{C}$, but only one minute at $70\text{ }^{\circ}\text{C}$ or above.
- Stir well while reading the thermometer.

Position of thermometer

If two thermometers are used, one in the water bath and the other in the air chamber, the air chamber thermometer reading lags behind the water bath one when the water is being heated. Which thermometer more closely indicates the temperature of the trapped air?

The results for two experiments using water bath temperature readings gave values of absolute zero of $-268\text{ }^{\circ}\text{C}$ and $-271\text{ }^{\circ}\text{C}$. In both instances the uncertainties were $\pm 10\text{ }^{\circ}\text{C}$. The corresponding results using the apparent air temperature readings were $-256\text{ }^{\circ}\text{C}$ and $-246\text{ }^{\circ}\text{C}$, with the same uncertainty value. An explanation for the second pair of values being high, and to the p - T gradient being too steep, is that the thermometer in the air chamber lags behind the actual air temperature it purports to record.

Result label	Apparatus type	Additional specification	Result / ∞C
1	STE Jolly's Bulb	Run 1	-266 ± 6
2	STE Jolly's Bulb	Run 2	-267 ± 8
3	Nicholl Absolute Zero Device	Run 3	-279 ± 26
4	Nicholl Absolute Zero Device	Run 4	-261 ± 20
5	PASCO Pressure Sensor CI 6532	Undried air, 125 ml flask	-261 ± 6
6	PASCO Pressure Sensor CI 6532	Dried air, 125 ml flask	-277 ± 7
7	PASCO Pressure Sensor CI 6532	Dried air, 250 ml flask	-276 ± 7
8	PASCO Gas Law Experimenter SE 8011	Run 1	-278 ± 20
9	PASCO Gas Law Experimenter SE 8011	Run 2	-276 ± 20
10	PASCO Gas Law Experimenter SE 8011	Run 3	-278 ± 12
11	PASCO Heat Engine TD 8572	Run 1	-296 ± 18
12	PASCO Heat Engine TD 8572	Run 2	-284 ± 30

Table 1 Results with different methods and apparatus.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%.

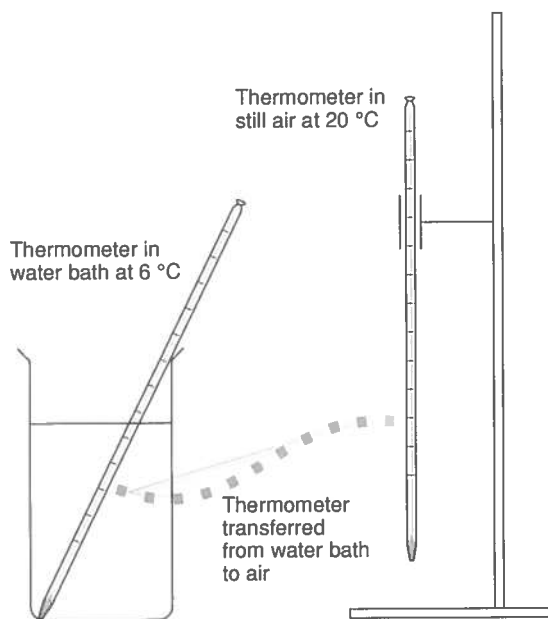


Figure 1 Test method which showed that a thermometer in still air can lag significantly behind air temperature.

The p - T experiment is usually performed by reading values of pressure and temperature every 10 °C. The following experiment shows that a thermometer in still air can lag significantly behind the air temperature if that temperature is changing. A 30 cm mercury thermometer was transferred from a beaker of cold water at 6 °C to still air at 20 °C, being quickly dried and suspended vertically in a clamp stand (Fig. 1). After 1, 2 and 3 minutes the thermometer readings were 12 °C, 15 °C and 17 °C. Thus because the time taken by a thermometer in the air chamber to equilibrate to the air must be well over 5 minutes, it would not be practicable to wait for equilibrium if taking a set of ten readings in a lesson. It follows that this arrangement is not practicable. The thermometer must be situated in the water bath.

Risk assessment

If the apparatus chamber is filled with air at atmospheric pressure and room temperature, the maximum positive and negative gauge pressures would be 30 kPa and -8 kPa under normal operating arrangements. The experiment is usually carried out with glassware. The Higher Still arrangements documents suggest using a round-bottomed flask. Generally glassware should never be subjected to a positive pressure. However given that this experiment is routinely performed, and given that SSERC has never been informed of such a flask exploding in this experiment, we may reasonably conclude that the risk of an explosion is very unlikely.

As preventive measures, the glassware should be inspected for scratches. Flasks damaged by scratch marks should not be used for this experiment. Every person in the laboratory should wear eye protection.

STE Jolly's Bulb and Gauge : Hogg : XPG070.10 : £21.95

In this version of Jolly's apparatus (Fig. 2), the 62 mm diameter glass bulb has a volume of about 100 ml. It is attached to a Bourdon gauge by a 60 mm length of plastic tubing. The gauge is calibrated from -20 kPa to 40 kPa in 1 kPa divisions. A careful observer should be able to read the 62 mm diameter scale to one fifth of a division, or 0.2 kPa. Thus across the operating range from temperatures of 0 °C to 100 °C the pressure scale has about 200 sub-divisions, giving it a suitable precision for this application.

Pressure readings are relative to atmospheric and must be corrected by adding barometric pressure.

The bulb and thermometer can be fitted in a 500 ml beaker. With such a relatively small volume of water, the time taken to obtain a set of readings might be about 25 min.

The fact that the results (1 and 2) are on the high side can be explained from using undried air. The close agreement between both trials (1 and 2) and small uncertainties are indicative of the high resolution pressure gauge which STE provide, the use by us of a 300 mm mercury thermometer situated in the water bath, and a competent observer.

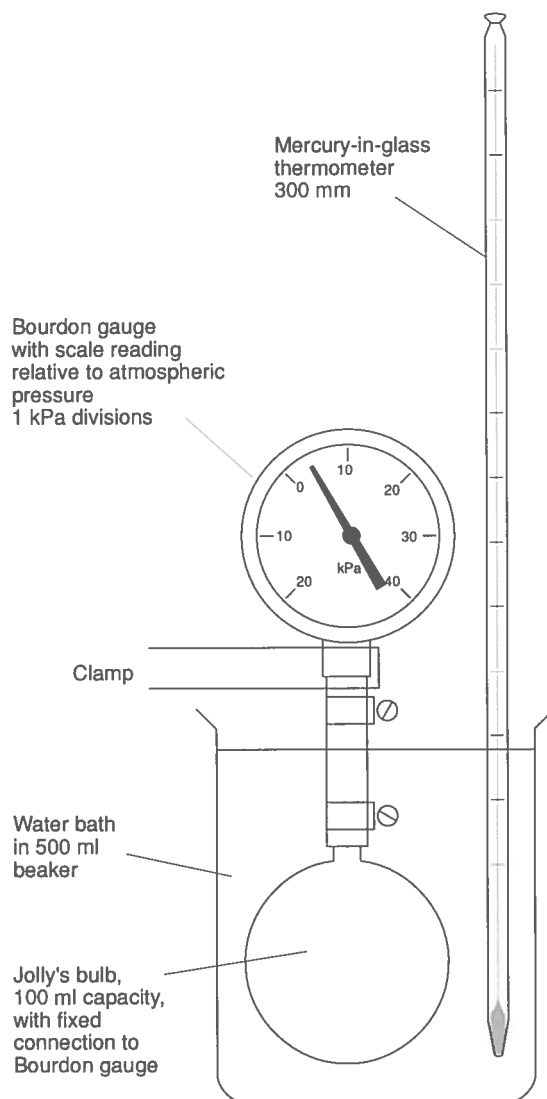


Figure 2 Apparatus with STE's Jolly's Bulb and Gauge.

Nicholl Absolute Zero Apparatus : £54

A prototype of this apparatus was exhibited at the 1999 IOP Stirling Meeting by Nicholl Education. The apparatus comes from The Science Source, a company based in Maine, USA.

The air chamber is a copper ballcock of 100 mm diameter and 600 ml volume attached via a 240 mm long brass pipe to a pressure gauge (Fig. 3). The Bourdon gauge reads absolute pressure, is marked in both kilopascals and p.s.i. units and, having a small dial (52 mm diameter), has a low resolution. Its range is 0 to 210 kPa. The large uncertainties in the results (3 and 4) are caused by the gauge's insensitivity.

The operating instructions direct the user to prepare three temperature baths : boiling water (100 °C), ice and water (0 °C) and dry ice and alcohol (-78 °C). Since dry ice would either be unobtainable or inconvenient for some schools, we tested the apparatus in the same manner as with the other

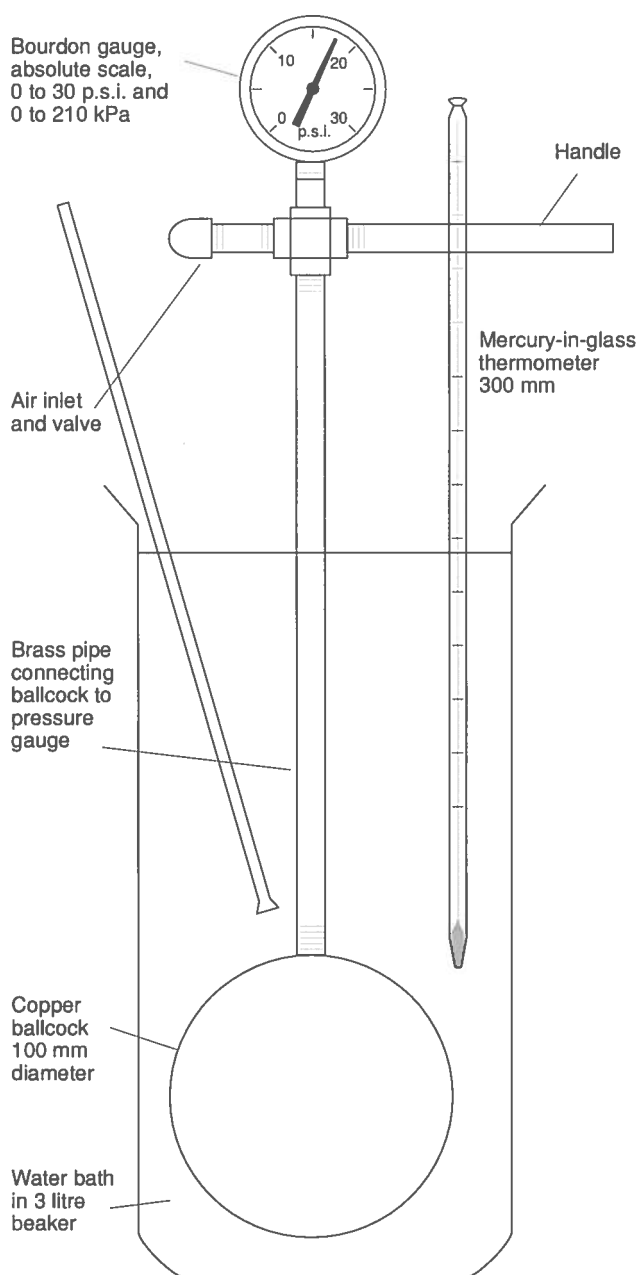


Figure 3 Nicholl Absolute Zero Apparatus shown to scale in 3 litre beaker.

apparatus in our trials, namely with a water bath between 0 °C and 100 °C. The results with a water bath in a 2 litre beaker are not quoted. They were far out because the greater part of the brass pipe projected above the water line. With a 3 litre beaker, 60% of the pipe was immersed, from which we obtained results 3 and 4 (-279 ± 26 °C and -261 ± 20 °C).

The fact that the two results differ in value by 18 °C, whilst agreeing with each other because of the uncertainty values, is an effect of the crudeness of the pressure gauge.

Because copper has a larger thermal coefficient of expansion than glass, the error caused by the expansion of the ballcock was evaluated. If this correction is applied, revised values of absolute zero shift to -273 ± 26 °C and -257 ± 20 °C, giving a mean value of -265 °C. The error can be explained by using undried air.

The apparatus has a tyre valve by means of which the ballcock can be pressurized by pumping air into it from either a bicycle or foot pump. This is hazardous because it is conceivable that it could be connected to an air compressor. We understand that the ballcock has not been pressure tested by the manufacturers. The equipment is fitted with a label warning not to exceed a temperature of 100 °C – presumably after filling with air at s.t.p. It would seem that the safety of the device is dependent on it being used, or its use being supervised, sensibly by a careful science teacher. This caution, in fairness, can be made about all other methods with pressurized air in this review.

In summary, considering the long time taken to warm a 3 litre water bath and the other difficulties we encountered, this apparatus from Nicholl is not recommended.

PASCO Pressure Sensor – Absolute (0 to 700 kPa) : CI-6532 : £99

The pressure sensor was used with the PASCO 500 Interface (CI-6765A, £411) operated by a pre-release version of *Data Studio*, a new software package that is superseding *Science Workshop*. With this arrangement, the resolution is 0.5 kPa. Since the pressure range between 0 °C and 100 °C is about 35 kPa, it can be inferred that the sensor resolves pressure into 70 divisions across the working range of this experiment. This is nearly three times cruder than reading the Bourdon gauge fitted to the STE Jolly bulb.

The experiment is usually performed, we understand, with a round-bottomed, glass flask. We used such a one whose capacity was 250 ml. We also used a 125 ml Erlenmeyer, or conical, glass flask. Finding no difference in performance (results 6 and 7), the smaller of the two is to be preferred because it fits into a smaller water bath, which takes less time to heat and is less dangerous when hot.

The flask was sealed with a one-holed, rubber stopper (Fig. 4). A short piece of glass tube was inserted into the bung. The pressure sensor was joined to this with the polyurethane tubing supplied with the sensor. The volume of air in this tube was about 3 ml, causing about 2.5% of the air in the system to be outside the water bath. The resulting p - T graph has a gradient which is erroneously low (Fig. 8).

The day of the quoted trials was rainy. Result 5 (-261 ± 6 °C) was obtained with undried air. The test was repeated with dried air. In preparation, the flask was placed in a drying cabinet for an hour; calcium chloride was placed in an evaporating basin to dry in an oven at 150 °C. The calcium chloride was then packed into a U-tube, air was pumped through the

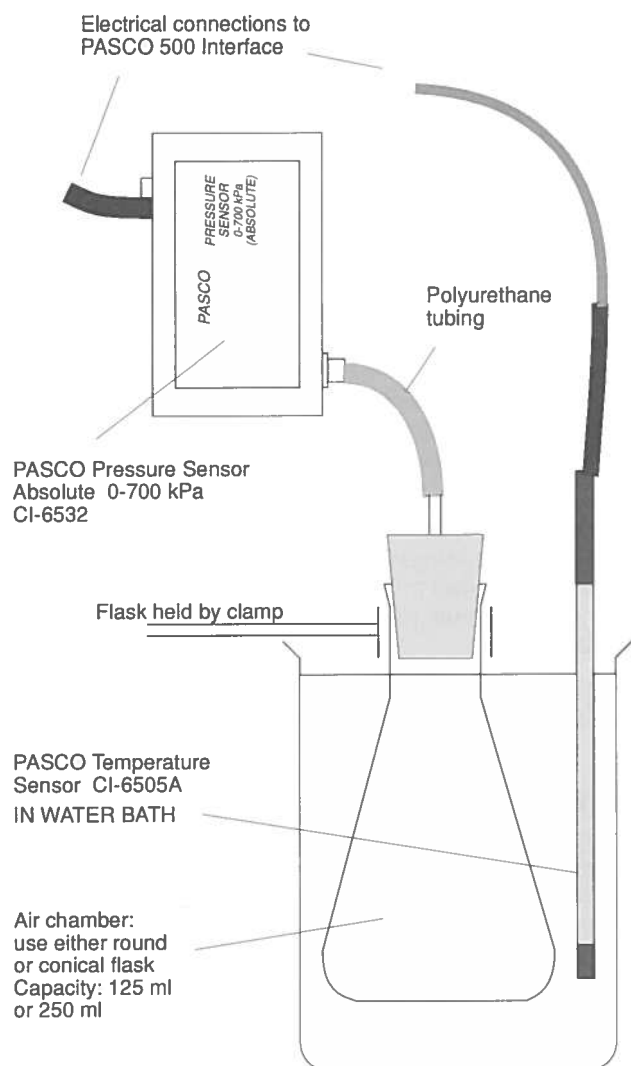


Figure 4 Method with pressure and temperature sensors from PASCO.

tube with an aquarium aerator allowing the dried air to flush through the flask for a period of about 5 min. The flask was then stoppered and connected to the pressure sensor.

The outcome with dried air was result 6 ($-277 \pm 7^\circ\text{C}$). It differs from result 5 in the direction one would expect if result 5 had been in error because of the effect of water vapour pressure.

Finally result 6 can be corrected for the 2.5% of the air being outside of the water bath. Because of this effect, result 6 is depressed by about 5°C . Correcting for it shifts result 6 to $-272 \pm 7^\circ\text{C}$ – a satisfactory answer!

The time taken in obtaining the readings with this equipment was 19 min. This included taking 11 sets of measurements of p and T and raising the water bath temperature from 1°C to 97°C , but does not include the time to set up the computer and interface and other apparatus, chill the water bath, dry the air, or plot a graph and analyse the readings. Because these final tasks can be efficiently done on the computer, the teacher needs to learn to operate the software with suitable proficiency.

Further comments on the pressure sensor's performance are made in the section on the Gas Law Experiment, below.

Thermometer	Error / $^\circ\text{C}$	Uncertainty / $^\circ\text{C}$
Mercury-in-glass, 300 mm length	+ 0.1	± 0.3
PASCO Temperature Sensor CI-6505A	+ 0.4	± 0.2

Table 2 Results of calibrating a mercury-in-glass thermometer and a PASCO Temperature Sensor CI-6505A.

PASCO Temperature Sensor : CI-6505A : £51

When doing gas law experiments with the PASCO pressure sensor CI-6532, the student may record temperature either with a mercury-in-glass thermometer, or with an electronic sensor. The former type generally is more accurate. If one is being used, temperature values are entered into the computer by the keyboard. If working with the sensor, readings are automated. There is no scope for observer error and the experiment is completed in a shorter period.

The results quoted here (5-12) were made with the Temperature Sensor CI-6505A. It and the 300 mm mercury thermometer used in the non-computerized experiments were compared with our laboratory standard thermometers. Both instruments performed well (Table 2), having very small, fixed value errors in the range 0°C to 90°C . Above 90°C the errors increased. The sensor fared poorly, being outwith its specified accuracy of $\pm 1^\circ\text{C}$.

PASCO Gas Law Experiment: SE-8011: £75

This kit is designed for use with a pressure sensor, such as the absolute sensor CI-6532, temperature sensor CI-6505A, computer and interface. It comprises an aluminium canister, syringe, tubing and valves, enabling students to show the pressure-temperature law, Boyle's Law, Dalton's law of partial pressure and Avogadro's principle. Values for the average molecular speeds of gases may also be found. In our context, we describe its use in the aforementioned experiment in this section of the article. Its use in showing Boyle's Law is described later.

Results 8 and 9 were got by following the procedure in the Instruction Manual. There were surprises. The aluminium canister holding about 1.1 litre of air is partially evacuated manually by withdrawing air with the 60 ml syringe. The instructions suggest removing about ten syringefuls, reducing the pressure to about 60 kPa. On removing our ten lots of air, the pressure had reduced to a little below 50 kPa. The procedure is to be applauded on grounds of safety; it removes the risk of an explosion.

The pressure sensor is then connected to the canister. The temperature sensor is strapped by rubber bands to the canister's exterior. A basin was filled with hot water at 65°C . The canister was immersed in the water and readings of pressure and temperature recorded automatically by the computer every 10 s. The water bath's rate of cooling was quickened by replacing hot water with cold, beaker by beaker.

Logging was stopped at 33°C and the data plotted (Fig. 5). It is startling that even for such a small temperature range (65°C down to 33°C), results 8 ($-278 \pm 20^\circ\text{C}$) and 9 ($-276 \pm 20^\circ\text{C}$), a repeat, were in close agreement with each other and with the accepted value.

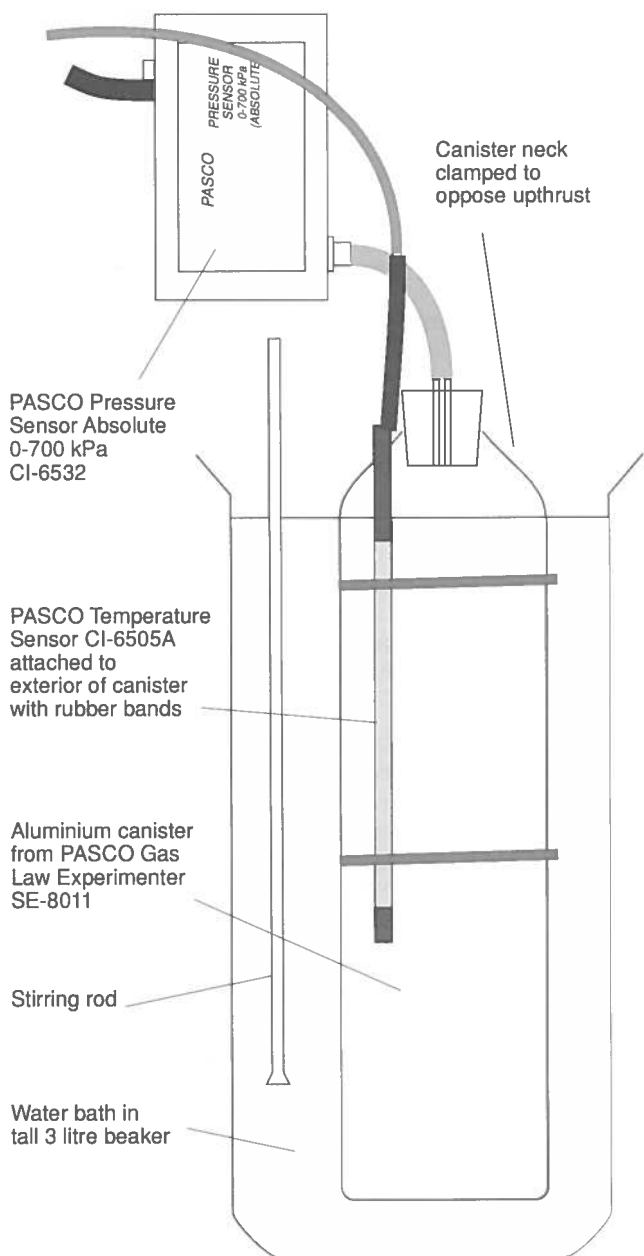


Figure 6 Using apparatus from PASCO's *Gas Law Experiment*. The diagram shows the aluminium canister immersed in a water bath in a 3 litre beaker. Pressure and temperature sensors are also in use.

Looking at the graphs overleaf (Fig. 5), it can be seen that the pressure values are stepped. Because of the analogue to digital converter in the *500 Interface*, pressure is resolved in steps of approximately 0.5 kPa. In both graphs, the pressure range is between 48.5 kPa and 53.5 kPa. There are only 10 jumps and 11 values in the lower graph. That explains why the uncertainties ($\pm 20^\circ\text{C}$) are large.

We may conclude that the gas laws can be satisfactorily conducted with quite short temperature ranges provided that the sensors are accurate and the other general conditions laid down in the introduction are met.

Result 10 was obtained in the conventional way. The canister was immersed in cold water in a 3 litre, tall form beaker and firmly clamped (Fig. 6). The water was heated with a Bunsen and nine pairs of readings were taken. Because of the larger temperature range (80°C) the uncertainty was smaller ($-278 \pm 12^\circ\text{C}$).

A comparison of results 5 to 10 shows that the uncertainties depend on the number of quantized pressure levels in each data set, which itself depends on the pressure sensor's 0.5 kPa resolution (Table 3).

It is concluded that the pressure sensor CI-6532 is suitably accurate and has an adequate resolution for gas law experiments. However if the sensor were to be redesigned by replacing the pressure device with one whose range is 200 kPa, then its resolution might be 0.1 kPa, which would be better.

Reverting to the Gas Law Experiment, because aluminium has a large coefficient of thermal expansivity, the p - T gradient is erroneously low. Correcting for this error would cause the results to shift up by about 7°C . For instance if the correction were to be applied to result 10, its value shifts from $-278 \pm 12^\circ\text{C}$ to $-271 \pm 12^\circ\text{C}$.

The report on the Gas Law Experiment continues within the article on Boyle's Law to be published in the next issue.

PASCO Heat Engine : TD-8572 : £278

The apparatus is set up as shown in the diagram (Fig. 7). The piston is clamped at the foot of the cylinder, minimizing the fraction of air outwith the temperature bath. The instruction manual directs that the temperature sensor should be sited within the air chamber. This is wrong for the reason already given. In fact we recorded a difference of 20°C between readings made inside the air chamber and in the water bath, showing by how much the wrongly sited thermometer lags behind the actual air temperature.

The main limitation of the apparatus is leakage of air at the piston. This shows up in the p - T graph as a gentle curve – the only instance in all of these methods where the p - T graph is not a straight line. Given this defect, the results ($-296 \pm 18^\circ\text{C}$ and $-284 \pm 30^\circ\text{C}$) seem tolerably fair. In reality they are obtained by fitting a straight line through a curved graph, which is unsatisfactory.

Result label	Lowest pressure / kPa	Highest pressure / kPa	Number of pressure levels	Uncertainty / ∞C
5	90.3	123.5	67	± 6
6	90.8	122.1	63	± 7
7	91.8	122.6	62	± 7
8	48.8	53.2	10	± 20
9	48.8	53.2	11	± 20
10	53.7	67.9	29	± 12

Table 3 Performance of PASCO Absolute Pressure Sensor CI-6532 in gas law experiments. The size of uncertainty is inversely related to the number of quantized pressure levels in a data set.

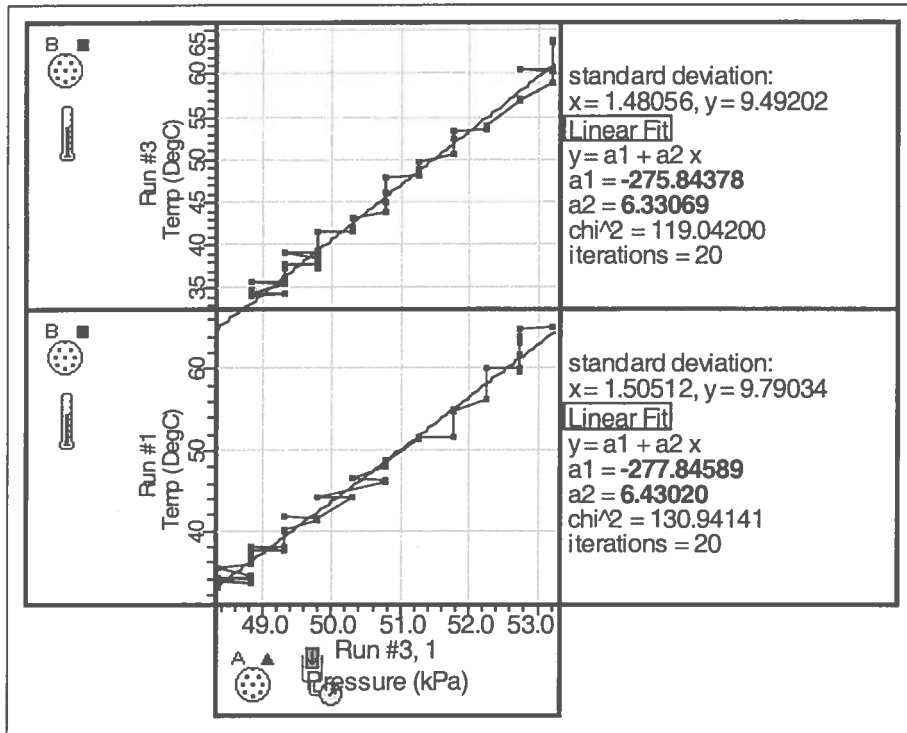


Figure 5 Results 8 and 9 obtained with the canister from the Gas Law Experimenter in a basin of hot water which was left to cool. Results graphed with *Science Workshop*. The pressure values jump by steps of 0.5 kPa.

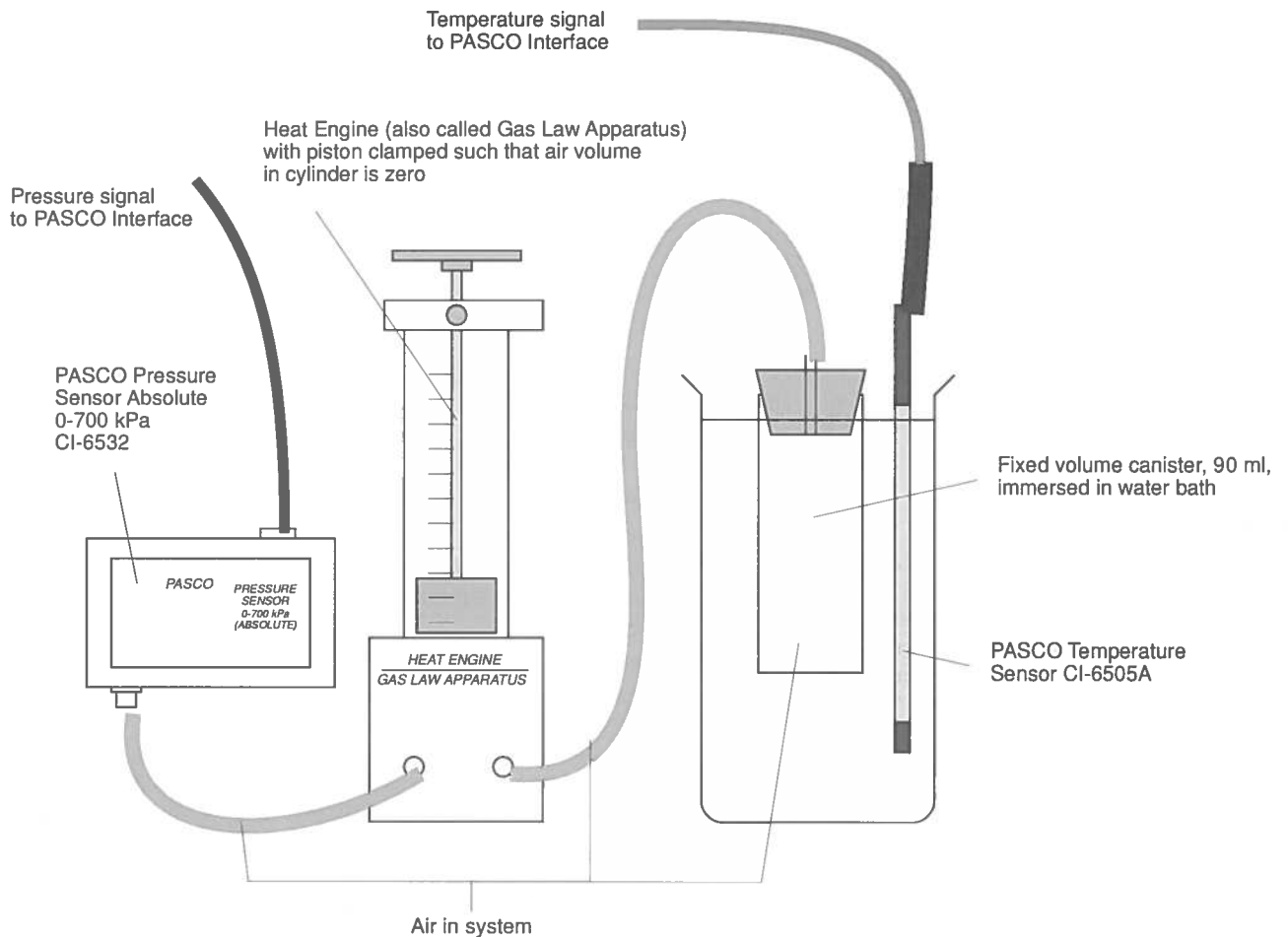
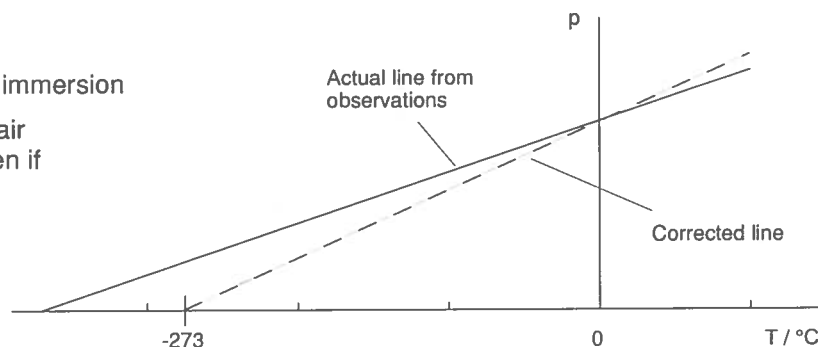


Figure 7 Showing the p - T law with apparatus from the PASCO Heat Engine.

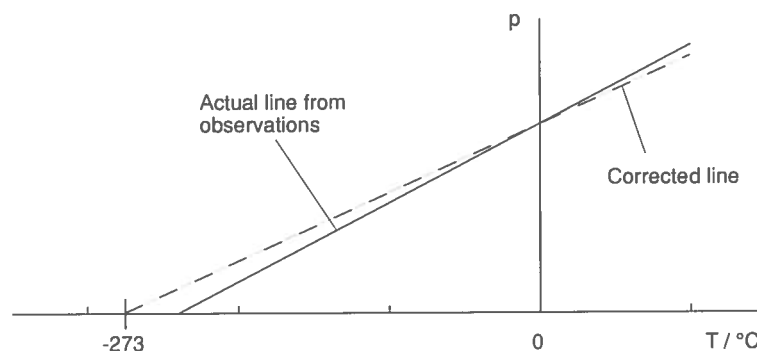
CAUSE OF ERROR : Incomplete immersion

EFFECT : At high temperatures, air pressure is less than would happen if the entire air chamber were immersed in the water bath. Results in the value of absolute zero being too low.



CAUSE OF ERROR : Vapour pressure

EFFECT : If air not dry, or if there is oil vapour, then at high temperatures the vapour pressure increases the recorded pressure a little further. Results in the value of absolute zero being a little too high.



CAUSE OF UNCERTAINTY : Random and systematic effects
EFFECT : Creates doubt in the value of absolute zero.

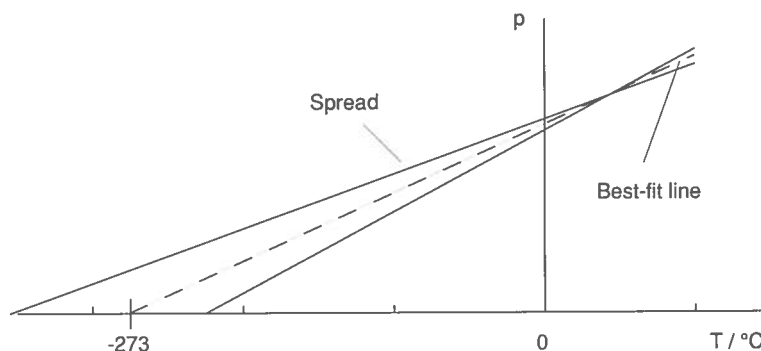


Figure 8 Effects of errors and uncertainties on the pressure-temperature experiments.

This apparatus will be reported on again in an article on methods for showing Boyle's Law, to be published in the next issue. Regarding this experiment, the Heat Engine is redundant. It plays no part in the experiment and should be omitted.

Conclusion

This Bulletin issue has carried a review of methods and apparatus for showing one of the ideal gas laws, namely the pressure-temperature law. Excellent results can be obtained provided that the experimenter attends to detail. Interestingly, in these particular experiments, the use of ICT does not give better results than the methods dependent on traditional apparatus.

Both the STE *Jolly's Bulb* and PASCO *Absolute Pressure Sensor* CI-6532 are recommended for showing the p - T law in Higher Still Physics. The PASCO *Gas Law Experimenter* would also be useful in this application.

The set of idealized graphs above (Fig. 8) show the effects of some of the more common sources of error.

The next issue will review methods and apparatus for showing Boyle's Law. Finally it will comment on the ideal apparatus concept with which, if it existed, all three gas laws might be shown.

Acknowledgement

We are grateful to Nicola Jones for doing much of the benchwork and analysis for this report. Nicola is now in her fourth year at Edinburgh University, where she is studying physics.

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- 1 Nuffield Physics : *Guide to Experiments 3* Longmans 1967 Class experiment 77.
- 2 *Activities 20A and 20B : Relationship between pressure and temperature of a fixed mass of gas at a fixed volume* Physics Higher Higher Still Support Materials HSDU 1998.
- 3 Nuffield Physics : *Guide to Experiments 3* Longmans 1967 Class experiment 77.
- 4 Jim Jardine *Nat Phil 'O'* Heinemann Educational Books London and Edinburgh 1974 Fig. 10-9.
- 5 Gas law experiments: Part 1 SSERC 1999 Bulletin 197 20-27.

Practical work with ICT

When, and why, might the use of ICT in practical work be appropriate?

Recent issues of this publication have carried a good deal of material on Information and Communications Technology (ICT) in science and technology education. That is not to say that we have accepted without question all of the undoubted hype which surrounds some recent ICT investments and initiatives. SSERC's avowal that we are but sceptical enthusiasts was meant to be taken seriously. The results of last summer's research programme, into apparatus for investigating and illustrating the gas laws, provided evidence that the quality of experimental results does not necessarily depend on ICT (see report in the previous article beginning on page 6, with, or after, which these notes are best read).

If that is so, then when might there be persuasive reasons for using ICT and what other factors might determine when educational uses are appropriate or otherwise?

ICT in datalogging

The evidence from our programme of testing apparatus shows that electronic sensors for use with computer interfaces or dataloggers not infrequently are less accurate than traditional instruments. For instance we recently tested an ultrasonic motion sensor, now superseded after our condemnation, finding that it had a resolution of 4 cm. Clearly the luddite with his metre stick marked in millimetres is better off. He can measure to about one hundred times better resolution.

To give another example, a comparison of temperature sensors showed that the one with the lowest error was the traditional mercury-in-glass thermometer. This sort of observation is not new, especially with regard to spot measurements. For example, the folly of using an electronic sensor and datalogger for simple, straightforward temperature records has been a well kent phenomenon since the early DIY days of interfacing.

The matter is not always quite so simple. With the motion sensor coupled to the processing power of the computer, successive values of distance can be recorded and worked out rapidly. We can then, in principle at least, quickly get information on derived quantities such as velocity and acceleration. But as the saying goes, "Rubbish in, rubbish out." Thus at the resolution typical of some school motion sensors you will be incapable of adequately monitoring the movement of a laboratory trolley.

In straightforward measurements where changes are relatively slow, variables few and relationships causal then using ICT may well not confer significant advantage when viewed from any objective stance. There may be other reasons for such applications but these need the most careful consideration.

ICT and the gas laws

Comparing our own results for the various pressure-temperature law methods (see Table 1 on page 6), there seems to be no significant difference between the best sets of results for traditional and ICT means.

The best sets of results with traditional equipment were obtained with Jolly's bulb apparatus. Being a sealed system, we were unable to dry the air. The direction of the error in the mean value, of -267 ± 6 °C, suggests that the results were indeed affected by water vapour pressure. If this explanation is accepted, these results do not seem significantly worse than those obtained with a PASCO pressure sensor fitted to a chamber filled with dried air. Both methods gave results consistent within themselves and close to each other. The only significant difference was that the air chamber used with the ICT apparatus could be opened, allowing for the flask and air to be dried. But this has no bearing on the relative qualities of ICT assisted and traditional methods.

If we compare the time taken by an experienced observer in getting sets of readings from both methods, the ICT method is the ostensible winner, taking 19 minutes as against 25 with the Jolly's bulb apparatus. The winning margin of 6 minutes is the time taken by the observer to read and write down ten pairs of measurements of temperature and pressure. With the ICT method, data sets are captured with a single key press.

Other factors in a comparison are the time to set up and clear away equipment, the time taken in learning how to operate the system and the time taken to analyse the data and extract results. Apart from the final matter, the traditional method wins easily. It is intuitively obvious in the direct method how to set up and obtain readings. It is instructive to list the items in the computer assisted method. They comprise: notebook computer, computer power supply, mouse, mouse mat, interface, interface power supply, interface to serial port lead, pressure sensor, pressure sensor tubing, temperature sensor, and other parts shared with the traditional method. Common faults include not powering up the interface, forgetting to make a connection, not making a good connection and forgetting how to operate the software. The last of these is probably the greatest difficulty. Although software is generally designed to be intuitively obvious, one single hitch can block proceedings, or a mistake can send you back to the beginning. Or even worse - suppose a pupil has meddled with the program or the operating system. How do you get out of that fix? One solution is to have on hand an ICT technician (a policy actually advocated by Jerry Wellington at the Institute of Physics Education Group 1999 annual conference). Another, possibly more practicable, is to use ICT kit and software sufficiently often as to avoid oft repeated ascents of the self-same learning curves.

Some teachers have drawn attention to what they call *experimental noise*, by which they mean factors which distract pupils from perceiving what the purpose of an experiment really is. For instance, in the pressure-temperature experiment one such distraction might be messing about with water. It has recently been asserted by Barton that noise can be reduced by replacing some traditional methods with ones based around a computer. In a well designed system under pupil control, or teacher demonstration, it may well be that much of the noise can be so avoided. The results, especially when graphed, can appear to be impressively clear. However, bearing in mind the guddle of equipment as listed above upon which some computerised versions may depend, the risk of noise distracting pupils in poorly designed ICT-assisted activities would seem to be at least equally great as those in more traditional practicals.

Our comparison of methods in physics had to be, understandably, with an experiment which can readily be done with traditional equipment. Where ICT methods clearly score in physical science are those experiments under more difficult conditions, such as those requiring fast data capture. There may be other instances, for example in biology or chemistry, where the advantage arises otherwise - say from a need to record many variables, or to log data over an extended timescale. Equally, not every process or principle is a matter of causality as here in these gas law examples. In some branches of science we may be as interested in complex relationships between sets of variables whether quantitative or qualitative. We may be interested in apparently minor, but still significant, differences between large data sets or in other aspects of correlation. We may be looking for a relatively small change in an otherwise steady background reading or trend. We may need to control as well as measure a number of variables. ICT clearly has potential in some or all of these areas of investigation. The trick lies in choosing and designing activities to exploit that potential and avoid the pitfalls. For our current examples from physics, however, we can readily summarise the comparison between the trad and the trendy. The results in this instance look like:

Activity	Winner
Quality of scientific results	DRAW
Time taken to obtain data	ICT
Time taken to set up and clear away	TRAD
Overall operational difficulties	TRAD
Likelihood of a fault occurring	TRAD
Experimental noise	DRAW
Extreme or complex conditions	ICT
Graphical presentation	ICT
Data analysis	ICT
Theoretical modelling	ICT

The factors tabulated at the foot of the previous column all have different weightings. Readers may rank them differently according to their interests. The author places quality of the actual measurements at the top of his list. If that is not assured, then the other factors seem of little or no importance. The telling outcome of the work reported on for the gas laws is that the quality of experimental results does not appear in general to depend on whether the method uses, or does not use, ICT.

Graphs, analysis and modelling

Continuing with the more objective aspects of this comparison, it is the computer's ability to graph data and allow that graphical display to be manipulated and analysed which seems to be where the ICT method streaks ahead of the traditional. Look at the graphical presentations for the pressure-temperature law in the previous article. Data points can readily be plotted with error bars with a best-fit straight line fitted through them (Figure 5, page 11). This line can then be extrapolated to cut an extended temperature axis and the graphs printed out for pupils to retain.

The analysis might then proceed by drawing a proportional plot for p against T , where the origin is 0 kPa and 0 °C. This clearly would be silly. The matter is resolved by rescaling temperature, or inventing the absolute scale. This is achieved by adding an extra column, which we call *Corrected Temperature*, to the table of results. The values in this column are the measured values to which is added 273 °C. When pressure is replotted against corrected temperature, it is now possible to fit a proportional plot through the data.

The concept of direct proportionality can be explained by moving the cursor from place to place on the p - T line. For instance if the cursor is set at 150 K and the corresponding pressure value read, then if the cursor is moved to 300 K, it should be seen that the new pressure value is twice the previous one.

An example of theoretical modelling will be given in the next Bulletin issue, where we will be writing about various methods for showing Boyle's Law.

Subjective factors

When this article was first mooted, there had been no intention that it might stray from the path of objectivity. We are scientists. It thus behoves us to at least strive to be intellectually open and honest in reporting our findings. Yet, in the contexts of learning and teaching, there are other factors which might have to be taken into account. For example if you witness a slick, professional demonstration performed by a skillful teacher using up to date technologies, you can be filled with wonder and delight. Your motivation to know more of science and its methods may improve.

There is also the less tangible but important business of the image of science. We live in an era where electronic media and communication methods are seen as part of *the spirit of the age*. Whilst as scientists and educators we need always to concentrate on the message rather than the medium, it would be folly for us to ignore these subjective aspects of ICT usage of which more, some other time.

* * *

BASIC Stamp : Part 3

Further information is provided on ongoing work at Arbroath High School in which a peripheral interface controller is used for teaching control technologies.

Background

In the Equipment Notes section of Bulletin 197 [1] we described a number of educational applications of peripheral interface controllers or PICs. As part of those reviews it was indicated that this was a topic to which we might return. In particular, we just about promised to bring you the further adventures of the Arbroath High BASIC Stamp project.

Somewhat earlier than anticipated it has proved possible to give readers both an overview of a teaching sequence and illustrations of some of the models which have been developed as aids to pupils' learning. The modelling approach used in Arbroath High, and described below, has some similarities to that developed by Danny Burns firstly for Standard Grade Technological Studies and in collaboration with Ian Buchanan here at SSERC then adopted also for Technological Studies at the Higher Grade. In illustrating this newer work, we have taken the same approach as we did earlier when Technological Studies was first brought in. Samples of the course materials and photographs of typical models are provided.

Control and 5-14

This new work at Arbroath High is intended for S2 classes (Year 9) and currently is being piloted at that level. We see no good reason, however, why it could not be introduced also into Standard Grade Technological Studies. If we assume (which is always dangerous) that the control element will remain in school based courses, both at 5-14 Environmental Studies and at the Standard Grade, then we would commend this kind of model or case study based approach. Figures 1 and 2 below show scaled down versions of the cover and simple technical notes from a Pupil Handbook for the course.

The structure of Alan Whyte's course is based on the idea that the pupils are given tasks to program a BASIC Stamp to control models which are themselves based upon a selection of everyday machines. This they do using a DIY Stamp Board (the *Stamp Interface*) and a set of thirteen different models designed and constructed by Alan Whyte himself.

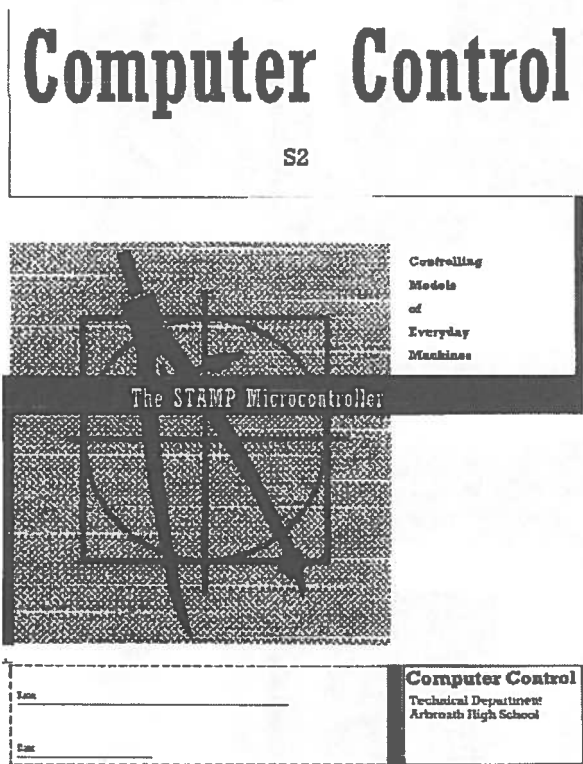
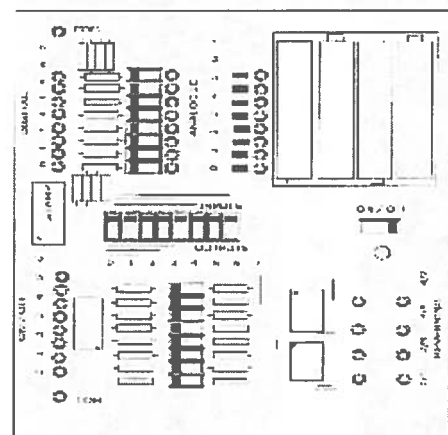


Figure 1 Title page of Pupil Handbook

THE STAMP INTERFACE



There are two versions of the STAMP INTERFACE, one where the STAMP CONTROLLER is connected onto the interface on the left hand side, the other where the STAMP is part of the INTERFACE assembly. Both work exactly the same way. The INTERFACE is switched on by means of a slide switch located by the insertion of the right hand LED indicator when switched on.

A row of eight slide switches located horizontally in the centre of the INTERFACE are used to select which of the communication lines (0 to 7) are inputs and which are outputs. UP for inputs, DOWN for outputs.

A row of eight slide switches located vertically at the top of the INTERFACE are used to select whether these inputs are either digital or analogue. LEFT for digital, RIGHT for analogue. The analogue lines have two connectors, the digital lines have one connector and a common at the top.

A row of eight slide switches located vertically at the bottom of the INTERFACE are used to select whether the outputs are straight through or whether they are reversing. LEFT for on/off, RIGHT for reversing. The on/off outputs have a common connector at the bottom of the board. Since it requires two lines of communication for each reversing output (one for on/off, and one for reverse/over-ride), there are only four outputs. They are connected as follows:

FORWARD - LOW HIGH 1 LOW HIGH 3 LOW HIGH 5 LOW HIGH 7
 REVERSE - LOW HIGH 0 HIGH 2 LOW 4 HIGH 6 LOW 8

Figure 2 Pupil Handbook : Outline of Stamp Interface

S2 Course Structure

The course is based around a sequence of tasks. These, typically, each comprise of entering, adapting or actually constructing a control programme on a computer, then downloading the resulting command sequences to the BASIC Stamp chip. The next step is for the pupil(s) to use the interface to connect the control chip to the particular model under investigation and run the program to test it.

The sequence of tasks in current use for the Arbroath course is tabulated in Table 1. The order is hierarchical in an attempt to build in some progression. That is, the tasks are deliberately sequenced from the relatively simple to the more demanding. Some of the models used for these tasks are shown in the sequence of illustrations captioned as Figures 3 to 5 inclusive, whilst Figures 6 and 7 (opposite) provide examples of data sheets for pupil tasks using digital inputs .

GIVEN PROGRAMME	FUNCTION	PUPIL PROGRAMME
Disco lights	on/off outputs	traffic lights
Game show selector	inputs/outputs	pelican crossing
Spin dryer door lock	multi inputs/outputs	burglar alarm
Garden pond pump	analogue input/output	skin temperature alarm
Boat rudder control	multi analogue input/output	sterilising unit
Sports arena display	reversing output	carnival carousel
Lottery drum	digital input/reversing output	up and over garage door
Automatic window blinds	analogue input/reversing output	constant temperature fan

TABLE 1 Sequence of control tasks

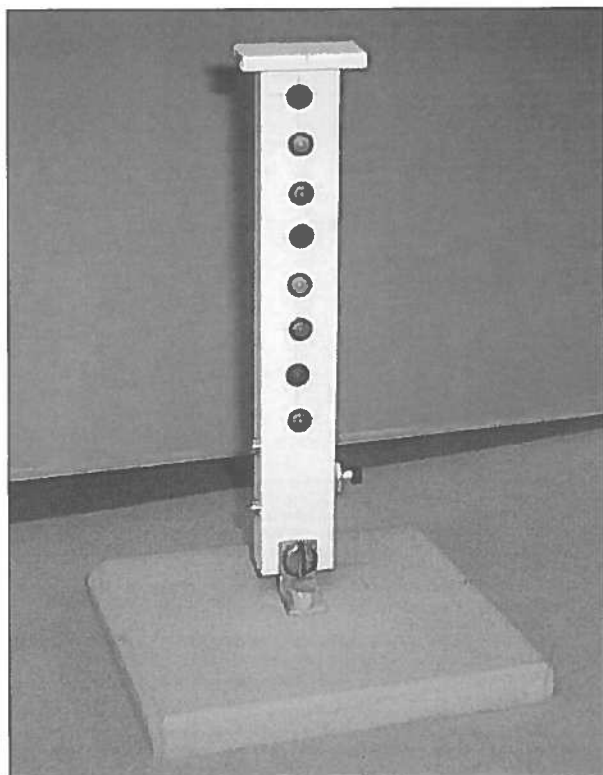


Figure 3 Disco lights model which also subsequently serves for a traffic light exercise and then extends into a pedestrian crossing application.

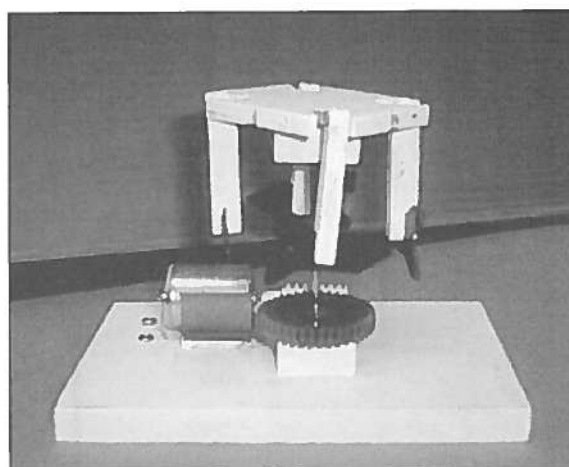


Figure 4 Fairground carousel or roundabout model

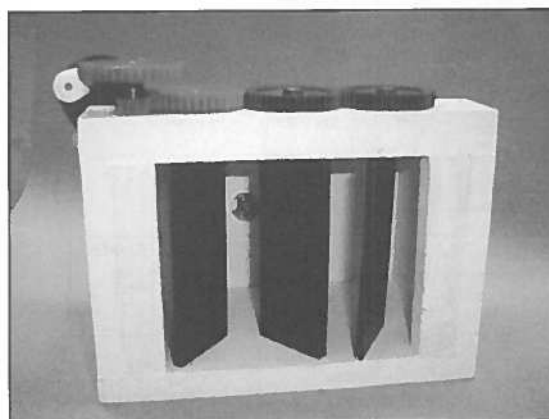


Figure 5 Automatic window blinds

MULTI-DIGITAL INPUTS - ON/OFF OUTPUTS

Spin Dryer Door Lock

The door of a spin dryer is kept locked by means of a solenoid. The spin cycle can only begin when the door is locked. To lock the door, the main switch must be on and the door closed. A small reed switch is closed when the door is shut. The spin cycle takes 30s. The door can only be opened when the machine has finished its cycle and the main on/off switched is set to off. Even after both switches are off, the door does not unlock until after a delay of 10 seconds - this makes sure the drum has stopped rotating before anyone puts their hand in to remove clothes. Using the STAMP controller, design a solution.

Go through the problem solving sequence: -

1) We will need two on/off outputs and two digital inputs.

2)

Pin No	0	1	2	3	4	5	6	7
DIGITAL IN		X	X					
ANALOGUE IN								
ON/OFF OUT				X	X			
REV OUT								

3) Set the first two switches to input.

Set the third and fourth switches to outputs - it does not matter about the rest.

Set the first two input switches to digital.

Set the third and fourth output switches to on/off

4) Connect the interface to the model - remember to connect the inputs to COM and the output to COM

5) Draw a flow chart

Use a motor as a spin dryer.

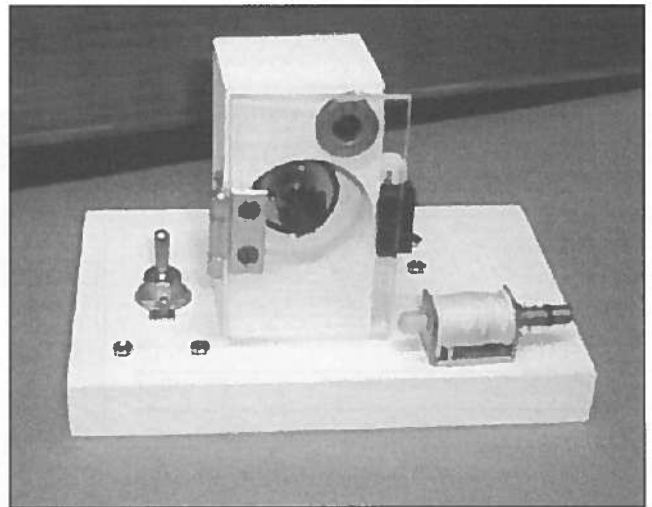
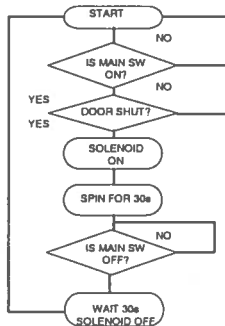


Figure 6 Spin dryer model used for task shown in the pupil data sheet in the lefthand column

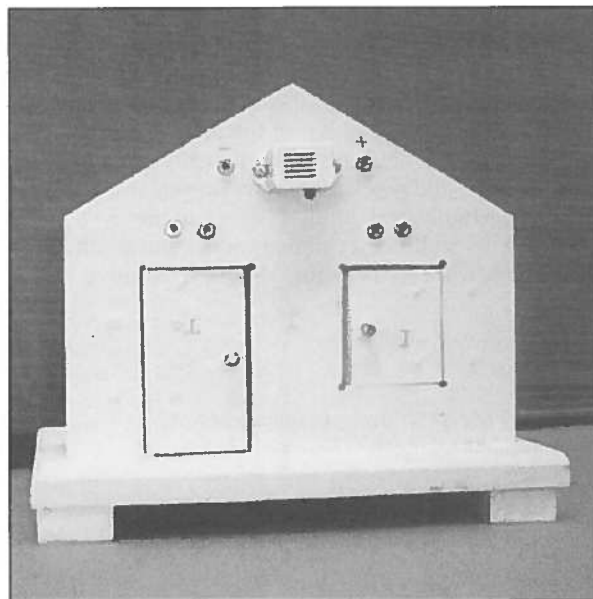


Figure 7 House model used for task shown in the pupil data sheet in the column opposite

MULTI-DIGITAL INPUTS - ON/OFF OUTPUTS

Task - Burglar Alarm

- A small flat has one door and one window.
- An alarm is to be fitted to operate in the following manner:
- The main on/off switch is hidden and only known by the occupant.
- Both the window and door have small micro-switches which close when either door or window is opened.
- When switched on, the alarm is not active until 10s have passed, to allow the occupant time to leave the flat, and when the door is opened, the alarm will sound after 10s unless the main switch has been switched off by the occupant, thus allowing time to return to the flat.

Solution

- 1) How many pins are required? . . .
- 2) Indicate them in the table below.

PIN NO	0	1	2	3	4	5	6	7
DIGITAL IN								
ANALOG IN								
ON/OFF OUT								
REV OUT								

- 3) Set all input/output switches on the interface.
- 4) Connect the interface to the model.
- 5) Draw a flow chart.

ANALOGUE INPUT - ON/OFF OUTPUTS

Task - Skin Temperature Alarm

In a hospital, the skin temperature of new born babies is to be constantly monitored. This is done using a thermistor taped to the skin. Should the skin temperature fall a few degrees below normal, a red light on the monitor comes on. If the skin temperature falls to excess, then an alarm buzzer will sound. Although there is no on/off switch, there is a reset button to cancel the alarm. Pressing this will switch off the alarm and restart the monitor after a delay of 30s, thus giving nurses time to bring up the temperature. Use the BASIC Stamp to model this situation.

Solution

- 1) How many pins are required?
- 2) Indicate them.

PIN NO	0	1	2	3	4	5	6	7
--------	---	---	---	---	---	---	---	---

DIGITAL IN

ANALOG IN

ON/OFF OUT

REV OUT

- 3) Set all input/output pins on the interface.
- 4) Connect the interface to the model.
- 5) Draw a flow chart

Hints:-

- Heat the thermistor in your hand to get a normal temperature reading, then allow it to cool to room temperature and take another reading.
- Use two numbers between these readings to first put the red light on, then sound the alarm buzzer.
- Remember to take a note of both Scale and Readings to use in your programme.

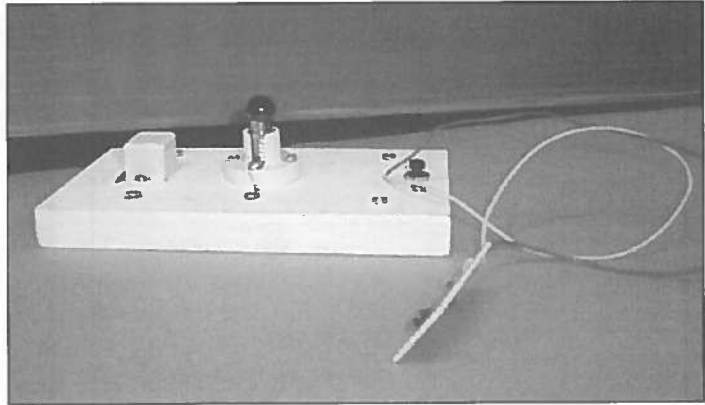


Figure 9 Model used in skin temperature alarm application with analogue inputs. The data sheet for pupils is shown opposite.

The example shown as Figure 9, and described in the data sheet shown above, is of interest (especially to those who may be presenting at Higher).

This is a control application using a PIC with an analogue input. So far pupils at S2 seem more than capable of dealing with such an application. Contrast that practical experience with the advice offered in the relevant section of the Scottish Qualifications Authority (SQA) Data Booklet for Technological Studies. That states that analogue inputs are:

“ . . normally outwith the scope of Intermediate 2 and Higher ”

Summary

In a relatively short article such as this, it is really only possible to give a flavour of such a technology course for the later levels of 5-14. At a time, however, when many are looking for ways to improve learning experiences across courses in S1 and S2, Alan Whyte's work at Arbroath High provides several elements which we see as examples of good practice. We are very grateful both to him and his headteacher for permission to publish this review.

The work has the potential to provide a sound introduction, for the lower secondary cohort, to basic electronics and mechanics (simple levers and gears). Importantly, in setting tasks requiring the use of a programmable interface controller, it puts such work firmly in a contemporary context - that of a relatively modern control technology.

Other elements of good practice include deliberate provision of both progression through, and coherence in, the course. Such thoughtful approaches may then carry forward into Standard Grade and on into Higher Still courses. In short, we judge that this kind of work holds considerable promise.

We would appreciate, and look forward to, the receipt of comment and constructive criticism on such an approach to course construction for technological subjects. It should go without saying but . .

We will naturally tend to give more weight to any views which we get from classroom practitioners. Non-practitioners and the apparently technologically illiterate may have had more than their fair share of influence in recent times. It's probably well past the hour someone made a fist of this technology education business, in S1 and S2 especially. Judging by the exam presentation statistics for Technological Studies here, and the reported state of health of technology education south of the border *they*, whoever *they* are, should get a move on.

Reference

1. *PICs again - The BASIC Stamp*, Equipment Notes, Bulletin 197, SSERC, 1999.

**SAPS Biotechnology Scotland Project
Teacher Vacancy**

As indicated in the last issue, the Steering Group for the above project has begun the process of looking for a second-tee to succeed Rodger MacAndrew the current postholder based at Edinburgh University. We are pleased to carry an advertisement for the post in this issue - see below.

SAPS Biotechnology Scotland Project

**RESEARCH AND DEVELOPMENT
TEACHER**

(2 year or 23 month appointment/secondment)



Based at the University of Edinburgh you will be responsible for:

- developing lively and innovative practical work in plant science and biotechnology
- sharing the ideas which you help to develop through a programme of workshops for teachers and technicians
- working closely with other organisations in this field to maximise the impact on the Scottish curriculum

In your research and development work you shall build on the achievements of the current post holder and maintain the SAPS tradition of excellent and practical support for biology teachers and technicians.

You will be a science graduate, an experienced and well qualified teacher with recent, relevant experience of teaching biology in a Scottish secondary school.

The appointment will be for up to two years, starting in August 2000. Salary will be dependent upon previous experience but is likely to match that offered to a Senior Teacher or a Principal Teacher of Biology, as appropriate. A period of secondment may be negotiated for a suitable applicant in which instance the appointment will run for a period of 23 months.

The closing date for applications is 25th February 2000. For an application form and further particulars please contact:

Richard Price, SAPS Director, Homerton College, Cambridge CB2 2PH

Telephone: 01223 507168 or e-mail rwhp100@cam.ac.uk

Colorimeter review

Specifications, test procedures and results are summarised for colorimeters from Griffin, Philip Harris and WPA with a 'best buy' suggested.

Colorimeters are required in a number of practical activities in biology and chemistry courses published as part of the Higher Still programme. Some of the biological applications were briefly described in the last Bulletin issue but only one model of colorimeter was mentioned [1]. Here, work with three different models is described and their performances are compared.

For those unfamiliar with such instrumentation we begin with a brief summary of the background theory of colorimetric analysis.

Colorimetry

The study of variations in the pattern of light absorption of a system with changes in concentration of some component or other of that system, is called colorimetric analysis. Generally the colour of such systems is due to the formation of a compound by the addition of a reagent, or it may be inherent in the material itself. Colorimetry is concerned with determining the concentration of a substance by measuring the relative absorption of monochromatic light and comparing this to a known concentration of the same substance.

The intensity of light transmitted through a solution (and conversely the amount absorbed) depends upon the amount of coloured species present. As the concentration of the coloured species increases, the colour becomes more intense and less light is transmitted through the solution.

The use of colorimeters in quantitative chemical analysis relies on the Beer-Lambert Law, which states that, within certain limits¹, the amount of light absorbed by a solution is directly proportional to the molar concentration of the absorbing species.

Colorimetric analysis is relatively quick and easy to perform when compared to other methods for determining the concentration of a substance. With simple construction techniques and a slight knowledge of electronics, it is possible to build your own instrument but that is outwith the scope of this present article.

Three commercially available models of colorimeter intended for the educational market were tested recently by SSERC (see Table 1 opposite) and are reported on here. In each case the mains operated model was tested but battery operated models are also available.

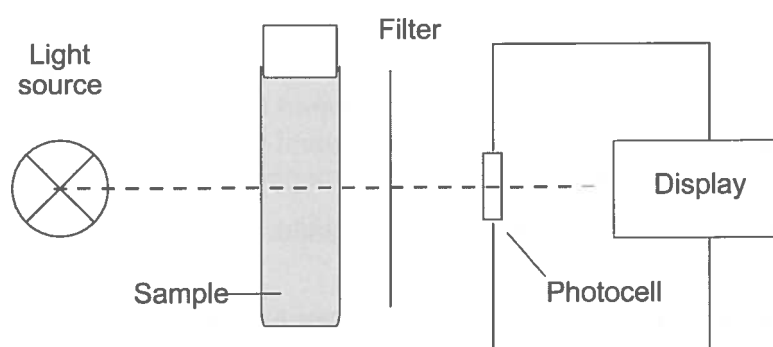


Figure 1 Schematic diagram of colorimeter system showing the essential components : light source; a filter or other mechanism for selecting an appropriate wavelength of light; a photo detector and an analogue or digital display.

Footnote : The Beer Lambert Law only operates for : dilute 'true' solutions over short path lengths. For suspensions, colloidal solutions etc the scattering of light becomes more important in a measurement technique termed 'nephelometry'.

Make	Model	Power source	Display	Supplier	Cost
Griffin	Model 41	Mains operated	Analogue	Griffin	£280.00
Philip Harris	S-Range	Mains operated	Digital	Philip Harris	£358.25
WPA	CO75	Mains operated	Digital	WPA	£280.00
As above	COJ-450-10T (CO75 Equivalent)	" "	"	Griffin	£234.00

Table 1. Colorimeters reviewed in this article.

Test and assessment criteria

In making an assessment of the suitability of these colorimeters for use in schools we assigned ratings on a three point scale in each of four broad aspects of overall performance : design; ease of operation; performance in selected activities in Scottish courses and electrical safety.

Our ratings in these sub-categories were assigned according to the scheme set out in the Text Box below. These ratings were then combined to arrive at an overall assessment of general suitability for use in Scottish schools and colleges.

1. Design:		4. Electrical Safety:	
<i>Rating</i>	<i>Criteria</i>	<i>Rating</i>	<i>Criteria</i>
A	Robust enclosure and parts. Secure fitment of parts. No significant weakness.	A	Complies fully with IEC 1010-1 as far as our tests are able to indicate, except for minor infringements; has no appreciable risk for use in schools or colleges.
B	Minor significant weaknesses identified.	B	Complies in general with IEC 1010-1, but one or more features where there is a very small risk of harm.
C	Major weaknesses identified.	C	One or more features present an unacceptable risk of harm.
2. Operation:		The ABC rating in general stands for:	
<i>Rating</i>	<i>Criteria</i>	A = Good B = Fair C = Poor	
A	Controls clearly marked. Operation simple, clear and obvious.	Overall Assessment Ratings :	
B	Minor weaknesses identified.	A = Most suitable for use in schools and non-advanced FE.	
C	Awkward to work with, or misleading to operate.	B = Satisfactory for use in schools and non-advanced FE.	
3. Performance:		C = Unsatisfactory.	
<i>Rating</i>	<i>Criteria</i>		
A	Performs to or near specification.		
B	Significant minor underachievement.		
C	Significant underachievement.		

Test Findings and Assessment Summary

Our test results are summarised in Table 2 below with short form test reports provided thereafter. Full technical reports, with supporting data etc, are available on request from the Director of SSERC.

All three colorimeters would be suitable for use in schools. However, there are some significant differences in price, ease of use and size.

The CO75 and S-Range models are well-designed, reasonably robust and easy to use. Of these, the CO75 is considerably cheaper and smaller although, unlike the S-Range, it does not produce transmission figures.

The Griffin Model 41 produced satisfactory results, but we found the cuvette compartment adapter a bit flimsy and cumbersome to work with. In addition, we found the procedure for referencing the filter (zeroing) to be time-consuming. Whilst this colorimeter is mainly well engineered, we did uncover a small number of minor electrical hazards which we reported to Griffin. Our assessment rating of this unit is subject to these being resolved.

Colorimeter	Design	Operation	Performance	Electrical Safety	Assessment
Model 41	B	B	A	B	B*
S-Range	A	A	A	A	A
CO75	A	A	A	A	A

*Overall rating on Model 41 is subject to resolution of the minor problems associated with electrical safety being resolved.

Table 2 Summary of assessments against stated criteria

Short form reports

Griffin Model 41 Cat. No. COJ-530-010C Display - analogue Price £280
Supplier Griffin & George [Fisher Scientific (UK) Ltd.]

This colorimeter (Figure 2, opposite) is supplied complete with filters to cover the range 470-680nm, mains lead, holders for filters, stray light cover, instruction book, test tube and cuvette adapters.

Spares are also available from the same supplier e.g.

COJ-534-010B	Set of 8 filters	£22.00
COJ-534-020V	Spare bulb, set of 3	£13.00
CXA-100-020U	Cuvettes, disposable pack of 100	£4.05

(cont./opposite page)



Figure 2

Description

The Model 41 is operated from a 240 V, 50 Hz mains supply. The instrumentation is housed within a metal body. Fitted on the top panel of the device are a three-position sensitivity switch, a fine sensitivity continuous control, a mains on indicator (green LED) and the cell holder. The analogue display is on an angled panel at the front of the instrument with 4 mm *kinetics* output sockets for connection to a chart recorder or computer interface being located on the back panel of the device. There is also a shelf on the left of the instrument, which provides storage for the filters, cell holder adapter and cover.

The filters are provided as a series of seven drop-in gelatin types, as shown in Table 3 below.

Filter no.	Nominal colour	Wavelength (nm)
2	blue	470
3	green/blue	490
4	green	520
5	yellow/green	540
6	yellow	580
7	orange	600
8	red	680

Table 3 Filter set characteristics

The output sockets (4mm) enable connection to a chart recorder or computer interface for continuous absorbance readings.

Performance

A series of solutions with known concentrations of KMnO_4 and CuSO_4 were accurately prepared and their absorbances measured (Figures 3a and 3b below). A straight-line direct relationship between absorbance and concentration should result. Deviations from a straight line suggest optical or other defects in the instrument. For this model, the maximum error in each of these plots did not exceed 0.04 absorbance units.

Electrical Safety

Results of the PAT test (whole system). Earthing and insulation tests were carried out using a Megger PAT2 device.

Earthing - satisfactory, all exposed metal parts are adequately earthed.

Insulation - satisfactory.

There are two screws on the casing which secure an earth conductor and which are not labelled with the earth symbol. It would be preferable if they were double nuted inside to prevent accidental loosening from the outside but at the very least they should be labelled with the earth symbol. Additional screws that could be accidentally loosened include one fixed through the tag of the fixed voltage (6V) regulator for heat dissipation and another tapped into the potted psu (power supply unit) for anchorage.

Documentation

The instruction manual provided with this instrument contains a number of suggestions for practical work. Details of operating instructions and maintenance are brief and of limited assistance.

Summary

This instrument is reasonably priced and should be able to perform most of the routine tasks required of a school laboratory colorimeter. The cell holder will accept 10mm cuvettes or test tubes with the use of an adapter. A used instrument supplied for this evaluation raised concerns about the cuvette and test tube adapters. On this particular instrument, the adapters appeared worn and were difficult to fit and align. The variable (min/max) control is very sensitive and this caused difficulties when attempting to set the Transmission to 100%. We found that when using test tubes, significant adjustments to reset the Transmission to 100% were required between readings.

Overall assessment

*B ** (*subject to the problems associated with electrical safety being resolved)

Fig. 3a Potassium manganate(VII) - filter 6, 580nm (cuvette)

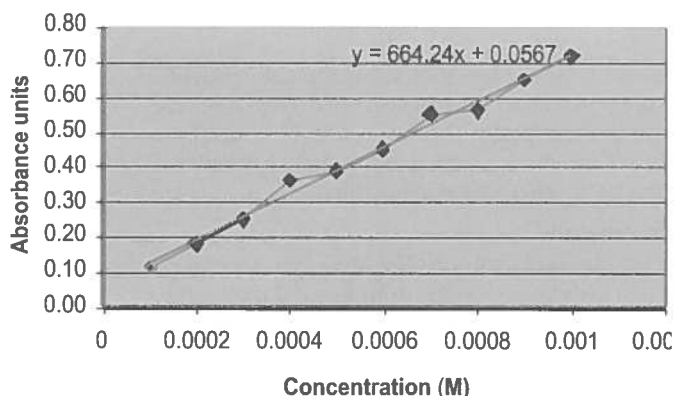
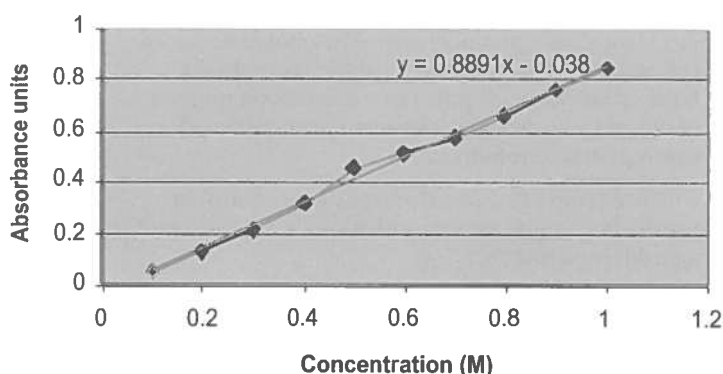


Fig. 3b Copper sulphate - filter 7, 600nm (cuvette)



Figures 3a and 3b Plots of absorbance v. concentration Griffin Model 41



Figure 4 Harris S Range Digital Colorimeter

Spares are also available from the same supplier eg :

R61030/4	Filter disc	£34.86
R61032/8	Spare lamp pack of 10	£12.93
R68800/7	Cuvettes plastic pack of 100	£9.05

Description

This colorimeter is operated from a 240 V, 50 Hz mains supply. The instrumentation is housed within a metal body with moulded plastic ends. Fitted on the top panel of the device are: a rotary knob for absorbance/transmittance selection, a push button PRESS to ZERO switch, the LCD display, two 4 mm female sockets for a 0-1 V output and the mains *on-off* switch with LED indicator. Access to the cuvette and filter holder sub-assembly is also via the top panel. This sub-assembly is designed to accept cuvettes only.

The manufacturers state that a constant light intensity from the incandescent bulb is maintained by a stabilised power supply circuit. The light beam passes through a glass infra - red filter, the cuvette and finally a second filter (pre-selected by a rotatable disc) to a silicon photodetector. The photodetector is connected to a logarithmic amplifier to produce a linear absorbance output. The transmission range is obtained by inserting an exponential amplifier after the logarithmic amplifier.

The circuitry features electronic gain control to provide automatic zeroing with a single depression of a pushbutton switch.

In the event of an accidental spillage of solution, a hole is provided in the base of the cuvette holder for immediate drainage. The whole assembly may then be easily removed for cleaning.

The tungsten lamp is easily replaced in the event of failure. The filters provided are a series of eight narrow band Ilford Standard Spectrum Filters (Nos. 610-608).

Filter no.	Nominal colour	Wavelength (nm)
1	violet	380-470
2	blue	440-490
3	blue/green	470-520
4	green	500-540
5	yellow/green	530-540
6	yellow	560-610
7	orange	580-700
8	red	625-i.r.

Table 4 Harris S Range colorimeter - filters

The 0-1 V output facility was traditionally provided to hook up to a chart recorder directly. This of course can still be done. It does however, provide scope for a number of interesting experiments using computer interfacing or other forms of datalogging.

Performance

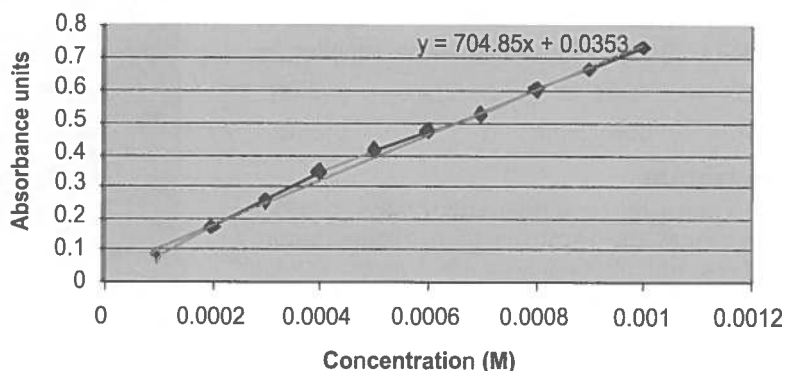
As for the tests on the Griffin Model 41, a series of solutions with known concentrations of $KMnO_4$ and $CuSO_4$ were accurately prepared and their absorbances measured (Figures 5a and 5b, opposite page).

A straight-line direct relationship should be the result. Significant deviations from a straight line suggest optical or other defects in the instrument.

The maximum errors observed in our tests, of this sample of the S Range instrument, were of the order of 0.02 absorbance units in the manganate (VII) test and 0.01 units in the case of the copper sulphate estimations.

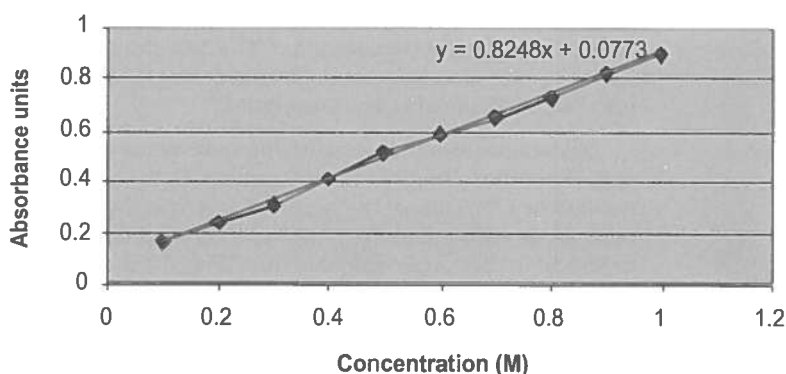
(See figures 5a opposite column and 5b, below).

Fig. 5a Potassium manganate(VII) filter 6, 580nm (cuvette)



Figures 5a and 5b Plots of absorbance v. concentration Harris S Range digital colorimeter

Fig. 5b Copper sulphate filter 7, 600nm (cuvette)



Electrical Safety

Results of the PAT test (whole system). Earthing and insulation tests were carried out using a Megger PAT2 portable appliance testing device.

Earthing - satisfactory, all exposed metal parts are adequately earthed.

Insulation - satisfactory.

It would be preferable however if the electrical rating plate was more positively fixed to the instrument base rather than just being glued on.

Documentation

The instruction manual supplied with the instrument is informative and easy to understand. The inclusion of more detailed information on requirements for interfacing would be useful.

Summary

This unit is priced within the upper range of the school colorimeter market. It is however well built, easy to use and although the design is beginning to show signs of its age, it should be able to perform most of the routine tasks required of a school laboratory colorimeter.

Overall assessment

A - most satisfactory for use in Scottish courses

cont./over

WPA CO75 Price £280

Supplier : WPA (Walden Precision Apparatus)

Spares are also available from the same supplier, eg :

CO75F	Spare set of eight filters	£40.00
CO75L	Spare lamp	£18.00

Description

This unit is operated from a 220/240V, 50/60Hz mains supply. The instrumentation is housed within a metal case with plastic side panels. A modern wedge shape ensures that any liquid spilled on the top surface runs straight off. On the top panel of the colorimeter are: the LCD digital display, a mains on indicator (green LED), a bulb on indicator (red LED), R-Reference (auto zero) press button, T-Test (spot reading) press button, the filter holder and the cell holder which will accept both 10mm cuvettes and 16mm tubes. There is also a rear shelf, which provides storage for both filters and cuvette/tubes. On the right hand side of the unit are the *kinetics* output sockets (4mm) for connection to a chart recorder or computer interface and a screwdriver aperture for adjusting the zero absorbance preset.

The manufacturer states that this unit produces a stable white light, which is directed through the reference cell and test solution to a silicon diode detector after being filtered to a single colour. Conversion of transmission figures to absorbance values is done electronically and the unit displays absorbance values only.

In the event of spillage, a gap is provided in the base of the cuvette/tube holder to allow for drainage. The cuvette chamber is designed so that all internal optics and electronics are separated

Bulb replacement is via a panel in the base of the unit. The spare bulbs are supplied prealigned and prefocussed in a holder. The manufacturer claims that the bulb life is sufficient for tens of thousands of spot readings but is limited to about 100 hours operation in kinetics mode. The kinetics output sockets (4mm) enable connection to a chart recorder or computer interface for continuous absorbance readings.

The filters are provided as a series of eight gelatin types.

Filter no.	Nominal colour	Wavelength (nm)
1	violet	440
2	blue	470
3	green/blue	490
4	green	520
5	yellow/green	550
6	yellow	580
7	orange	590
8	red	680

Table 5 CO75 Filter set characteristics



Figure 6 WPA CO75 colorimeter

Performance

As before, a series of solutions with known concentrations of $KMnO_4$ and $CuSO_4$ were accurately prepared, their absorbances measured and absorbance plotted against concentration. The best straight line fit in each case was calculated and drawn (Figures 7a and 7b top of page 25 opposite).

Deviations from that straight line show up any optical or other defects in the instrument. In these tests of the CO75 model the maximum error in the manganate estimations (Fig 7a) was 0.03 absorbance units and in the copper sulphate runs (Fig. 7b) it was 0.02 absorbance units.

Electrical safety

Earthing and insulation tests were carried out using a Megger PAT2 device.

Earthing - satisfactory, all exposed metal parts are adequately earthed.

Insulation - satisfactory.

Documentation

The instruction manual provided with this instrument contains relevant information and is easy to understand.

Summary

This instrument is reasonably priced, whether sourced from WPA or through Griffin (as COJ-450-10T). It is very easy to use, well designed and built. It should be able to perform most of the routine tasks required of a school or college laboratory colorimeter.

Overall assessment

A - most satisfactory for use in Scottish courses.

Fig.7a Potassium manganate(VII) - 580nm filter (cuvette)

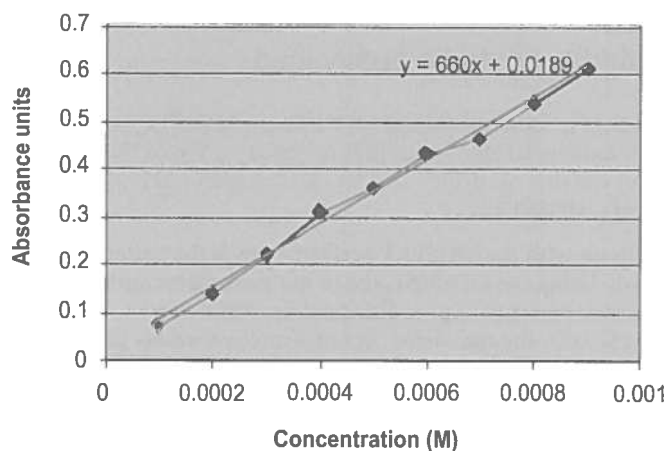
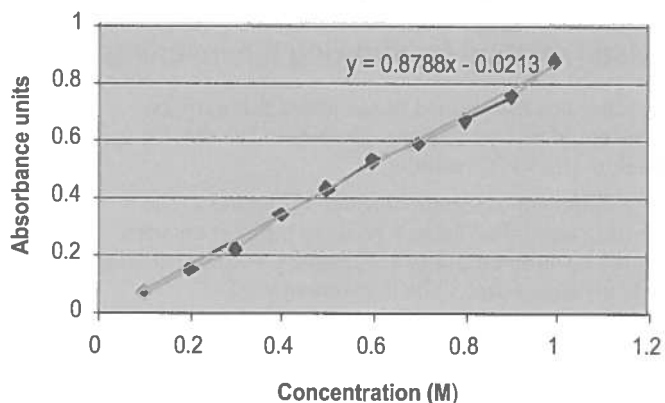


Fig. 7b Copper sulphate - 590nm filter (cuvette)



Figures 7a and 7b Plots of absorbance v. concentration WPA CO75 colorimeter

Conclusions

Our overall findings and impressions were summarised at the top of page 20. In choosing which models to test and report upon we had already whittled down the choice to three models. There are many other instruments on the market but in the main these are intended for more sophisticated applications and that is reflected in their price.

If we were asked to plump for a 'best buy' it would have to be the WPA CO75 model. There is little to choose between the Harris S Range instrument and the CO75 on grounds of performance. The CO75 does, however, have the edge both on price and in having a more up-to-date design and a neater appearance with a smaller 'footprint' on the bench.

On price alone there is nothing to separate the CO75 and the Griffin 41 (which is actually also made by WPA) but again the CO75 wins on performance and ease of use.

The CO75 was also trialled with a number of biological practical activities in courses from the Higher Still programme (see Bulletin 197 [1]). Here, too, it proved the most convenient to use and gave the best performance at the price.

Best buy overall - the WPA CO75.

Reference

1. *Colorimetry and Higher Still*, SSERC 1999, Biology Notes, Bulletin 197, 16.

Higher Physics: Electricity: Activity 21

A revised method for showing the inverting amplifier used to control a heavy load.

A teacher has telephoned to ask about this activity, which he could not get to work. Defects in the details supplied by HSDU [1] include:

1. The positive input signal V which is applied to the inverting amplifier. Being a positive input, it ensures that the op-amp output is at a negative voltage causing the transistor switch to be permanently off.
2. The lack of purpose of the inverting amplifier. Were it to be removed, the transistor switch would operate perfectly well off V from the potentiometer. In this application, the inverting amplifier serves no useful function.
3. The transistor base resistor value is unspecified.
4. Reed switches are unsuitable for switching a heavy load.

Having given some thought to how the circuit might be improved, we considered, but rejected, several types of resistive sensor inputs such as the thermistor, LDR, or platinum film resistor. All of these could quite reasonably be wired in a potential divider to directly operate a transistor switch without the necessity of including amplification. Two other sensors were considered to be suitable, namely a strain gauge, and a Hall effect device. The signal from both of these devices can be of the order of a few millivolts. Clearly some amplification would be required to operate a transistor switch. Of the two, the Hall effect device is the simpler because strain gauges are difficult to mount and wire up and are delicate. Details of circuits with a Hall effect sensor are thus given. It is suggested that this would make a satisfactory substitute for Activity 21.

The Hall effect device is resistor R9 on Chip 01 of the University of Edinburgh and Motorola Teaching Chip Set (see pages 2 and 3 of the new datasheet [2]). This is very easy to use and costs only £2 a chip, or £1.50 if part of a set, which is cheap for this kind of sensor. It is available from SSERC. If a neodymium magnet (also obtainable from SSERC) is placed on Chip 01, the Hall voltage is about -10 mV when current from a 3 V battery is applied across R9. The inverting amplifier has a nominal gain of about x1000. In practice, op-amps don't perform too well at such a large gain and some degradation in the signal occurs. The voltage

output from the op-amp is about +8 V into the MOSFET IRF520N as shown (Fig. 1), but falls to about +5 V into the 2K2 input resistor connected to a bipolar transistor 2N3053 in place of a MOSFET.

The circuit with the MOSFET performs much the better of the two. Using the MOSFET, the motor runs faster and the transistor does not appreciably heat up. With the bipolar, 2N3053, the transistor becomes uncomfortably hot and the motor runs less fast. Try both versions, getting a direct comparison of driving a load with a MOSFET and a bipolar. Some of the values are fairly critical. The input resistor should not be less than 4K7. Protection diodes are required as shown. Take care that neither the metal tag on the MOSFET, nor metallic can of the bipolar, touch other conductors. They are commoned respectively to the drain and collector. The semiconductors are available from Rapid and RS.

References

- 1 Physics: Electricity and Electronics (H) - Student Material Activity 21: *The inverting amplifier used to control heavier loads* Higher Still Development Unit Autumn 1998.
- 2 Datasheet: The University of Edinburgh and Motorola Teaching Chip Set SSERC 1999.

	Bipolar 2N3053		MOSFET IRF520N		Op-amp TL071CP	
Rapid	81-0264	20p	47-0284	45p	TL071	38p
RS	293-561	44p	254-0853	73p	304-245	36p



Figure 2 Pinouts for the MOSFET and bipolar transistors.

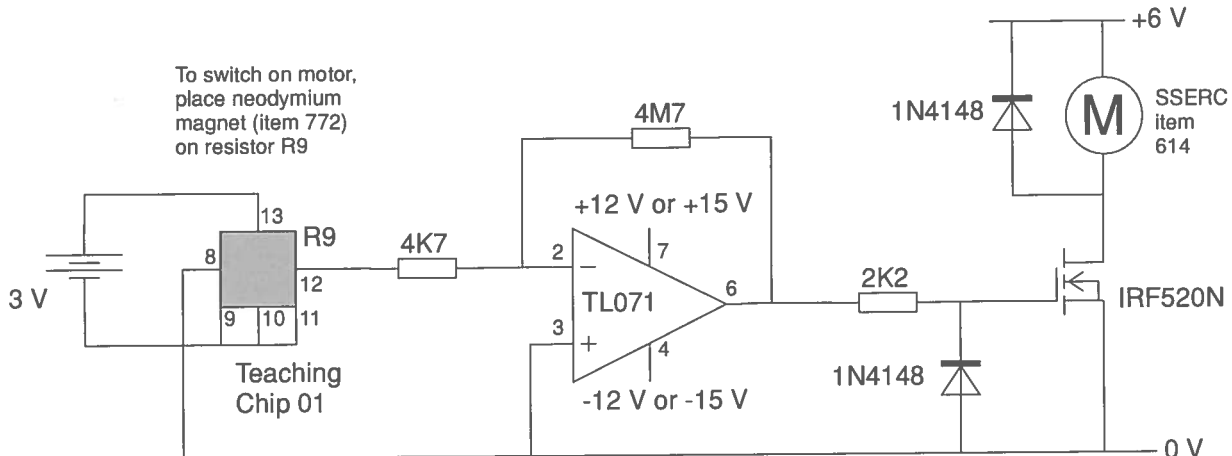


Figure 1 Circuit diagram showing a motor being driven by a MOSFET from an amplified signal from a Hall effect sensor.

Odds and ends

An eclectic list of recently published resources and newish apparatus, which may be of interest.

Practical Fermentation

The National Centre for Biotechnology Education (NCBE) has recently published a new learning and teaching resource which describes fourteen fermentation investigations. Sponsored by the Society for General Microbiology the guide has been written by John Schollar and Benedikte Watmore with John Grainger as Consultant Editor. It is intended for students taking an advanced course in biology, especially those taking an option in biotechnology or micro-biology.

In Scotland that means it is likely to support learning and teaching at Intermediate 2, Higher and probably, eventually at Advanced Higher. It is also intended for students taking science courses which include work on fermentation. Each pack contains five Student Guides and two Technical Guides, which at £15 per pack is good value.

Supplier: **NCBE**
Order code: **Practical Fermentation** Price: **£15.00**

Other biotechnology 'stuff'

The SAPS Biotechnology Scotland Project, Edinburgh University, University College London and SSERC have also been co-operating in work on bioreactors, particularly for investigations at Advanced Higher. Some of that work shall be reported on in the next issue of the Bulletin.

Also on their way from NCBE is a set of eight biotechnology topic books with practicals and investigations the production of which has been sponsored by Unilever. The first of these, on DNA technologies is due out soon. All of these publications will be downloadable from the NCBE website as pdf (portable document format) files. NCBE's website www.reading.ac.uk/NCBE is also directly accessible via the biology hotlinks section of the SSERC website:

www.sserc.org.uk

Microscale Vacuum Apparatus

The apparatus comprises of a tiny, polycarbonate, bell jar just 85 mm tall and 62 mm internal diameter, with which students can carry out vacuum experiments such as determining the density of air, boiling water at room temperature, or watching a marshmallow expand. Air is pumped from the bell jar with a 60 ml syringe. About twenty strokes are needed to reduce pressure to a few kilopascals.

A credit card is the best way to order as it automatically takes care of the exchange rate. Include \$19.35 for shipping via airmail, which takes about ten days.

Supplier: **Educational Innovations**
Order code: **VAC-10** Price: **US\$34.95**

Stomp Rocket

The name is misleading, because it is a projectile rather than a rocket. Nonetheless the paradox is instructive and the product is of great educational interest.

The 'rocket' consists of a lightweight plastic tube, 200 mm long by 18 mm in diameter. With a soft rubber nose cone and tail fins, weighing just 13 g, it may safely be fired indoors. The firing mechanism consists of a bladder connecting to a long tube, onto which the rocket fits. If the bladder is jumped upon, hence the name, the 'rocket' is projected by the pressurization of air caused by compression.

The dynamics can be analysed by estimating to one significant figure. For instance from estimating the compression, a value for pressure can be found, from which can be derived a value for the average force acting on the 'rocket'. Knowing the length of the launcher leads to a value for the velocity at projection. The times of flight, range and maximum height can then be found. Since these last three quantities can all be measured, the interesting question is to see whether there is agreement with the derived estimates.

Supplier: **Hawkin's Bazaar**
Order code: **A648** Price: **£13.99**

DiVA Digital Spectrometer

This is a relatively low cost digital spectrometer designed for educational use. It is sensitive to wavelengths in the range 380 nm to 900 nm with a resolution of 7 nm. It may be used to analyse the spectra of emission lamps, flames, or daylight. Results are analysed on a PC to give a graph of relative intensity versus wavelength.

Supplier: **Nicholl Education**
Order code: **ND-1** Price: **£875**

Solar Hydrogen Technology Kit

The kit includes a solar cell, PEM water electrolyser with gas storage cylinders, PEM fuel cell and a load measurement box which has decade resistors, lamp, electric motor, voltmeter and ammeter. With these parts, the experimenter can electrolyse water with current from the solar cell, operate the fuel cell off oxygen and hydrogen and quantify the electrical energy output.

Supplier: **Griffin**
Order code: **XHV-105-545N** Price: **£165**

Equipment Offers

Items are arranged by similarity of application, or for other reasons, and not by stock number sequence. Often the item number serves only for stock identification by us in making up orders. Newer stock items are underlined, so as to be more easily seen.

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

Postage : Postage and, where necessary, packing, will be charged for. It is therefore best not to send cash with an order, but wait for us to bill you. Official orders may be used.

Please try and ask for at least £10 worth of goods because the administrative costs of handling orders are significant.

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

Motors

- 778** Stepper motor, Philips MB11, been stored in damp conditions but unused and retested. 4 phase, 12 V d.c., 100 mA per coil, 120 W coil per phase, step angle 7.5°, with 7 mm x 2 mm dia. output shaft. Dimensions 21 mm x 46 mm dia. on oval mounting plate with 2 fixing holes, diam. 3 mm, pitch 42 mm, at 56 mm centres. Circuit diagram supplied. £2.50
- 755** Pulley wheel kit comprising: - plastic pulley wheel, 30 mm dia., with deep V-notch to fit 4 mm dia. shaft, - two M4 grub screws to secure pulley wheel, - Allen key for grub screws, and - 3 mm to 4 mm axle adaptor. The whole making up a kit devised for SSERC tachogenerators with 3 mm shafts. Specially supplied to SSERC by Unilab. £1.25
- 848** Motor, 12 V d.c., no load current 2 A at 12 V and 1.5 A at 5 V. Min. no load starting voltage, 2 V, min no load running voltage 0.8 V. 64 X 37 mm dia., shaft, 11 X 3 mm dia. £2.50
- 614** Miniature motor, 3 V to 6 V d.c., no load current 220 mA at 9600 r.p.m. and 3 V, stall torque 110 mN m, dims. 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia. 45p
- 593** Miniature motor, 1.5 V to 3 V d.c., no load current 350 mA at 14800 r.p.m. and 3 V, stall torque 50 mN m, dims. 25 mm x 21 mm dia., shaft 8 mm x 2 mm dia. 30p
- 739** Miniature motor, 1.5 V d.c., dimensions 23 mm x 15 mm dia., shaft 8 mm x 1.7 mm dia. 25p
- 621** Miniature motor, 1.5 V to 3 V d.c., open construction, ideal for demonstration, dimensions 19 x 9 x 18 mm, eight tooth pinion on output shaft. 25p
- 839** Motor, solar, 12 mm long by 25 mm dia., shaft 6 x 2 mm dia. (see also Item 838 - solar cell) £1.70
- 773** Tachometer (ex equipment) £2.25
- 811** Worm and gear for use with miniature motors, 34 : 1 reduction ratio plastic worm and gear wheel. 35p
- 378** Encoder disk, 15 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole. 80p
- 642** Encoder disk, 30 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole. 80p
- 772** Encoder disk, 4-bit Gray code, stainless steel, 81.28 mm dia., 3 mm fixing hole, slots sized to register with components mounted on 0.1" stripboard. Applications: shaft position sensing, wind direction indicator. For related circuitry see Bulletin 146. £3.00

Precision motor stock

- 785** Precision motor with optical shaft encoder, 0.25 to 24 V d.c., no load current and speed 9 mA and 6,600 r.p.m. at 24 V, stall torque 23 mNm, 9 segments. Overall body length including shaft encoder 59 mm, dia. 23 mm with output shaft 20 x 3 mm dia. Back EMF constant 3.6 V/1000 r.p.m. Suggested application - tachogenerator. Data on shaft encoder section available on application. £15
- 787** Precision motor with attached gearbox, 0.15 to 12 V d.c. With a supply of 3 V, the no load current is 25 mA and the output shaft turns at ca. 20 r.p.m. Gearbox ratio 1 : 365. Overall body length including gearbox 43.5 mm and diameter 16 mm. Output shaft 6 x 3 mm dia. with flat side to maximum depth of 0.3 mm along outer 5 mm length of shaft. Application - any system where a very slow angular velocity is required. £15
- 836** Motor mounts, plastic push-fit with self adhesive base pad, suitable for SSERC motors 593 & 614, pk of 10 £1.95

Miscellaneous items

- 801** Propeller, 3 blade, to fit 2 mm shaft, 62 long. (Replaces Item 791 at lower cost). 35p
- 792** Propeller kit with 10 hubs and 20 blades for making 2 or 3 bladed propellers. 130 mm diameter. Accepts either 2 mm or 3 mm shafts. £3.40
- 790** Buzzer, 3 V. 55p
- 827** Buzzer, 6 V. 55p
- 821** Reducer, 3 mm to 2 mm, enables gears, pulleys and wheels to be fitted to motor shaft, per 5 25p
- 867** Reducers, as above but 4mm to 2mm, pack of 5 25p
- 868** Ditto, 4 to 3mm 25p
- 846** Sound module, includes 'melody' chip and Piezo transducer. £1.00
- 710** Sonic switch and motor assembly. First sound starts the motor, a second reverses the direction of rotation, a third sound stops the motor. Driven by 4 AA cells (not supplied). 85p
- 715** Pressure gauge, ca. 40 mm o.d. case, 25 mm deep and 33 mm dia. dial reading 0 to 4 bar (i.e. above atmospheric). With rear fitting for 1/8" BSP. Suitable for use as indicator for pneumatic circuits in Technological Studies. 75p

165 Bimetallic strip, original type length 10 cm; high expansivity metal: Ni/Cr/Fe - 22/3/75 low expansivity metal: Ni/Fe - 36/64 (invar)	15p	808 Electrodes for making lemon or other fruit cells etc. 1 pair, comprising 1 of copper, 1 of zinc, each approx. 60 mm square, per pair	50p
166 Ditto, but 30 cm length.	40p	716 3-core cable with heat resisting silicone rubber insulation, 0.75 mm ² conductors, can be used to re-wire soldering irons as per Safety Notes, Bulletin 166. Per metre.	£1.35
861 <u>Bimetallic strip</u> (new type - won't rust after exposure to Bunsen flame hence higher price) 10 cm length.	30p	756 Silicone coated, braided glass sleeving, yellow, 2.5 mm dia., gives both heat and electrical insulation to conductors (e.g. for autoclave rewiring). Price per metre.	55p
862 <u>Ditto</u> , but 30 cm length.	80p	714 Sign "Radioactive substance" to BS spec., 145 x 105 mm, semi-rigid plastic material. Suitable for labelling a radioactive materials store. With pictogram and legend.	£2.70
758 Loudspeaker, 8 W, 0.5 W, 66 mm dia.	50p	763 Sign "DANGER, Electric shock risk" to BS spec., rigid plastic, 200 x 150 mm.	£2.70
771 Neodymium magnet, 13.5 mm dia. x 3.5 mm thick.	£1.30	764 Sign "DANGER, Laser hazard" to BS spec., rigid plastic, 200 x 150 mm.	£2.70
837 Ring magnet, 40 mm o.d., 22 mm i.d.	35p	727 Hose clamp, SOLD OUT	
815 Ceramic block magnets, random polarisation, 19 x 19 x 5 mm.	15p	731 Re-usable cable ties, length 90 mm, width 2 mm, 50 per pack.	12p
823 Ceramic block magnets, poles at ends, 10 x 6 x 22 mm.	12p	752 Shandon chromatography solvent trough.	£1.00
824 Ceramic block magnets, poles on faces, 25 x 19 x 6 mm.	35p	805 Condenser lens, bi-convex, 200 mm focal length, 75 mm dia. Crown glass.	£12.50
825 Forehead temperature measuring strips	50p	806 Condenser lens, plano-convex, 150 mm focal length, 75 mm dia. Crown glass.	£12.50
745 Sub-miniature microphone insert (ex James Bond?), dia. 9 mm, overall depth 5 mm, solder pad connections.	40p	833 5" double density floppy disks, box of 10	60p
723 Microswitch, miniature, SPDT, lever operated.	40p	834 5" high density floppy disks, box of 10	60p
354 Reed switch, SPST, 46 mm long overall, fits RS reed operating coil Type 3.	10p	Components - resistors	
847 Rocker switches, panel mounting, (mixed stock).	15p	420 resistors, 5% tolerance, ~ W : Per 10.	6p
738 Relay, 6 V coil, DPDT, contacts rated 3 A, 24 V d.c. or 110 V a.c.	75p	1R5, 4R7, 5R6, 6R8, 8R2, 10R, 15R, 22R, 33R, 47R, 56R, 68R, 82R, 100R, 120R, 150R, 180R, 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R, 1K0, 1K2, 1K5, 1K8, 2K2, 2K7, 3K3, 3K9, 4K7, 5K6, 6K8, 8K2, 10K, 12K, 15K, 18K, 22K, 27K, 33K, 39K, 47K, 56K, 68K, 82K, 100K, 150K, 220K, 330K, 390K, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M.	
774 Solenoid, 12 V, stroke length 30 mm, spring not provided.	£2.25	421 DIL resistor networks, following values available: 62R, 1K0, 6K8, 10K, 20K, 150K. Per 10.	30p
742 Key switch, 8 pole changeover.	40p	BP100 Precision Helipot, Beckman, mainly 10 turn.	10p-50p
382 Wafer switch, rotary, 6 pole, 8 way.	70p	Components - capacitors	
688 Croc clip, miniature, insulated, red.	5p	813 Capacitors, polystyrene:	4p
759 Ditto, black.	5p	180 pF, 220 pF, 330 pF, 560 pF, 1000 pF, 2400 pF, 3000 pF, 3300 pF, 3900 pF & 4700 pF	
788 Crocodile clip leads, assorted colours, insulated croc. clip at each end, 360 mm long.	£1.35	695 Capacitors, tantalum, 15 µF 10 V, 47 µF 6.3 V.	1p
809 Wire ended lamp, 3 V	10p	696 Capacitors, polycarbonate, 10 nF, 220 nF, 1 µF, 2.2 µF.	2p
741 LES lamp, 6 V.	15p	697 Capacitor, polyester, 15 nF 63 V.	1p
770 LES lamp, but 12 V.	15p	698 Capacitors, electrolytic, 1 µF 25 V, 2.2 µF 63 V, 10 µF 35 V.	1p
789 MES lamp, 3.5 V, 0.3 A	9p	358 Capacitor, electrolytic, 28 µF, 400 V.	£1.00
690 MES lamp, 6 V, 150 mA.	9p		
866 Lens-end lamps, MES, 1.2 V. Ideal where a concentrated beam of light is needed. Box of 100	£3.50		
691 MES battenholder.	20p		
692 Battery holder, C-type cell, holds 4 cells, PP3 outlet.	20p		
730 Battery holder, AA-type cell, holds 4 cells, PP3 outlet.	20p		
845 <u>Battery holder</u> , holds two C-type cells, PP3 outlet.	20p		
835 Battery holder, AA-type cell, holds 2 cells, PP3 outlet.	15p		
729 Battery connector, PP3 type, snap-on press-stud, also suitable for items 692 and 730.	5p		
724 Dual in line (DIL) sockets, 8 way.	5p		
760 DIL sockets, 14 way.	7p		
826 DIL sockets, 16 way.	8p		

cont./over

Components - semiconductors

- 807** Schools' Chip Set, designed by Edinburgh University, Now with a comprehensive 12 page set of Datasheets. The 4 chip set comprises : Resistors; MOSFETS; Diodes and Optoelectronics, and Ring Oscillator. £6.00

Single replacement chips: £2.00 per chip:

- 871** Chip 1 - Resistors
872 Chip 2 - MOSFETS
873 Chip 3 - Diodes & Optoelectronics
874 Chip 4 - Ring oscillator
- 322** Germanium diodes 8p
701 Transistor, BC184, NPN Si, low power. 4p
702 Transistor, BC214, PNP Si, low power. 4p
717 Triac, Z0105DT, 0.8 A, low power. 5p
725 MC74HC139N dual 2 to 4 line decoders/multiplexers 5p
699 MC14015BCP dual 4-stage shift register. 5p
711 Voltage regulator, 6.2 V, 100 mA, pre-cut leads. 10p

Sensors

- 615** Thermocouple wire, Type K, 0.5 mm dia., 1 m of each type supplied: Chromel (Ni Cr) and Alumel (Ni Al); for making thermocouples, (Bulletins 158 and 165). £3.10
- 640** Disk thermistor, (substitute type) resistance of 15 kW at 25°C, b = 4200 K. Means of accurate usage described in Bulletin 162. 30p
- 641** Precision R-T curve matched thermistor, resistance of 3000 W at 25°C, tolerance ±0.2°C, R-T characteristics supplied. Means of accurate usage described in Bulletin 162. £3.00
- 718** Pyroelectric infrared sensor, single element, Philips RPY101, spectral response 6.5 µm to >14 µm, recommended blanking frequency range of 0.1 Hz to 20 Hz. The sensor is sealed in a low profile TO39 can with a window optically coated to filter out wavelengths below 6.5 µm. Data sheet supplied. For application see SG Physics Technical Guide, Vol.2, pp 34-5. 50p

- 503** Kynar film, unscreened, 28 µm thick, surface area 12 x 30 mm, no connecting leads. £1.00
- 504** Copper foil with conductive adhesive backing, makes pads for unscreened Kynar film to which connecting leads may be soldered. Priced per inch. 15p
- 506** Resistor, 1 gigohm, ~ W. £1.40

Optical and opto-electronic devices

- 838** Solar cell, 100 x 60 mm, 3.75 V per cell max. £2.10
- 507** Optical fibre, plastic, single strand, 1 mm dia. Applications described in Bulletin 140 and SG Physics Technical Guide Vol.1. Priced per metre. 50p
- 508** LEDs, 3 mm, red. Price per 10. 50p
761 Ditto, yellow. Per 10. 60p
762 Ditto, green. Per 10. 60p
- 858** Flash bulb older type (getting difficult to source) for UV triggered reactions in chemistry. Pack of 5. 85p

Economy variable volume micropipettors

Of slimline profile, these micropipettors are fully autoclavable (121° C max.). They have a nominal accuracy of ± 1.75%. Supplied with spare O-ring and lubricant. Tip ejector swivels, thus pipettors are suitable for either left- or right handed users. Colour coded bodies for ease of identification. Supplied with two tips and stocks of spare tips available. Three sizes :

- 849** micropipettor, 1 cm³, range 100 to 1000 µl £16.00
850 micropipettor, 5 cm³, range 500 to 5000 µl £16.00
851 micropipettor, 10 cm³, range 1000 to 10,000 µl £16.00
- Replacement tips in packs of 25 tips :
- 852** replacement tips for 1 cm³ micropipettor, pack. £1.50
853 replacement tips for 5 cm³ micropipettor, pack. £1.70
854 replacement tips for 10 cm³ micropipettor, pack. £2.15

Other biotechnology items for Higher Practicals:

- 859** Eppendorf tubes, 1.5 cm³, for use in TEP/SAPS/NCBE microcentrifuge, pack of 50 85p
- 860** Nylon mesh for protoplast isolation/fusion protocol, 70µm pore size, per 305 mm square. £7-00

Pipette fillers

- 863** 0-2 cm³ pipette filler (Pi pump type), each £5.75
864 0-10 cm³ as above £5.75
865 0-25 cm³ as above £5.75

New - gloves

- 869** Gloves blue latex*, extra strength, lightly powdered*, ambidextrous. *Small size only therefore suitable also for pupils.* *NOTE : Some individuals may be sensitised to the glove material and, or, the powder or become so. Pack of 50 (25 pairs, normally £9-£10 per box). £5.00

Items not for posting

The following items are only available to callers because of our difficulties in packing and posting glass items and chemicals. We will of course hold items for a reasonable period of time to enable you to arrange an uplift.

- 768** Sodium lamp, low pressure, 35 W. Notes on method of control available on application. 85p
- 810** Watch glasses, assorted sizes 20p
- 712** Smoke pellets. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans : large, 50p, small, 40p

* * *

SSERC, St Mary's Building, 23 Holyrood Road,
Edinburgh, EH8 8AE. Tel: 0131 558 8180, Fax: 0131 558 8191,
Email: sts@sserc.org.uk Website: www.sserc.org.uk
User name and password as given in Bulletin 197.

Scottish Science Consortium Training : as above meantime.

ASE (UK, HQ), College Lane, Hatfield, Hertfordshire, AL10 9AA.
Tel: 01707 283000, Fax: 01707 266532, Website: www.ase.org.uk

ASE Booksales, College Lane, Hatfield, Hertfordshire, AL10 9AA.
Tel: 01707 283000, Fax: 01707 266532,
Email: timbarrett@ase.org.uk Website: www.ase.org.uk

ASE Scotland, Dr Susan Burr (Secretary), Newbarns, 18 Holding,
Mainholm, Ayr, KA6 5HE.
Website: www.asescotland.org.uk

Biotechnology Summer School : c/o Tracey Martin, SCCC, Gardyne
Road, Broughty Ferry, Dundee DD5 1NY
Tel. 01382 455053, Fax 01382 455046

Educational Innovations Inc., 151 River Road, Cos Cob,
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Web store: www.teachersource.com

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Novara House, Excelsior Road, Ashby Business Park, Ashby-de-la-
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Website: www.philipharris.co.uk/education

Hawkin's Bazaar, Hawkin & Co., St Margaret, Harleston,
Norfolk, IP20 0HN. Tel: 01986 782536, Fax: 01986 782468.

Higher Still Development Unit, Scottish CCC, Ladywell House,
Ladywell Road, Edinburgh, EH12 7YH.
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Bedfordshire, LU1 1LP. Tel: 01582 410055, Fax: 01582 458674,
Email: sales@jprelec.co.uk Website: www.jprelec.co.uk

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Rapid Electronics, Heckworth Close, Severalls Industrial Estate,
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Tel: 01206 751166, Fax: 01206 751188,
Email: sales@rapidelec.co.uk

RS Components Ltd., PO Box 99, Corby, Northants., NN17 9RS.
Tel: 01536 201201, Fax: 01536 201501,
Websales: <http://rswww.com>

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rwHP100@cam.ac.uk Website: www.saps.plantsci.cam.ac.uk

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Email: scs@scichem.co.uk

Scottish Qualifications Authority (SQA), operates from two sites for
general enquiries Tel. 0141 242 2214 or Email helpdesk@sqa.org.uk
Else contact either: Hanover House, 24 Douglas Street,
Glasgow G2 7NQ Tel. 0141 248 7900, Fax 0141 242 2244 *or*
Ironmills Road, Dalkeith, Midlothian EH22 1LE Tel. 0131 663 6601,
Fax 0131 654 2664.

STE UK Limited, 137 John Wilson Business Park, Whitstable, Kent,
CT5 3QY. Tel: 01227 263636, Fax: 01227 273363.

WPA, The Old Station, Linton, Cambridge, CB1 6NW.
Tel: 01223 892688, Fax: 01223 894118.

