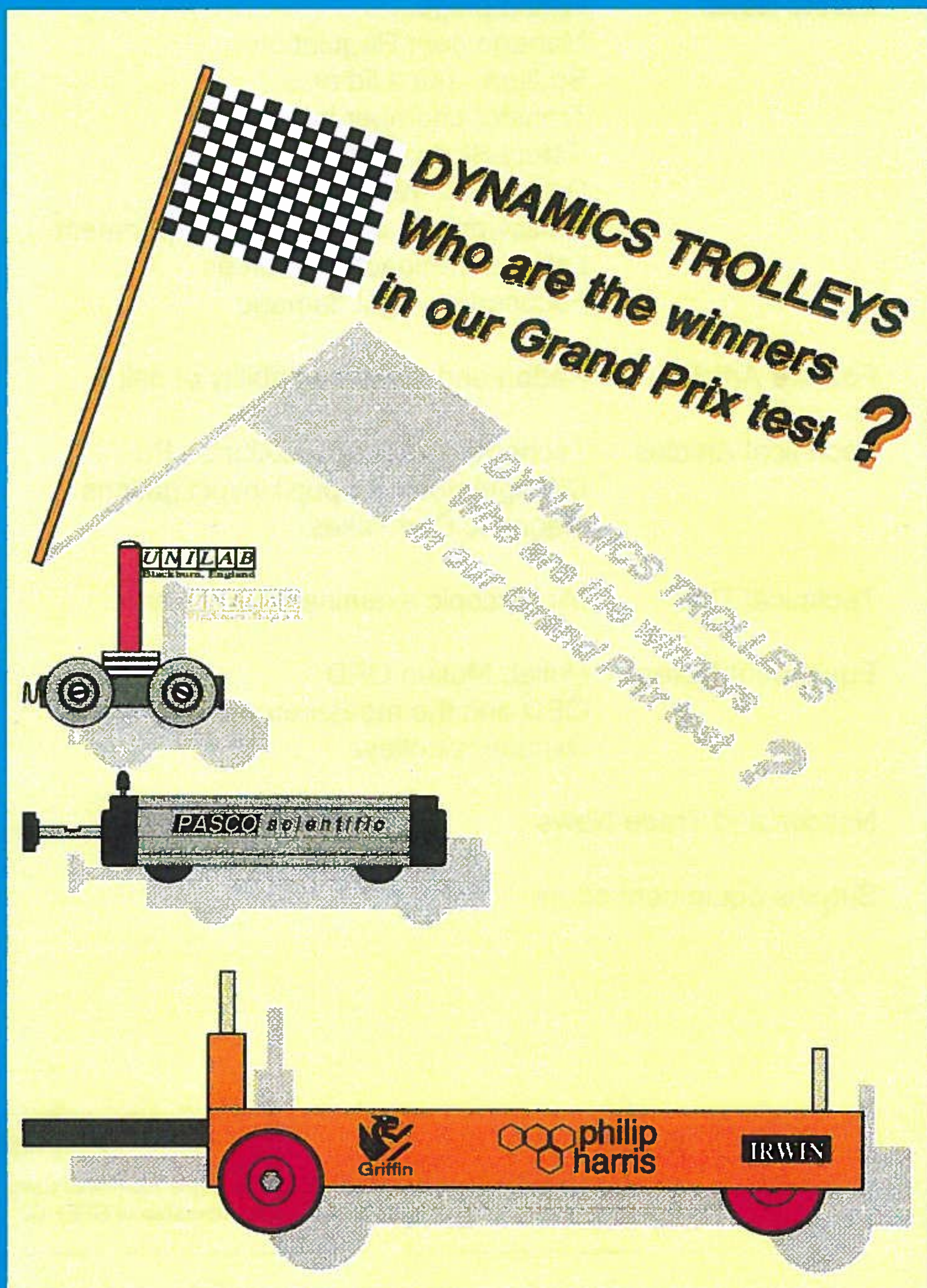
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE

Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences



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Deregulation

Deregulation is a cornerstone policy of the Government. Were it to affect Scottish education, what might happen? Would it be welcomed?

Firstly, as regards content in the syllabus, this is wholly regulated between years S3 to S6 in the several science syllabuses, and has been so since 1980. I have only once heard this issue discussed at a public meeting. This was just prior to the replacement of the broad outline O Grade and H Grade syllabuses of the sixties with our present fully specified form of syllabuses. I recall Norman Fancey using his chairman's prerogative at a SESPEG[1] meeting, which over one hundred of us attended, to outline the dangers that he perceived might befall education if syllabuses became over-regulated. Norman challenged us to respond to his concerns. No teacher supported him, but several spoke in favour of a tightly specified content. As I remember it, the reason forcefully made related to the need for fair treatment for candidates sitting a public examination. It was felt then that some exam questions did not wholly lie within an ill-defined syllabus. Anyway the supporters of regulation won and ever since we have all known exactly what to teach and, perhaps more importantly, what to leave out.

I cannot now recall in any detail what Norman's own concerns were at that meeting. However mine was, and remains, that a fully regulated content erodes the capacity of a teacher to teach effectively. The selection of subject matter is part of teaching. By working out the content yourself, you have an intimacy and directness to your material that should result in a better delivery. If the scope for applications is unbounded, then you are free to select whatever material you think appropriate. You can then follow up your own enthusiasms, or the interests of your pupils. Furthermore, because the knowledge base of science and technology is continuously growing, you can incorporate some of the most up-to-date ideas in your lessons.

Looking secondly at teaching methods, these too are bound by regulations. For instance Standard Grade Physics is application based; Standard Grade Technological Studies applies the systems approach. Even if you choose not to follow the recommended method in Physics, you are expected to use the specified applications. Certainly teaching should be illustrated with applications. But to fetter the teacher with a prescribed set of them limits the scope of the teaching. In Technological Studies, no variance from the systems approach seems possible because the assessment is partly a test of how the method is applied to problem solving.

Both syllabuses are over-directed. The teacher does not have freedom to pick the method or application he or she thinks appropriate. That decision has already been made by the authorities. What is it like to work as a teacher under this arrangement? It is as if a dead hand is pressing down on your mind preventing the full use of your imagination. Your brain is set in concrete. "This is what you will teach, and this is how you will teach and this is what you will illustrate it with". With 1984 behind us, we are all now conditioned to think as the Thought Police direct!

Thirdly, there are those organisational structures which take so much time and energy to operate. Questions need to be organised into knowledge and understanding, and problem solving. Not quite the same as knowledge, understanding and problem solving! Practical abilities incorporate practical techniques and investigations. Investigations include record and report.

And the siren call of SCOTVEC beckons. That temptress of organisational minutiae. At least with the Exam Board we have holistic course assessment. Still! But to assess each learning outcome one by one by one is so pedantic and so bureaucratic. By tolerating this form of assessment we allow our teaching to become wholly bound by regulations. Everything is stultified by red tape. And this red tape will strangle everyone! Where can anyone, teacher or pupil, think for himself or herself? They have already thought it all out for us. Everything in the universe that need be known has been written down in SCOTVEC descriptors.

Let's look on the bright side. We are an all-graduate profession. Surely we are capable of working out for ourselves the minutiae of everyday teaching? Many of us would prefer to be allowed to get on with it ourselves. By applying a hearty dose of deregulation to the syllabuses and to the arrangements for assessment, the Government could restore that freedom we have so largely lost.

How far should any deregulation go? In my opinion, back to the format of the sixties and seventies would be sufficient. From experience of working within that framework, the degree of direction then was midway between a minimalist form of guidance and an oppressive set of directions. It wasn't perfect. But then its faults were trivial compared with those of the present set-up.

1 South East Scotland Physics Education Group

Concern over pupils wiring plugs

Reappraisal of safety measures to prevent accidents

It is widely recognised that this exercise wherein pupils practise wiring 13 A plugs is hazardous. It is only natural that beginners' errors might be made. It is all too likely, whether by chance, natural curiosity, or malfeasance, that plugs are inserted into 13 A socket outlets. The hazard is that these sockets might be live!

We have been contacted by a school whose science staff are disturbed at the risk, which they believe to be significant, of serious injury, or even of death from electrocution, due to this practical activity. To their ken, there have been several near hits within their own establishment.

For the record, individual laboratories within this school have not been fitted with master switches to isolate the local electricity supply.

"Should not this activity be banned throughout all Scottish schools?" asked a member of staff.

In response to this enquiry, and in consultation with the Health and Safety Executive, the Centre makes two general points :

- It is right and proper that schoolchildren are taught how to wire a plug.
- Work must be conducted in a safe environment. This implies that every 13 A socket outlet in the room must be dead and that the isolation switch must be under the sole control of the class teacher, or that the plug must be altered in such a way that it cannot be inserted into a socket outlet.

Let's discuss these two points in the order given. Firstly, why should pupils be taught how to wire a plug? Because electricity supplies are ubiquitous and hazardous, it is right and proper that the entire population receives some basic training in the rudiments of working safely with electricity. This training can only be effective if done with the real thing - and done practically.

The most commonplace electrical device, handled by everyone, is the 13 A plug. Whilst cord to new apparatus is fitted with non-rewirable plugs, most plugs in circulation are still, and for many years will continue to be, of the rewirable type. From experience garnered in testing portable appliances, we know that the commonest sources of failure are faulty plugs and cords. This supports the need for basic training in wiring a plug.

Laboratory activities which are hazardous should not necessarily be banned. They must, however, be so arranged that there is no appreciable risk of harm. This brings us to the second point. When pupils are being taught to wire plugs, and if the plugs they are using are unmodified, all the 13 A socket outlets in the room must be made dead and the means of isolation from the supply must be under the sole control of the class teacher.

The effective way of ensuring this is by the fitment, in every laboratory or workshop, of a master switch that can isolate all the mains sockets in that room.

Additionally, in classrooms fitted with master switches, the teacher must be continuously present during the period when pupils are wiring plugs or related components and must closely oversee the work.

If the only means of isolating the supply is remote from the classroom, then there must be some engineering device in place that ensures that the isolation switch can be operated only by the class teacher, cannot be operated by another person and cannot be overridden by some other means. In general, Regulations 12 (Means for cutting off the supply and for isolation) and 13 (Precautions for work on equipment made dead) of the Electricity at Work Regulations 1989 would have to be complied with.

We are aware that installations in some schools do not presently meet this requirement. In places where this standard of isolation cannot be met, we recommend that pupils are not allowed to wire plugs unless these plugs have been modified in such a way that the pins cannot be inserted into a 13 A socket outlet. This advice will undoubtedly pose some authorities with operational problems. Not only would the educational benefit to the community be lost, there would be a specific difficulty with meeting the requirements of the Standard Grade Physics syllabus, wherein pupils are expected be able to demonstrate how to wire a 13 A plug correctly.

Bastardized plugs

Working with modified 13 A plugs is very much second best to the real thing. By drilling a hole through each pin, through which a screw is fitted and secured with a nut, the plug is altered in such a way that it cannot be inserted into a socket outlet. The screw thread ends should be flattened with a ball or cross pein hammer to prevent the nuts from coming off.

However the Centre does not, on educational grounds, recommend using such plugs. Children should always be treated with respect and the best should always be expected from them. In return, you get back what you deserve - usually! If pupils are given modified plugs to practise on, then the message being signalled to them is that they cannot be trusted. For this reason, such plugs should only be used as a last resort until a master switch is fitted to control the supply to fixed installation socket outlets.

Management Regulations

In this section of Bulletin 179 we indicated a degree of general uncertainty as to the effects of Government policy on deregulation. More specifically we did not then know how such a policy might influence official guidance on the so-called "Six-Pack" especially that on the Management of Health and Safety at Work Regulations 1992.

We were aware that advice and guidance for the schools sector was being prepared by the Education Service Advisory Committee (ESAC) of the the Health and Safety Commission. It had been expected that this would have been published in April of this year but it was delayed. We are given to understand that now it should be available sometime in the late summer or early autumn.

In our opinion, those with responsibilities in this field would be well advised to await publication of the ESAC document before getting too deeply into new arrangements or preparing great wadges of paperwork. We have become increasingly impressed with the quality and ease of reading of a lot of recent HSE publications. Faced with a choice of interpreting an HSE drafted ACoP (Approved Code of Practice) for ourselves and using some so-called *expert* commentary on the Regulations we would go for the HSE ACoP or Guidance Note nearly every time.

The Management Regulations are intended to meet the objectives of an EC Framework Directive and were made under the enabling arrangements of the Health and Safety at Work Act (HSW). Basically they flesh out some of the general duties laid on employers and employees under the Act.

A systematic approach to the management of health and safety is required which includes identified elements such as *organisational arrangements* which include:

- communication
- control
- co-operation
- competence

Also required is *systematic planning* which means :

- looking for and recognising hazards
- identifying who is at risk and how
- assessing risks and priorities for action
- recording the findings

Of particular interest are requirements to close the loops of managerial control. It is not enough to issue an instruction that a particular thing is to be done even if it is spelled out who is to do it, when and how. Management is also expected to monitor its own systems through inspection and in turn to improve its own managerial performance by means of audit and review. Put simply- it is necessary also to see that something has been done and to continually seek to improve the ways of doing it.

We understand that the ESAC guidance will cover most if not all of these topics. It will also suggest different management functions for Education Authorities, Headteachers, Heads of Department or Principal Teachers and for unpromoted staff. It will be entitled Managing Health and Safety in Schools.

SSERC is likely to offer Open Courses based on the Management Regulations and the HSC Guidance. Some of these for Science and Technical Support Staff were piloted during last session. More general courses can also be run for school managers.

Put a lid on it - the sodium

In Bulletin 180 we reported an incident in which a piece of sodium had jumped over the top of a safety screen. Precautions were described for the handling of sodium in demonstrating its reaction with water.

We had a phone call subsequently from Perth Academy which reinforced the recommendations made, particularly the need for cold water and a cover over the water trough.

The PT Chemistry made a very good point that water from a cold tap can in fact be quite warm. This may be so if the pipes to the cold and hot supply run in close proximity and if no cold water has been drawn off for some time. Thus further recommendations are to :

- Don't assume that water from the cold tap is cold. Check and, if necessary, cool it down with a few bits of ice from the fridge.
- Cover the trough with a lid (a square of perspex is perfect).

At the lower temperatures the sodium is less likely to jump, but if it does, the small pieces can be washed off the underside of the perspex lid afterwards.

Fortunately this demonstration is carried out early on in Standard Grade and no pupil watching is going to be conjuring up an image of the walls of the trough being the activation energy barrier over which sodium atoms at the lower temperature have insufficient energy to jump. Analogies and models are often useful and also harmless since they are clearly not the real thing. As this image has some elements of reality to it the temptation to mention this is best resisted.

Transfer chamber incident

This also was reported upon in the last issue. We have since had correspondence with Philip Harris who supply this apparatus. They agreed with our conclusion that the most probable cause of the damage to the glass was an incorrect positioning of the burner. They have asked us to remind readers who have their chamber that there is a positive location device built into its base. This takes the form of four, domed head bolts in a pattern which defines and delimits the position of the burner base.

Together with the position of the gas inlet and the short length of the supply tube this should ensure that the burner is placed accurately under the chimney. Harris have stressed that this is the first such incident reported to them. We have apologized to the firm for not seeking their comments earlier. The incident had been reported to us however just before the last issue was being finalised for printing and we had a deadline to meet (which, like many, had already passed!).

Safety Signs Regulations

Member states of the EEC are required to implement the Safety Signs Directive (92/58/EEC) by 24th June 1994. The idea is to keep the text to a minimum and for the symbols to be dominant. This will ensure that signs are readily understood by visitors or indeed colleagues from other European countries and further overseas.

All new signs have to comply, but existing signs don't have to be replaced until Christmas Eve 1995.

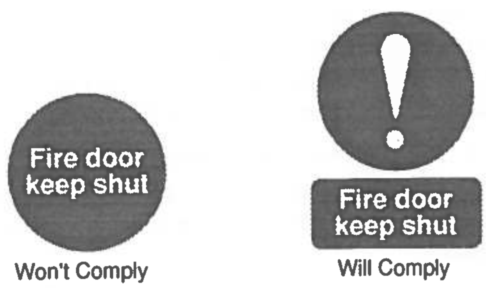


Fig.1 Changes to Mandatory fire safety signs. An example of the type of change needed is that the wee blue circles with white lettering are no longer current; the required replacement has an exclamation mark in the blue circle with the text on a small blue rectangle below it.

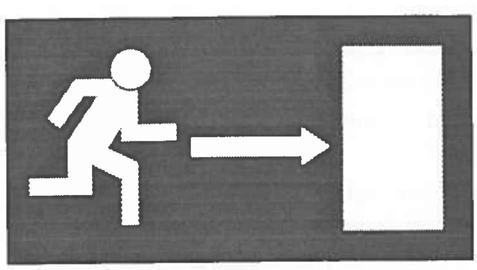


Fig.2 Another example is that *Fire Exit* signs cannot rely solely on the words in white on a green rectangle. There must be a symbol of a running man and, or, an arrow but the text can be appended alongside.

Many of your signs will still comply, but one of the easiest ways of checking is to compare any sign with its new equivalent in the current catalogues of reputable sign makers. The names and addresses of three such firms are given in the address list on the inside rear cover of this bulletin issue.

Dangerous Irwin switch

Certain models of electrical apparatus manufactured by Irwin and dating from about 1970 were fitted with a rocker switch which, if dismantled, is dangerous. The problem is to do with the rocker cap on the switch. This can be prized off by a pen knife blade, small screwdriver, or other small implement, to reveal metal conductors that can be at hazardous live.

Although it is not obvious that the switch can be dismantled, it is actually very easy to remove the cap and expose the danger.

The switch in question has a black, plastic, rectangular frame and white plastic rocker (Fig. 1) below. To our knowledge, it has been fitted to power supply models EJ 32 Mk III, EJ 1 Mk III and EJ 176. We suspect that it may also have been fitted to other Irwin apparatus.

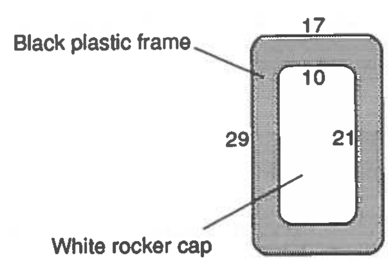


Fig.1 Irwin rocker switch

Irwin issue a replacement switch (part number 2S 223) free of charge. We understand that the company circulated customers many years ago to notify them about this problem. However from our experience of running electrical safety training we are aware that, despite notification, sets of apparatus with defective switches are still around in Scottish schools.

SAFETY NOTES

Glassware for density of air experiment

We were recently asked for advice on what type of glassware would be safe to use for the standard experiment wherein a glass flask is evacuated to find the density of air. As others may find the advice useful, it is given here :

If using conventional glassware :

- only a round bottom glass flask should be used;
- the flask must comply with ISO 1773, or the equivalent British Standard BS 2734;
- suitable material is Bibby Pyrex;
- the flask must be in good condition;
- there should be no scratches or blemishes in the glass.

These conditions being met, the flask should be able to take a full vacuum. It should be noted that a glass flask is always stronger under compression. It will not withstand tension however. If the internal gas pressure were to rise much above atmospheric, the flask would explode. The maximum safe differential pressure at positive internal pressure is very small - perhaps a few percent.

Glassware should be inspected against the check list and only used if it meets with the above criteria. Since the measurement of air density is a standard experiment, it would be prudent to set aside one flask known to be in good condition for use in this application.

A suitable flask for this experiment is a Pyrex flask made by Bibby and specified as : boiling flask, round bottom, narrow neck, 500 ml, type 1100/18. This flask is available from several stockists, including Griffin (FHB-275-070C, £9.46 for 2) and Harris (R82404/3, £4.49).

We also contacted Duran, a German manufacturer of quality glassware and found that they were not prepared to recommend using their equivalent round bottom flask for full vacuum work. The flasks Duran are prepared to recommend for this work are designed to a higher specification, namely ISO 6556 (similar to BS1739). Two suitable 500 ml types have been identified : Duran items 21 204 445 and 21 205 445. The latter is plastic coated to protect against mechanical damage in the event of an implosion. Both these flasks have the erlenmeyer (or conical) shape and come complete with plastic hose connection. Duran flasks can be obtained from Hogg Laboratory Supplies. The prices are likely to be upwards of £10 and £15 apiece respectively.

How should you jump on this one? Because good quality round bottom flasks have been extensively used and as far as we are aware have a good safety record, and because Bibby advise that, subject to the conditions in this article, these flasks are safe to use for full vacuum work, our advice is to use their flask.

The following measures should be taken during the experiment to reduce the chance of an implosion and to prevent harm :

- the flask should be gently supported and must not be clamped tightly in the jaws of a clamp stand;
- a suitable containment and support for this experiment is a large plastic beaker with cotton wool padding between the flask and internal walls of the beaker as recommended in the Memorandum [1];
- allow air or water to enter the flask slowly after the vacuum state so as not to subject the flask to an abrupt change in pressure;
- eye protection should be worn by everyone in the laboratory;
- if the experiment is being demonstrated, a safety screen should be positioned between the apparatus and the pupils and another between apparatus and demonstrator;
- if the experiment is being conducted by pupils, a small safety screen should be placed between the experimenters and the flask; this screen should be small enough to allow them to manipulate the apparatus with relative ease.

Reference

1. *Mechanics and properties of matter* : Higher Physics, Curriculum Support Series No. 1, SCCC, 1990.

Labgear radioactive sources

A relatively small number of schools have radioactive sources made by the now defunct Labgear Company. These sources are quite distinctive. The radioactive material is embedded in resin glue which is held at the centre of a 50 mm square perspex plate. The source may either be in the form of a section of a pellet formed by a sintering process, the section being embedded in the resin or it may be in the form of a powder set in resin (Fig. 1). (continued over)/

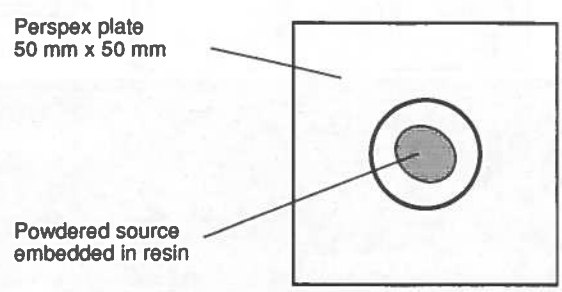


Fig.1

From examination of some Labgear sources, there is evidence that the resin is deteriorating. There is therefore a conceivable risk that the radioactive material might be released from the seal and cause contamination.

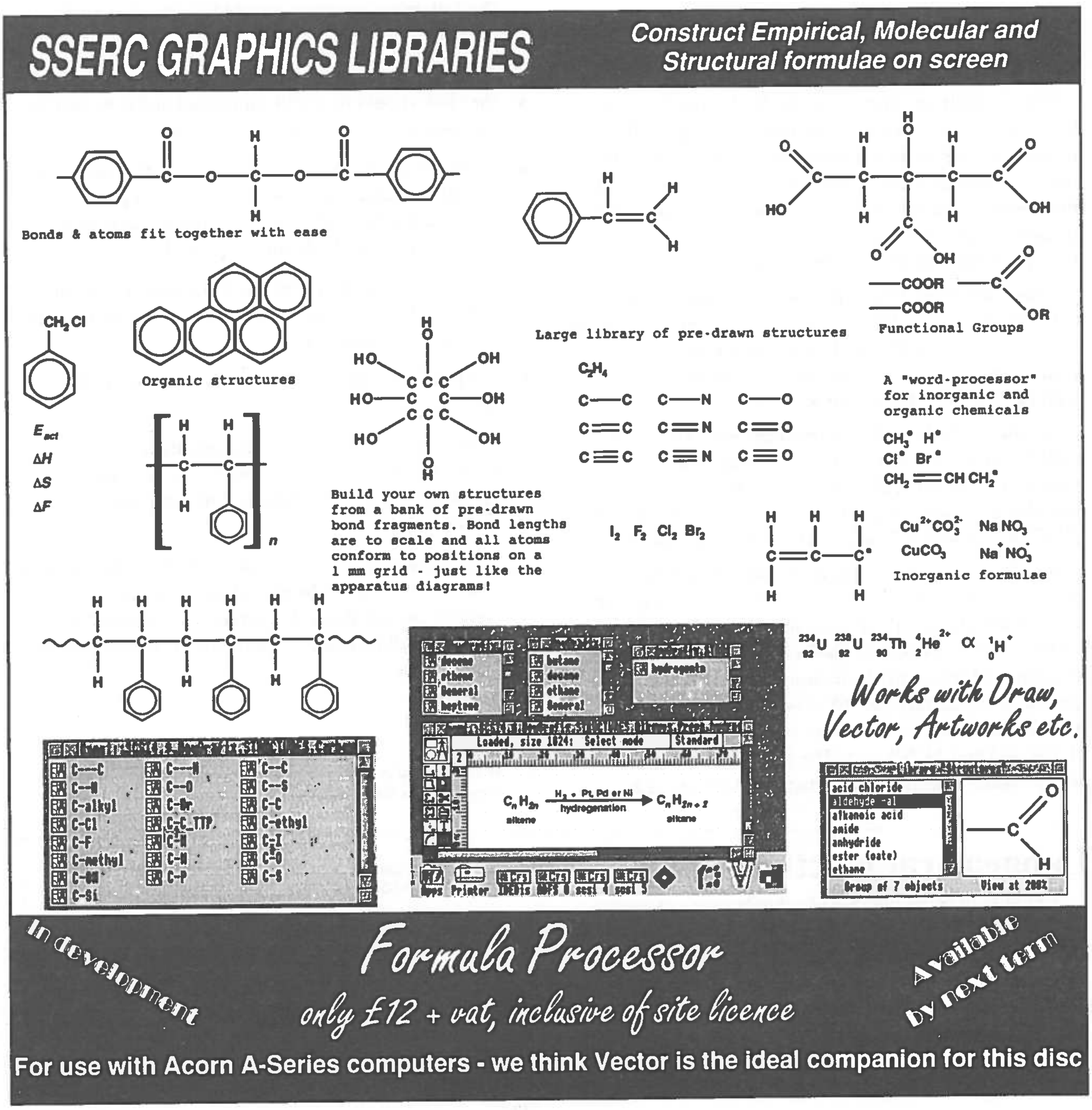
This type of source is no longer in production. Its form of construction does not meet with approved forms for use in schools today.

It would be prudent to dispose of any Labgear source you have and replace with modern approved types.

Focused sunlight damage

We had a report from a school of an incident caused by a tray of reagents placed near a window in direct sunlight. The bottles were of 1 litre capacity. After a period of 90 minutes, two holes, each a few inches in size, had been burnt through the plastic tray by the focused sunlight.

Although this is such a well known hazard, incidents like this do keep recurring. This report serves then as a useful reminder.



FEATURE ARTICLE

Radon and the acceptability of risk

By detecting the presence of radon in the atmosphere, teachers are able to introduce the concepts of risk and comparative risk.

In the "Opinion" section of Bulletin 180 we expressed concern about one means whereby science and technology courses are used as vehicles of general health and safety education. The approach to which we object is that which relies on separate and specific provision - mini-topics or special lessons, projects or publications on safety issues. In that same article we announced our intention to publish an example of an alternative approach of teaching about general health and safety issues as and when they arise naturally within an existing course. The article we have chosen to illustrate such an approach was originally presented as a paper by a member of the Centre staff. It was delivered as one of the workshop sessions at the 1993 European Conference on Health and Safety at School, attended by representatives from all EC member countries.

"In this talk I shall describe a specific example of an attempt to bring a health and safety matter into the curriculum of secondary schools in Scotland. The subject matter is radioactivity. Because of understandable public concern about nuclear radiation, two separate science syllabuses, chemistry and physics, have recently been amended to include information on sources of background radiation [1, 2]. This helps to educate the public that the world is, whether we like it or not, naturally radioactive, and it places in context the relative contributions to dosage from artificial and natural sources.

To give an example from one of the amended syllabuses, the Higher Grade Physics syllabus now has the learning outcome :

Describe factors affecting the background radiation

and suggests the following practical work in support :

Monitor the radon background by measuring the count rate from dust collected on filter paper

In fact, schools make use of two simple methods for detecting the presence of radon. The apparatus required for the first of these [3, 4] (Fig. 1) comprises a vacuum cleaner or air blower, tissue paper and a radiation detector.

If tissue paper is placed across the collection pipe of a vacuum cleaner, and air is pumped through it, dust particles contaminated with radon daughter products adhere to the tissue paper. These can then be detected using a Geiger-Muller (GM) tube. The radioactivity level of the contaminated tissue paper gives an indirect measure of the abundance of radon in the air.

The second detection method [5,6] uses a nuclear sensitive film called TASTRAK, which has been devised by a research team at the University of Bristol in England. TASTRAK is a polymer that is sensitive to alpha particles, low energy protons, and heavier ions, but is insensitive to beta particles, gamma rays, X-rays and sea level cosmic radiation. This selectivity makes it a useful material for detecting radon. If an alpha particle hits TASTRAK, some of the polymer bonds are broken to leave an active site which can be further opened up by the developer, 6 mol l^{-1} sodium hydroxide at 98°C. These developed tracks are visible under the microscope at x100 or x200 magnification, or if projected from a slide projector (Fig. 2). A quantitative measure of radon concentration in Bq m^{-3} can then be obtained by counting the number of tracks per unit area of film.

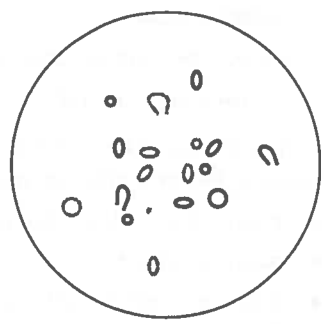


Fig.2 Appearance of magnified image of developed, exposed TASTRAK plate showing alpha particle tracks.

TASTRAK is obtained from the University of Bristol. When required for use, the film is removed from its metallic bag and exposed for a period of one week or several weeks, either in the air or in the soil. After this, the film can either be developed by the school itself, or returned to Bristol for developing.

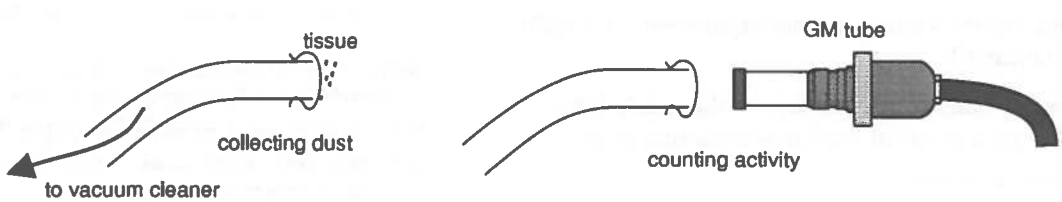


Fig.1 Air filtering method to detect the presence of radon

Comparing the two methods, the vacuum cleaner and tissue paper method has the advantage of immediacy, giving evidence of the presence of radon in a procedure which need last no more than 15 minutes. It costs nothing, since air blowers and GM counters are standard apparatus found in every school. It shows up short term variations due to the location or ventilation in buildings, or to weather conditions. On the other hand TASTRAK takes a long period of time to expose, thereby losing the impact of immediacy, costs several pounds to buy, and cannot be used for short term variations.

Looking at the relative advantages of TASTRAK, it is simple to work with and can be used by primary school children, it can sample anywhere, including in the childrens' own homes, it is an integrating counter which ignores short term fluctuations and gives a long term average reading, and it can provide an absolute measurement of radon concentration in Bq m^{-3} for comparison with other sites throughout the country, and indeed throughout the world. Further to these is the sense of wonder that can come from the realization that each track seen on a developed film was caused by an individual alpha particle. In school science practical work, as indeed in everyday life, almost every phenomenon seen is the cumulative effect of countless millions of atoms. Here on TASTRAK there is a one to one correspondence between atoms and tracks.

We see therefore that the two detection methods are complementary. Both are useful in their own way.

To find out what impact, if any, this part of the syllabus is having, a questionnaire was sent out by SSERC to a small number of schools.

number in sample	16
number of replies	14
number using dust sampling method	11
number using TASTRAK	4

The impact of the practical work on pupils is best summarized by listing some of the responses :

- pupils surprised, and the teacher the first time !
- pupils impressed;
- pupils are convinced by scientific evidence rather than hearsay;
- pupils are quite surprised by the result;
- helps reinforce the idea that radiation is ever present;
- increases interest and relevance;
- the dust sampling brings home immediately that radiation is all around and being inhaled;
- pupils like the vacuum cleaner experiment - it is really quite bizarre !

These and other comments support the widely held belief that good practical work in science education :

- captures attention;
- prompts questioning;
- provides opportunity to discuss the broader issues;
- provides pupils with a lasting memory of the experience, and ideas to retain in later life;
- can have a profound effect on the imagination, one of surprise, wonder, amazement and marvel, and in the best sense of the meaning of education, leads ideas out of pupils and gets them thinking in ways that they have never thought before.

The surprisingly high count rate from the dust sample gives teachers a chance to discuss underlying issues. One of these is the risk to health from breathing air infused, naturally, with radon. The annual average dose to persons in the UK resulting from this is 1.2 mSv [7]. The risk of a 1 mSv dose is 30 deaths due to cancer per million persons exposed [8]. A rough and ready calculation shows therefore that the risk of death from breathing is roughly 1 in 350 in a lifetime.

From considering the contribution of radon to natural background radiation, even one of the most basic of human functions, breathing, can be shown to be not entirely free from danger and from risk of harm.

Summary

By focusing attention on a specific example (radon in the atmosphere), teachers are able to explore broader underlying issues.

Scottish schools make use of two experimental methods to show the presence of radon in air.

Our survey of schools has shown that this practical work helps to interest pupils in this subject.

Schools are able to use these experiments as a means of discussing risk and looking at comparative risk assessments.

This helps put in perspective the relative contributions to risk of harm from man-made and natural causes.

Through studying natural background radiation, we have an opportunity of showing that there is nothing that is completely safe and without risk."

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3. P Thomsen, 1982, *Teaching nuclear physics to all young people*, Hong Kong Science Teachers Journal, 10, 2, 100-113.
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6. *Revised Higher Grade Chemistry - radioactivity*, Bulletin 175, 15-24, Scottish Schools Equipment Research Centre, 1992."
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8. R H Clarke, 1988, *NRPB guidance on risk estimates and dose limits*, *Radiological Protection Bulletin*, 88.

TECHNICAL ARTICLE

Tachogenerator applications - Part 1

A number of ideas on how to measure motion inside the laboratory with interfaces and outside with dataloggers - not a highly technical article - we just show you what is possible, with graphics of suggested gear and real data.

We have been here before in Bulletins 160 [1] and 163 [2], 6 years ago would you believe. There must have been close on 400 precision motors sold since then and we have limited stocks of suitable ones left.

As before, the motors are used as generators. Their precision makes for a smooth voltage output which is directly proportional to the speed of rotation of the motor shaft.

The usefulness and range of applicability of the concept has expanded recently with the advent of portable dataloggers, increasingly capable datalogging software and spreadsheets linked to graphical display. In Bulletin 167 [3] the chemist was made aware of Datadisc Plus's ability to differentiate and integrate data. Many software packages can now do this and we summarise a range of applications for the physicist and one for the biologist.

1. Peak Flow

Set up the tachogenerator and propeller (Fig.1) on a stand and feed the output from the motor directly to an analogue port connector or datalogger.

Blow as hard and for as long as you can on the propeller. Although it is tempting, try not to make this a competitive exercise as some children in your class may suffer from asthma. Depending on the severity of their condition it may be advisable to recommend that they do not take part in this activity. Watch out too for children being too enthusiastic and hyperventilating.

Some trial and error will be required by the subjects to find the optimum blowing position and direction. It is therefore important to stress that this is as much a test of skill in blowing at the correct spot as it is some measure of peak flow and possibly lung capacity.

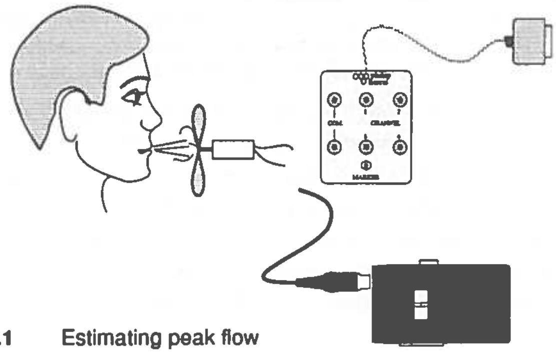


Fig.1 Estimating peak flow

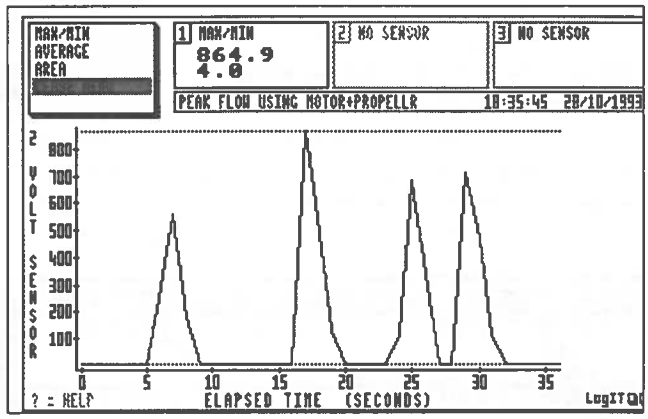


Fig.2 Four subjects tested. LogIT datalogger and LinkPack+ software used.

The area under peaks will be proportional to the volume of air blown out by the subject. It should be possible to use this to calibrate the tachometer output in litres/second when this area is compared to the volumes obtained by conventional techniques.

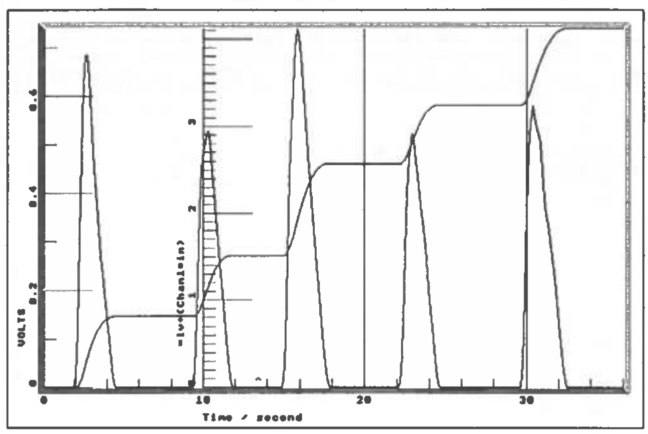


Fig.3 Breathing data analysed with Datadisc Plus software

The stepped trace shows the cumulative area under the peaks. This was achieved using the *Calculate related data* section of the *Utilities* menu of Datadisc Plus and Datadisc PP software :-

i.e. *New channel = lv+(Chan.1*in)*

where *lv* represents *last value* calculated and *in* is the time interval between readings. A cursor can be switched on to scan along the data to read off step levels. Therefore the *area/volume* breathed out by each subject can be inferred.

2. Car Dynamics (speed, distance & acceleration)

Here we develop the principle of wind blowing on a propeller but this time we move the tacho/propeller assembly. A propeller attached to the shaft of a precision motor proves a handy way of producing calibrated tachographs describing the motion of cars, motobikes, bicycles and humans on rollerblades!

First check that the propeller is fixed tightly to the shaft of the motor and is not skewed. We taped one of those black plastic, A4 length, document spines to the outside of the motor to give a reasonably secure point of attachment. This was poked through the car grille (watch your radiator!) and secured to the car using a bosshead and clamp.

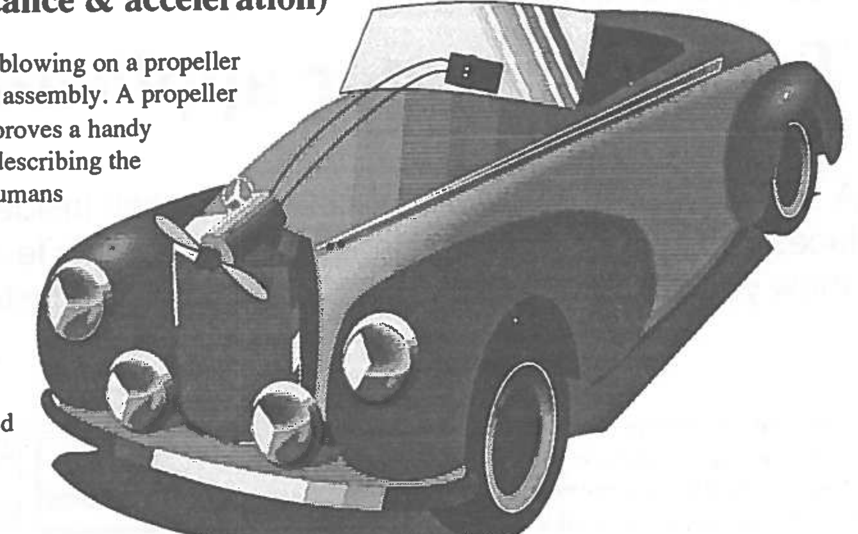


Fig.4 Car dynamics

Depending on the tacho output at speeds up to the legal limit, and more with a headwind, a voltage divider may be needed between the motor and logger. A circuit which divided the voltage by a factor of 10 was suitable here.

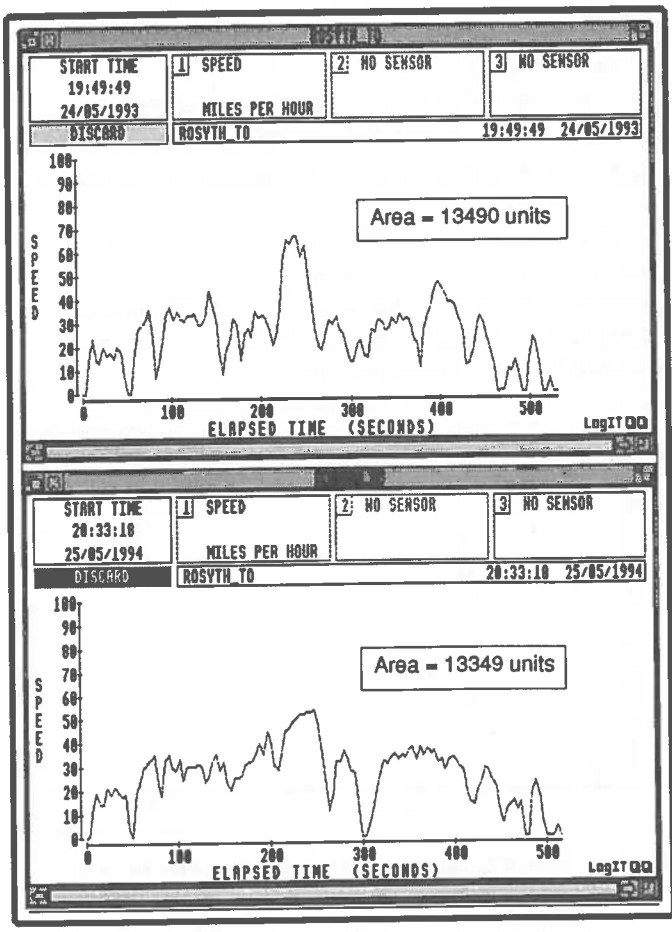


Fig.5 The journey from Rosyth to Dunfermline logged on two separate evenings- not a year apart - we noticed the date had been wrongly set up! LogIT was used with a 1 V sensor lead and default calibration in miles per hour. We had to voltage divide the output to bring it within the logger's measuring range (in this case 0-2 V, but more usually 0-1 V). The area (distance travelled) under the speed/time graphs on the separate runs was to within 1% - amazingly so, considering that it is derived (integrated) from windspeed. LogITLink software was used.

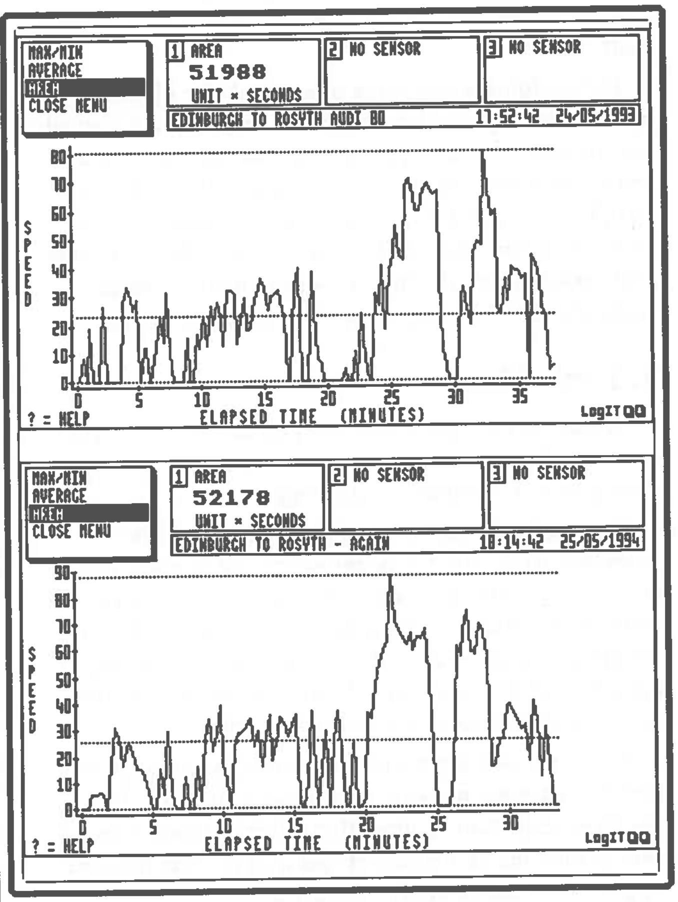


Fig.6 The journey from Edinburgh to Rosyth logged on two separate evenings. The area (distance travelled) under the speed/time graphs on the separate runs was to within 0.36%. LinkPack+ software was used above.

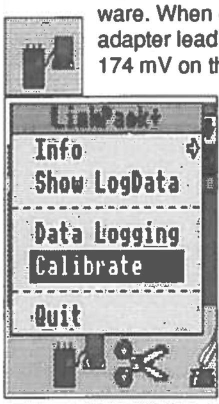
When we first thought of integrating the speed/time graph to get the distance travelled we were concerned how consistent the results would be over the same route in different weather conditions. The results are remarkably consistent when you consider that the prevailing wind strength and direction may vary as may car/lorry slipstream effects on different days.

Calibration of tacho output

The voltage generated by the tacho depends on a number of factors - the output characteristics of the motor, blade type and number on the propeller, prevailing windspeed and the speed of your car. To work out the calibration in mph, km/hr, m/s etc. follow these procedures for the LogIT LinkPack+ Arc software :-

1. Log data over a known distance d for a known time *t* with the logger reading an incoming voltage on the default scale of e.g. 0-2000 mV (LogIT "1 V sensor").

2. The calibration option can be selected on the Arc by pressing the MENU button over the LinkPack icon installed on the icon bar. Click SELECT on Calibrate to load the calibration software. When calibration is being carried out the1 Volt adapter lead must be connected to the LogIT (e.g. 174 mV on the default scale). On the Archimedes LinkPack+ software the DEFAULT can be set up so that each time a 1 Volt Sensor lead (Sensor type 9) is connected the program will display graphs in the pre-configured units.



Note that only a minimum of two points are required if you know the sensor/tacho has a linear response. The table can be edited by moving the cursor keys and typing in the required numeric values. The current value from LogIT is shown and can be automatically inserted into the table by pressing the L key. Press ESCAPE to finish the calibration and save data.

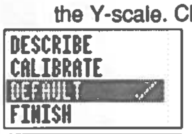
Sensor type 9
Name: SPEED
Scale: MILES/HOUR
Reads: Analogue input level

No	Sensor reading milli-volts	Your scale value MILES/HOUR
1	0.00	0.00
2	75.70	10.00
3	757.00	100.00

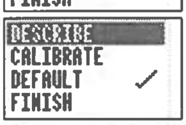
Current reading 0 milli-volts

? = HELP PRESS ESC TO FINISH EDITING TABLE LogIT

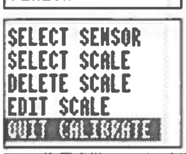
3. The display above shows the current default sensor and scale when a 1 Volt adapter lead (Sensor type 9) is connected to LogIT. Any data recorded with this lead attached or in fact viewing any data recorded previously with a 1 V lead would be shown graphically with MILES/HOUR on the Y-scale. Choose SELECT SCALE to obtain another scale or to configure your own. If the scale you choose is to be the new default then this must be selected as shown.



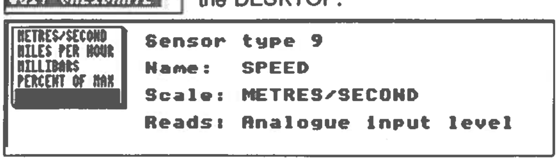
4. If you want to configure the input to read in say METRES/SECOND then you have to DESCRIBE the sensor thus :



Enter the data as requested by the software about NAME, UNITS, MAXIMUM, MINIMUM & DECIMAL PLACES. Make sure DEFAULT is clicked on if you want this new scale.



Select QUIT CALIBRATE to take you back to the DESKTOP.



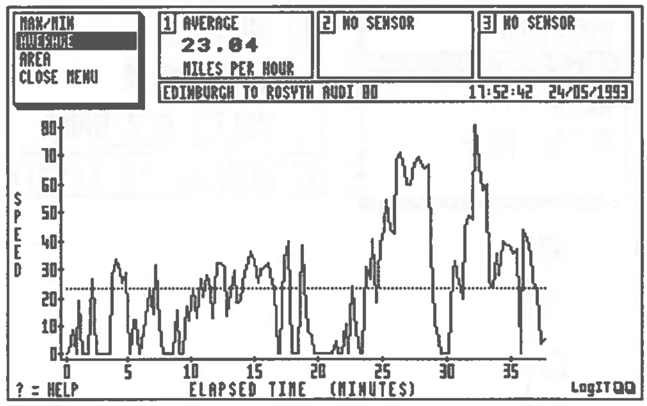


Fig.7 LogIT LinkPack+ software used to analyse data and calculate average speed.

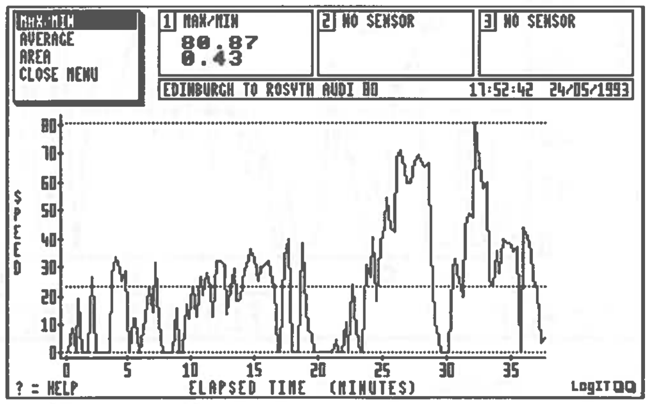


Fig.8 LogIT LinkPack+ software used to analyse maximum/ minimum speeds.

With Datadisc Plus and PP software use the *Calculate related data* section of the *Utilities* menu to work out the *voltage distance* travelled (in volts x seconds) :-

i.e. *New channel = lv + (Chan.1*in)*

where *lv* represents *last value* calculated and *in* is the time interval between readings. The average speed (in mV) can be deduced by dividing the *voltage distance* by the time. The * means "multiply" here.

Work out the real average speed from *d/t*. This figure corresponds to the average speed calculated by the software or calculated above e.g. 23 mph = 174.4 mV. You now know the relationship between voltage output and the speed units of your choosing.

Interpretation of data - On the journey from Edinburgh to Rosyth (Fig.9) it is a relatively easy task to pick out the main junctions and rare areas within the city where some speed can be maintained. It is highly illuminating to find that the average speed is only 23 mph over a route which includes dual-carriageway for at least half of the distance. Indeed as several time trials between bicycles, buses and cars have proved, the bicycle is the quickest form of transport within Edinburgh!

For further analysis the data can be saved from the datalogging software in a number of file formats e.g. *CSV* (comma separated variable), *TSV* (tab separated variable), *SID* (software interchange data), *Presenter* and *Key+*. Fig.10 shows the data as a *Pipedream* spreadsheet.

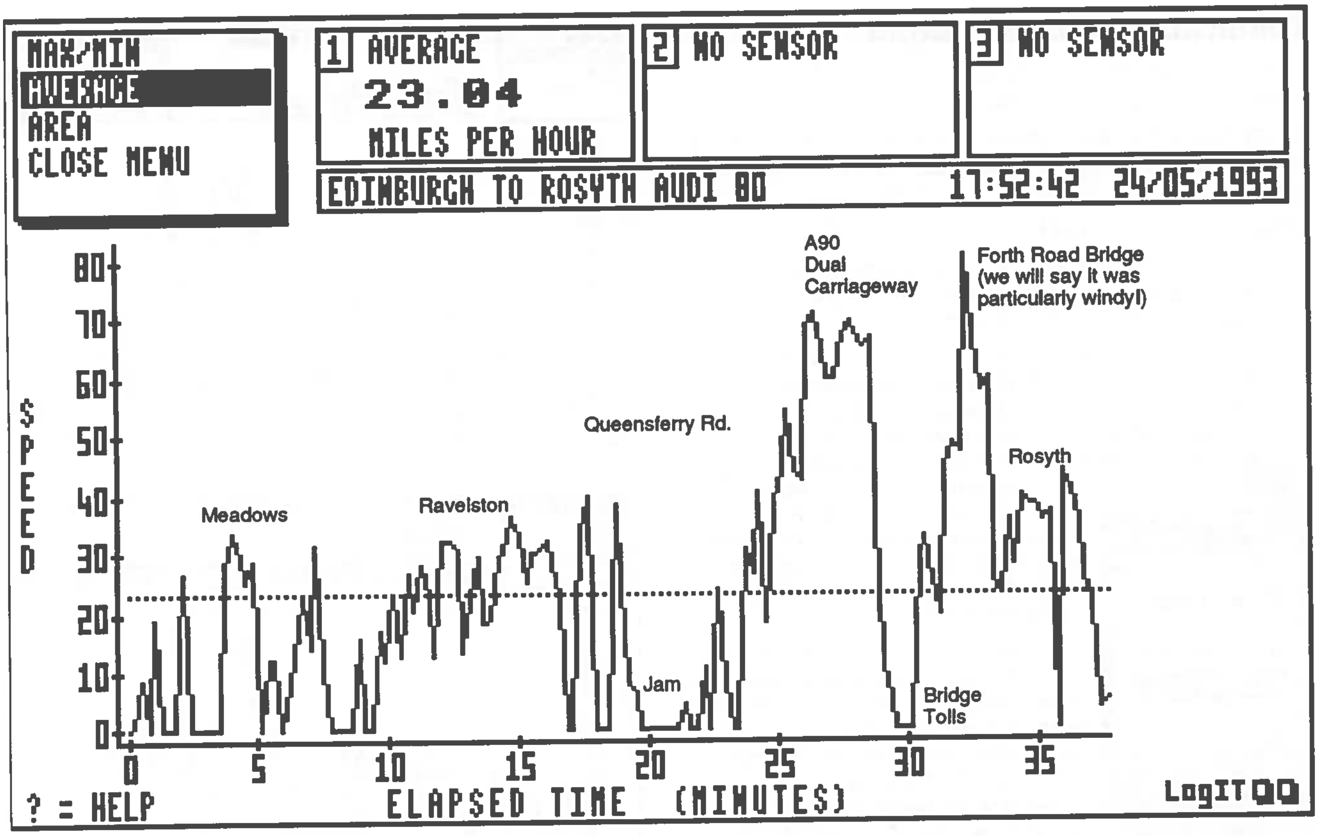
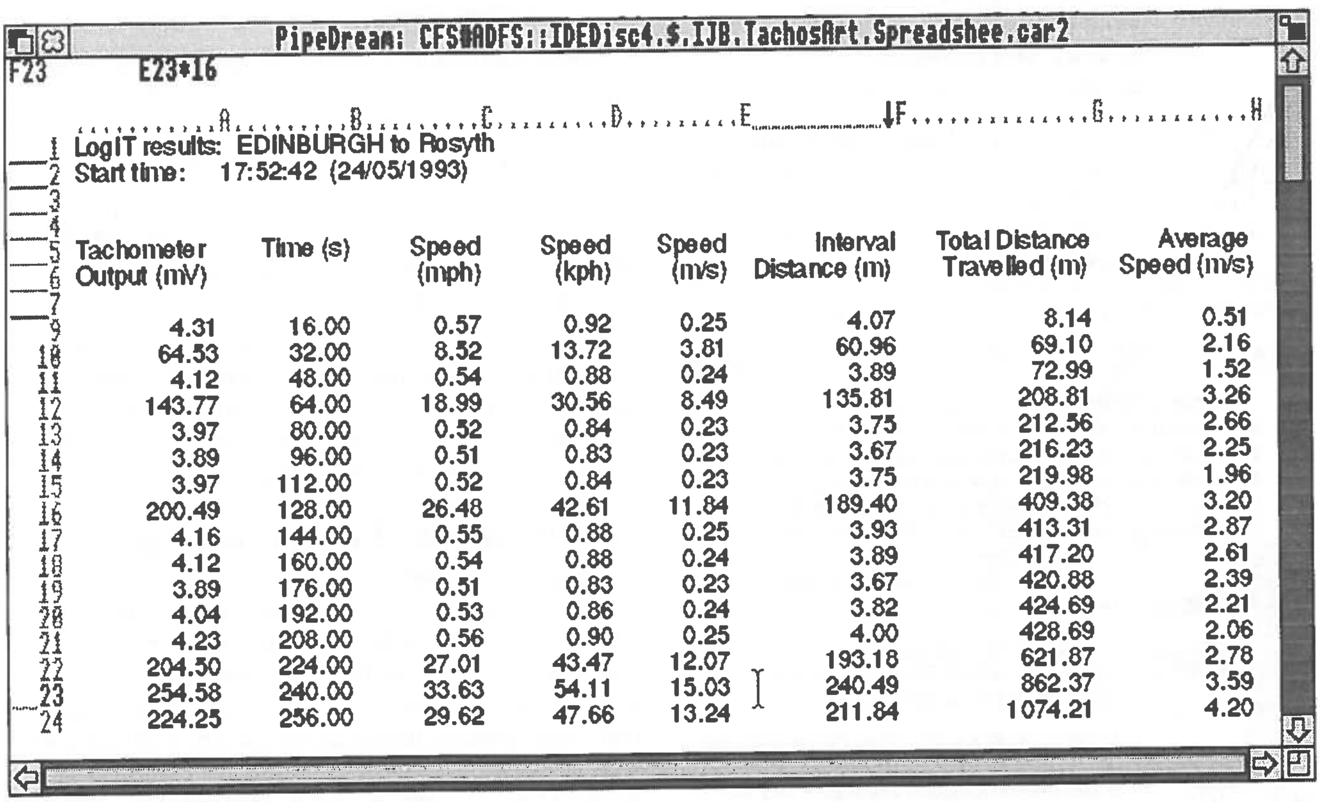


Fig.9 Tachograph interpreted



LogIT results: EDINBURGH to Rosyth
Start time: 17:52:42 (24/05/1993)

Row	Tachometer Output (mV)	Time (s)	Speed (mph)	Speed (kph)	Speed (m/s)	Interval Distance (m)	Total Distance Travelled (m)	Average Speed (m/s)
9	4.31	16.00	0.57	0.92	0.25	4.07	8.14	0.51
10	64.53	32.00	8.52	13.72	3.81	60.96	69.10	2.16
11	4.12	48.00	0.54	0.88	0.24	3.89	72.99	1.52
12	143.77	64.00	18.99	30.56	8.49	135.81	208.81	3.26
13	3.97	80.00	0.52	0.84	0.23	3.75	212.56	2.66
14	3.89	96.00	0.51	0.83	0.23	3.67	216.23	2.25
15	3.97	112.00	0.52	0.84	0.23	3.75	219.98	1.96
16	200.49	128.00	26.48	42.61	11.84	189.40	409.38	3.20
17	4.16	144.00	0.55	0.88	0.25	3.93	413.31	2.87
18	4.12	160.00	0.54	0.88	0.24	3.89	417.20	2.61
19	3.89	176.00	0.51	0.83	0.23	3.67	420.88	2.39
20	4.04	192.00	0.53	0.86	0.24	3.82	424.69	2.21
21	4.23	208.00	0.56	0.90	0.25	4.00	428.69	2.06
22	204.50	224.00	27.01	43.47	12.07	193.18	621.87	2.78
23	254.58	240.00	33.63	54.11	15.03	240.49	862.37	3.59
24	224.25	256.00	29.62	47.66	13.24	211.84	1074.21	4.20

Fig.10 Data can be transferred to a spreadsheet for further analysis

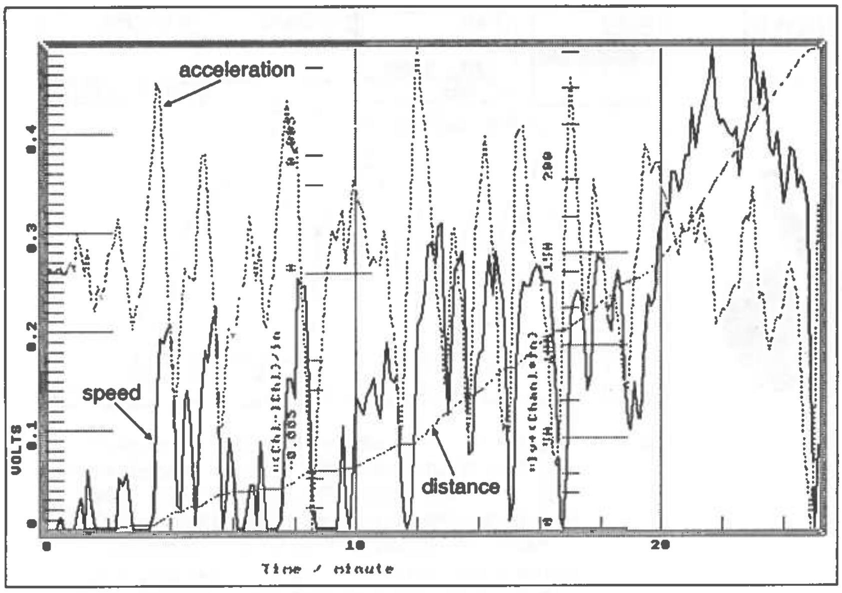


Fig.11 Car dynamics again with Datadisc Plus software - the diagonal trace shows the cumulative area (α distance) under the dark trace (α speed). The uppermost jagged trace (α acceleration) was calculated as related data using the formula:

New channel = (x- lx)/ln

where ***x*** represents any given reading on a channel and ***lx*** is the reading previous to it. The time interval between these two readings is given by ***ln***. Therefore the formula is simply the equivalent of (v-u)/t or the gradient of the speed/time graph for every time interval. Here is an excellent demonstration in one graph of integration and differentiation - something which years of maths education might never instill

3. Lego Buggy Dynamics

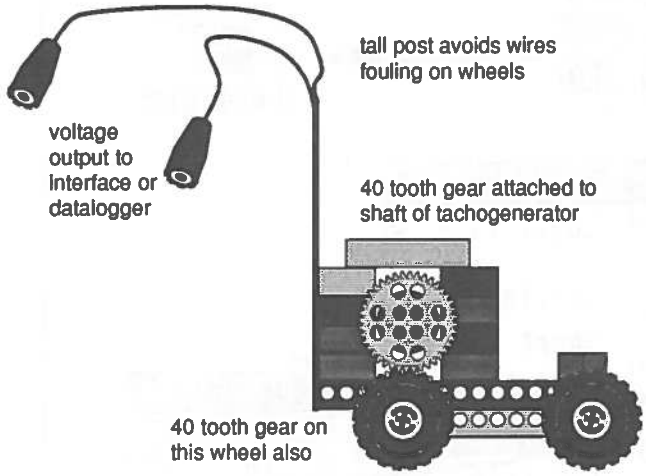


Fig.12 Lego Buggy construction. The gearwheel attached to the shaft of the buggy wheel drives the gearwheel set in the shaft of the tacho motor.

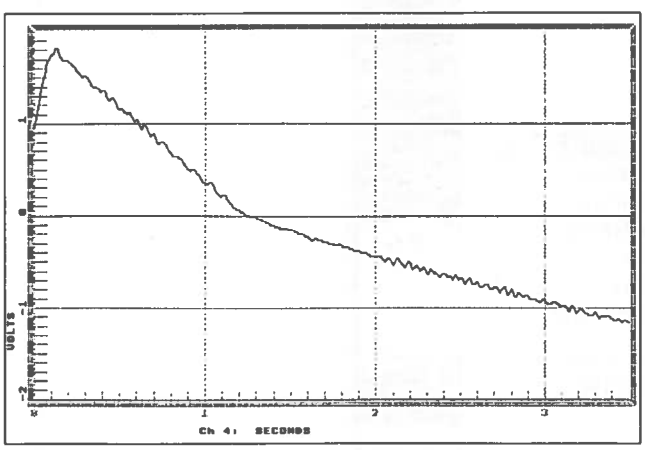


Fig.13 Lego Buggy pushed up slope then allowed to run back down. Logged on VELA Program 2 then downloaded to Datadisc Plus software - true velocity vs. time graph.

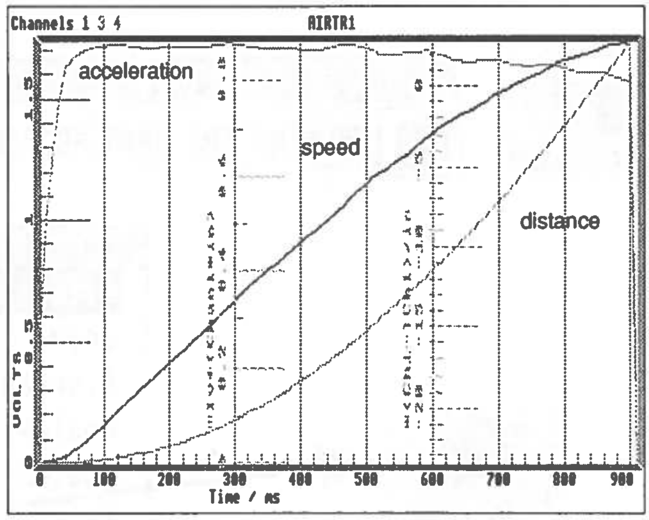


Fig.14 Buggy going down slope at fairly constant acceleration. Datadisc Plus software used to calculate related data.

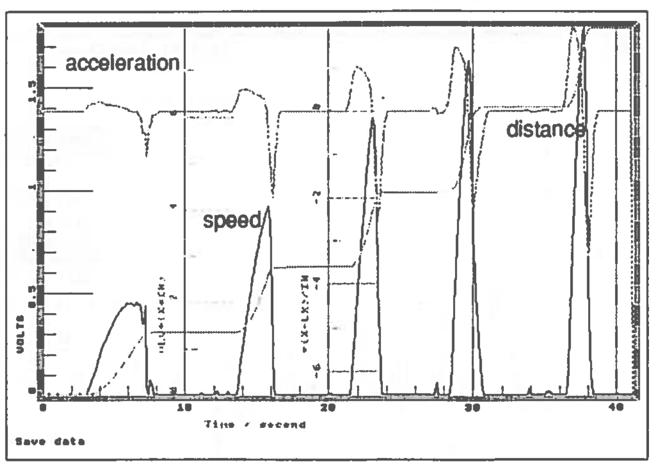


Fig.15 Series of runs down slopes of increasing steepness. If the logging time is extended e.g. for 100s or 0.1 s between readings then a number of runs can be obtained on the one channel. This also has the advantage that when the acceleration data is derived there are no wild variations due to noise on the speed/ time trace.

4. Wooden Buggy -Walkin' the dawg!

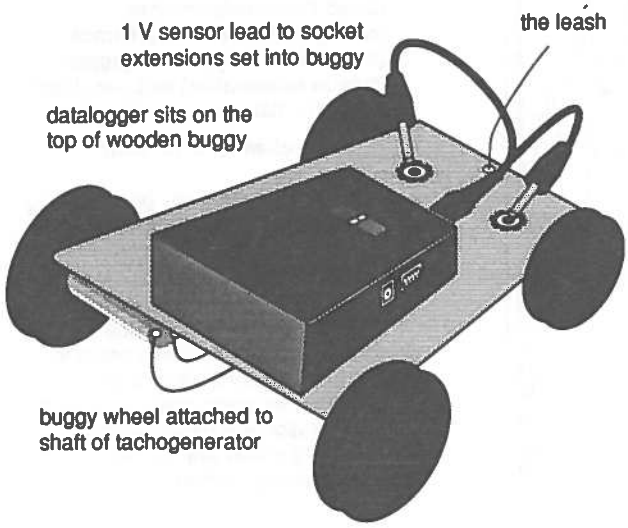


Fig.16 Wooden Buggy ready for walkies

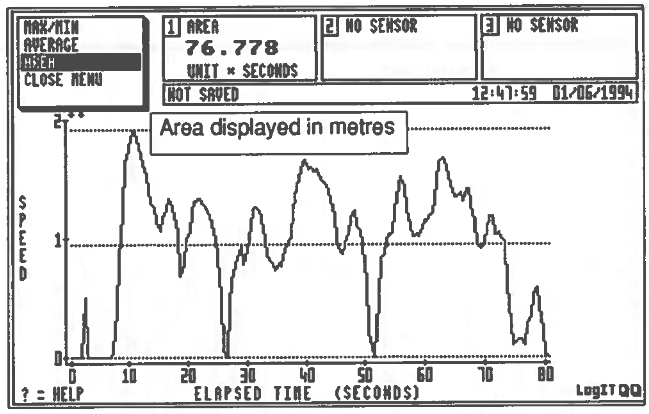


Fig.17 Output from tacho calibrated to read in metres/second. Portability of data is essential. It can be passed between applications with ease. In Fig.18 we show the route to transfer data from LinkPack+ to LogITLink via a SID file to Insight. All this can be done on an Archimedes computer with ease as the RISC OS operating system allows mult-tasking (more than one application can be active in the computer's memory at the same time).

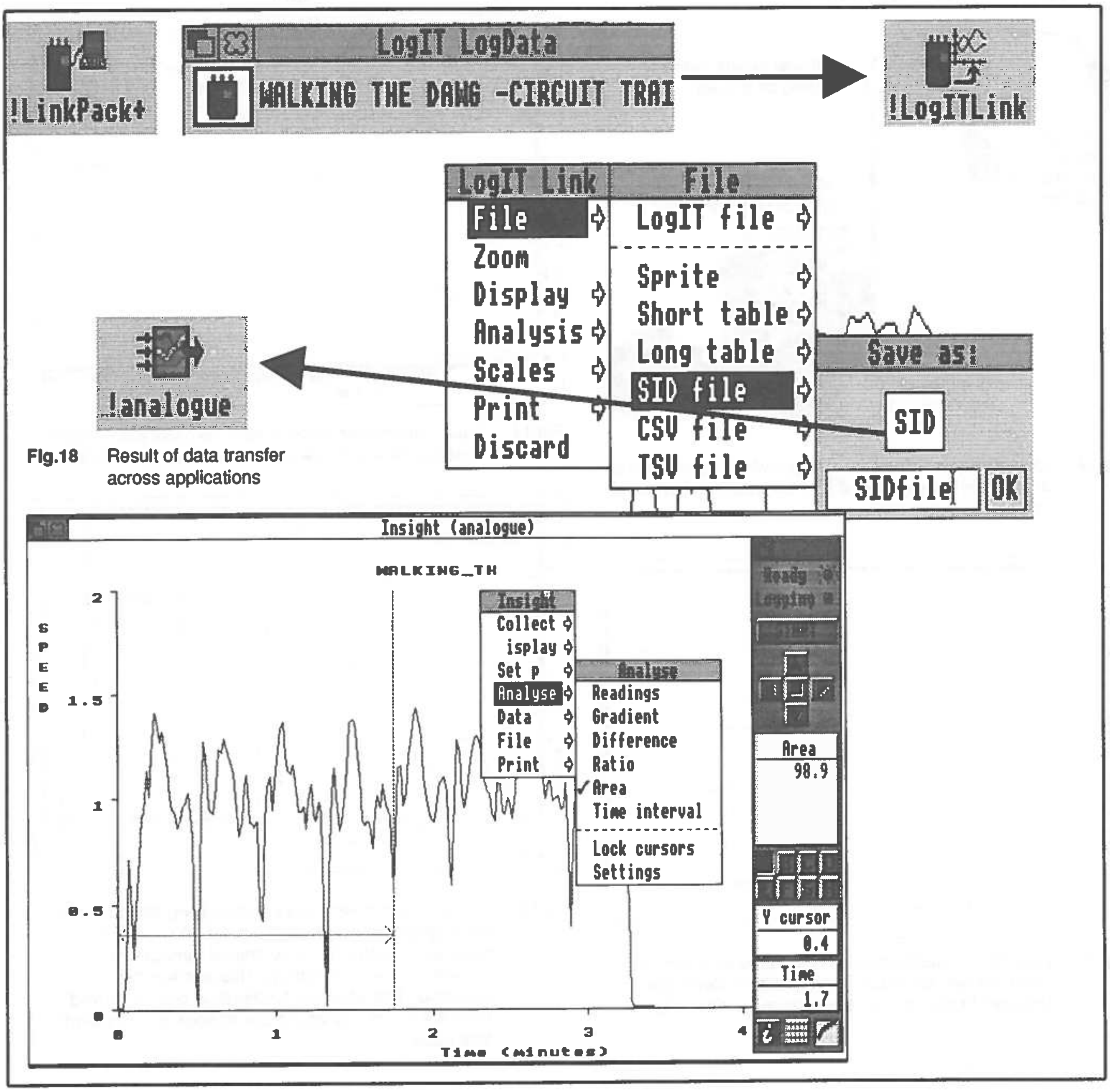
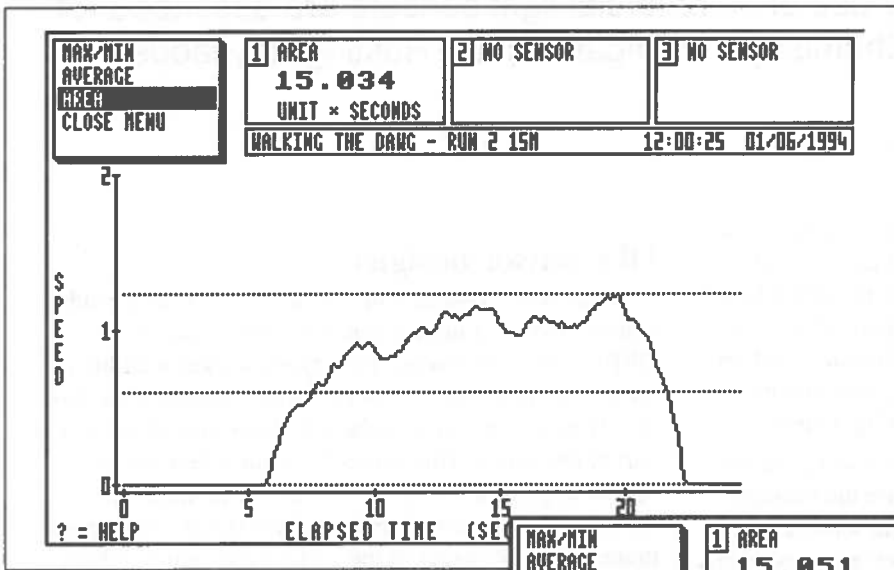
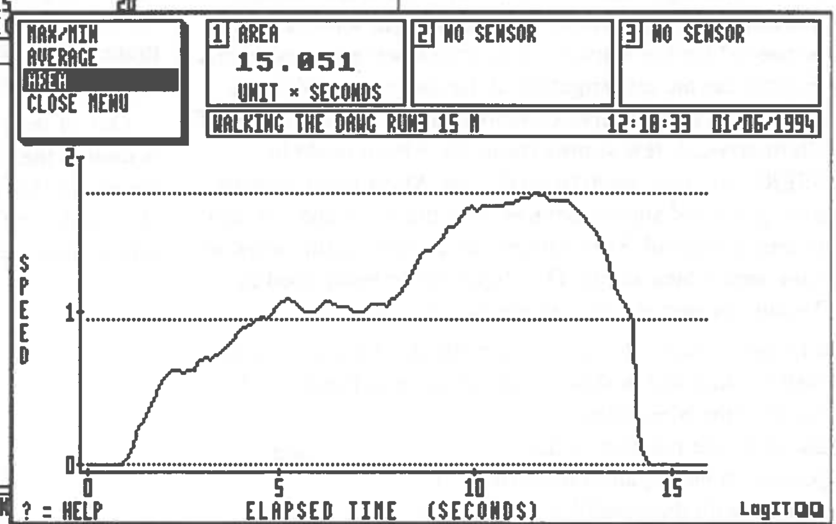


Fig.18 Result of data transfer across applications

Distance trial

A 15 metre straight run was measured out. The buggy was taken for three runs (Fig.19) and the distances travelled calculated. Once calibrated the distance was accurate to ±1%. This is consistent with previous results and may be explained by the fact that our *dawg* is not the most obedient of beasts as he tends to wander from the straight and narrow.





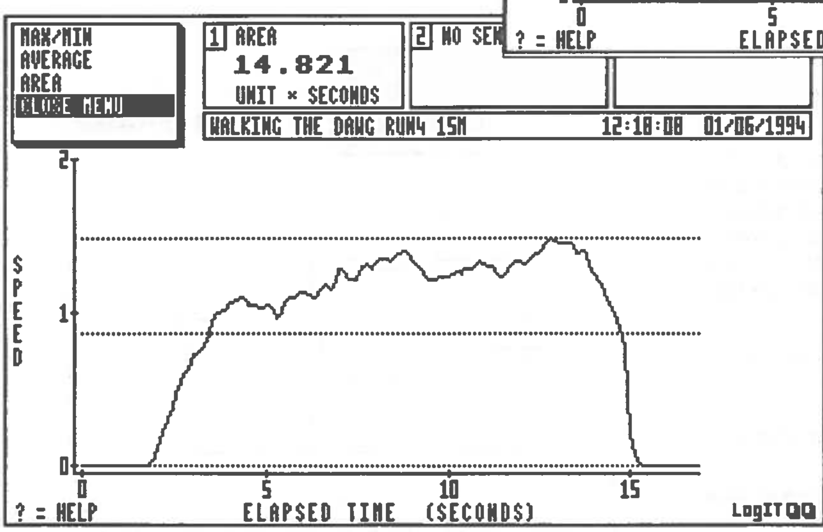


Fig.19 Distance trial results. The three horizontal lines, starting from the uppermost, represent maximum, average and minimum speeds respectively. It is interesting to see how these vary from run to run but the area stays the same. This area calculated by the software and displayed in the channel 1 box, is the distance travelled in metres.

Tachogenerator applications Part 2

Watch this space for even more applications which utilise this versatile concept. Coming in the next issue will be Rosyth to Edinburgh on a bicycle, an anemometer, one-piece apparatus to demonstrate constant acceleration, speed & deceleration, measuring *g*, wheel balancing demo, pendulum and damped oscillations.

References

1. *Continuous recording of velocity*, p4-6, SSERC Bulletin 160, June 1988.
2. *DIY transducers for distance & velocity v. time*, p30-34, SSERC Bulletin 163, September 1989.
3. *Manipulating data with Datadisc Plus - some chemistry applications*, p14-23, SSERC Bulletin 167, September 1990

TECHNICAL ARTICLE

DIY lightmeter for Pupil investigations

Two DIY alternatives to the use of commercial light sensors are described for use in a Standard Grade Chemistry Investigation into "Rusting" (syllabus reference - Topic 12).

The guidance on the Assessment of Investigations for Standard Grade Chemistry as outlined in the recently published document from the Scottish Examination Board [1] generally requires fairly basic equipment which does not entail much additional cost. The equipment listed for the investigation on corrosion (Teachers' Notes on page 22) however includes an "ESMI or other light meter".

Many chemistry or science departments will have one or two such light sensors. However to ease the management of the investigations, additional light sensors would be needed for the activity on corrosion were several pupils to carry out the investigation at the same time. We have been asked by a number of schools about inexpensive DIY alternatives. A few simple forms have been made in SSERC and they seem to do the job. Many other persons have produced similar devices over the years and the idea is hardly original. For example, since starting this work we have seen a nice simple DIY light sensor being used in Tayside as part of a recent interfacing course.

The procedure - A basis for a method is illustrated in the SEB booklet and is shown redrawn here as figure 1. The depth of the blue colour produced by the reaction of the potassium hexacyanoferrate(III) reagent with the iron(II) ions produced in the first stage of corrosion gives a measure of the amount of that corrosion. The more corrosion, the more intense the blue colour and the lower will be the reading for transmitted light from the sensor. The device as shown using a commercial sensor is thus a crude colorimeter. But, it lacks an optical filter, stabilised light source or linearising circuitry and, because of the highish concentrations of the reagents, Beer's law is unlikely to be obeyed. However even this simple device can place the solutions in a rank order which matches the amount of corrosion.

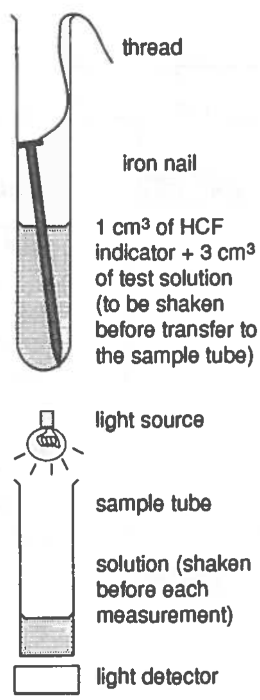


Fig.1 Redrawn from the SEB booklet p. 20

DIY sensor designs

Home built versions with simple circuitry, using either a photodiode or a light dependent resistor such as an ORP12 were constructed. Both types worked well but in the end the older ORP12 device was favoured. This was mostly on account of the relatively large area of the active part of the sensor. This makes for a much less critical optical alignment and hence for easier construction, especially in *horizontal* versions. This factor outweighed those other advantages of the smaller photodiode which are its more even spectral response and better linearity.

One of the versions, which we called the *vertical* model is used in the same way as the British Gas ESMI device or the Philip Harris Bluebox sensor. This is with a lamp shining down through a solution in a small beaker or sample tube set on top of the sensory device itself (Fig.2).

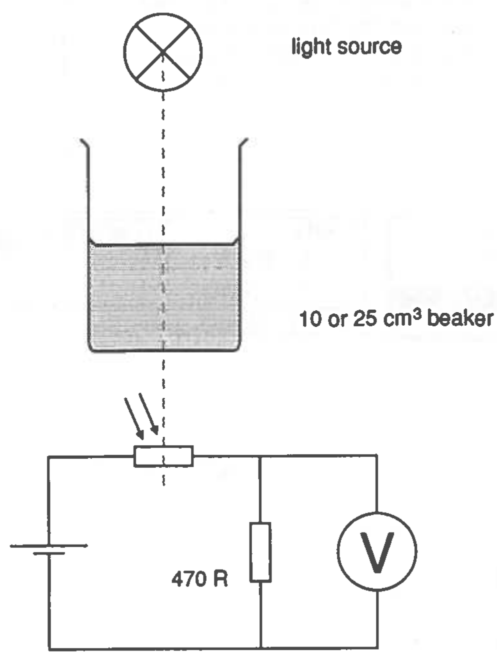


Fig.2

A second version - the *horizontal* model has its own built-in light source in the form of a miniature MES bulb with a horizontal light path through a cuvette and onto an ORP12 sensor (Fig. 3 overleaf). A square section 10 mm path plastic cuvette is used because of its low cost and the lack of any focusing effect as would be caused in using a cylindrical tube.

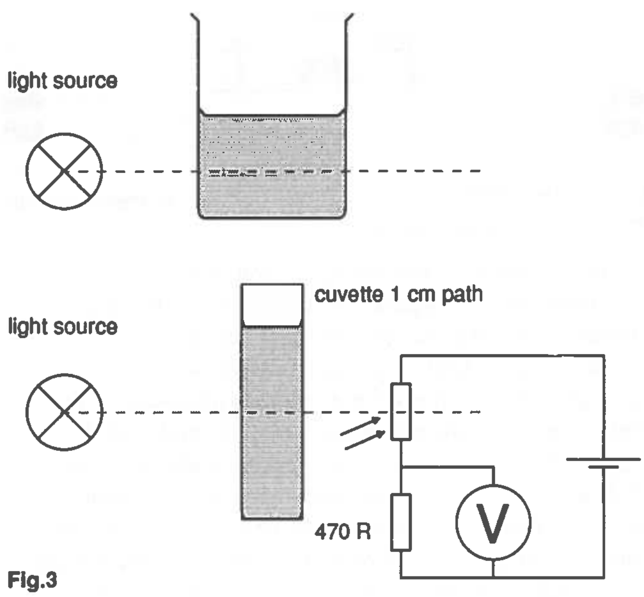


Fig.3

Both of these designs were first made as lashed-up prototypes in a large cork suitably drilled out with cork borers to accept the sensor, cuvette and bulb. These versions could be made up in minutes, but mounting the components in a box gives a more durable and robust instrument. Even cheap potting boxes are man to the task, but the more expensive types with lids do have operating and constructional advantages (see later section on constructional hints). The light levels for a rusting experiment were monitored on each of the two DIY meters and, for comparison, with two commercial models.

Nails were degreased, conditioned in 2 mol l^{-1} hydrochloric acid as per the SEB Teachers' Notes and then placed in the various suggested environments for 10 minutes. The nails were all gently agitated from time to time during the 10 minute period. Four sets of apparatus were used. Three of these used *vertical* systems each with a different sensor and a 12 V ray box held 200 mm above it as the light source. One DIY *horizontal* system of the type shown in figure 5 was also used. This had its own built-in light source. The results for just one such trial are shown in Table 1. (cf. first set of typical results in the Teachers' Notes p.23).

Environ. M = mol l^{-1}	Harris sensor (horizontal) (V)	ESMI meter (British Gas) (lux)	DIY meter designs (vertical) (V)	(V)
water	0.78	990	2.06	1.484
HCl				
0.01M	0.56	370	1.39	0.828
0.001 M	0.70	690	1.84	1.126
0.0001 M	0.74	730	1.87	1.238
NaCl				
4 M	0.73	620	1.74	1.036

Table 1

Some further pointers - The above measurements were made with 4 cm^3 of solution in a 25 cm^3 beaker. A 10 cm^3 beaker may increase the sensitivity because of the greater path length of the light in the liquid.

A 40 mm nail was used to allow partial exposure to air (in the suggested volumes in standard 16 mm or 19 mm diameter test tubes a 25 mm long nail is practically submerged).

Sample tubes were tried in place of beakers, but the readings were greatly affected by even a small displacement of the tube. This effect was much less pronounced with a beaker. The maximum reading was taken with the beaker approximately centred. For a reading of 0.600 V in the centre of the beaker, those at the four cardinal points each at halfway to the perimeter were 0.583, 0.591, 0.610 and 0.593.

Changes in ambient light greatly affects the readings on the vertical models whether they be commercial or DIY. Keeping the apparatus away from any windows and using a bright artificial source will lessen the effect of such changes in ambient lighting.

The British Gas ESMI has a distinct disadvantage for this particular experiment. There is no flat surface above the sensor on which to rest a small beaker. Consequently it is necessary to hold a beaker or sample tube above it. Hence the reading is not very steady and it is necessary to make educated time-averaged guesses.

Many other sets of readings were taken and we think there is a lot more of interest to be discovered.

For example : The readings in Table 1 show what might be expected for a given electrolyte - hydrochloric acid in this case - namely that the higher the concentration the faster the corrosion. However when other concentrations were trialled, for instance 0.01, 0.005 and 0.0025 M HCl, strange and interesting things happened and the expected relationship broke down. Were our solutions wrongly made up or contaminated? No, when checked with a conductivity meter they were obviously okay. Fresh solutions then were made up but yielded the same unexpected results.

We were left pondering also on other aspects of the method :

(i) should the nail be agitated or not?

If the contents are not gently agitated then diffusion might be the rate determining step. This might be one of the additional variables for investigation.

(ii) should the potassium hexacyanoferrate reagent be added after the corrosion had occurred?

Perhaps the blue deposit on the nail slows down the diffusion of the initially formed iron(II) ions or protects the nail to some extent? Or does it catalyse the process? We tried adding the reagent afterwards and it did not change the rank order of the rates of rusting;

(iii) should only one nail be used in each test?

Because of previous differences in their history, despite the same 15 min conditioning and each nail having come out of the same pack, there could be unexpected variation.

Some nails may have more incipient active sites for initiation of the corrosion reaction. Instead of one nail for each set of conditions we would then need a large number per experimental condition. In practice this is out of the question as it would make the investigation too cumbersome. Perhaps pupils who suggest this sampling factor deserve bonus marks? The design and execution of the experiment should perhaps matter more than the appearance of such apparently maverick results.

The horizontal meter - This DIY model is a little more difficult to construct than the vertical types, but has several advantages. The geometry is fixed and the readings for the same solution should be constant provided that the same bulb and the same voltage supply to that bulb are used. In addition unlike the vertical models it is little affected by changes in the ambient light.

Comparative costs - the prices of the two commercial models used are:

Harris Light sensor (Cat. No. E60124/5)	£39.80
British Gas ESMI	£47.00

The DIY models are adequate for this purpose and, as can be seen from Table 2, can be constructed very cheaply.

Source	Cat. No.	Component	Price (£)
Rapid	58-0130	ORP12SL	0.70
SSERC		470R resistor, ¼W, 10 off	0.06
Rapid	30-0555	potting boxes, 50x75x 35mm, 2@0.30	0.60
SSERC	691	bulb holder	0.20
SSERC	690	bulb, MES, 6 V, 0.15 A	0.09
Rapid		input sockets, 4 mm	
"	17-0145	black socket, shallow, 2@0.12	0.24
"	17-0560	black socket, deep, 2@0.15	0.30
"	17-0580	red socket, deep	0.15
"	17-0565	blue socket, deep	0.15

Table 2

For the vertical model the above list can be reduced by one box, the bulb holder and bulb and by two of the sockets reducing the total cost by 83p.

Construction - The designs illustrated here are intended to serve as examples only. We made a number of versions using different basic materials - plastic, metal or wood - and constructional methods for mounting the sensor or the cuvette in the *horizontal* model. None of this proved critical to their actual performance. A competent technician or teacher could come up with any number of variants on the basic theme.

Our vertical model is very simple. The ORP12 is best recessed below the surface of the box in order to reduce the effect of ambient light coming from an angle. In the potting box version this was achieved by mounting the ORP12 and the rest of the circuit (Fig.2) on a small piece of stripboard which was held below the the surface by a few extra nuts or spacers. (Fig.4). The voltage applied across the ORP12 is not critical. 1.5 up to 6 V will do and this is probably best provided externally so that you don't have internally mounted batteries which may be forgotten about (and corrode!).

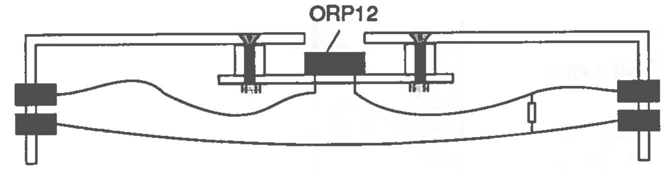


Fig.4 Potting box version

In the horizontal version, again nothing is too critical provided you use a square section 10 mm path plastic disposable cuvette. Its flat sides will not cause any focusing and an ORP12 provides a large target. The basic arrangement is as in Fig.3 but methods of mounting the light source, cuvette and sensor are many and varied. Again it may well be a case of working with your own choice of materials. Shown below (Fig.5) is our own preferred design. This we built mainly in wood and put into two potting boxes. Two of the PB4 boxes are needed to give sufficient length and since the boxes have slightly tapered edges the second box has to be inverted to provide a straight bottom right through both containers. Shallow sockets for the bulb supply ease fitting the holder.

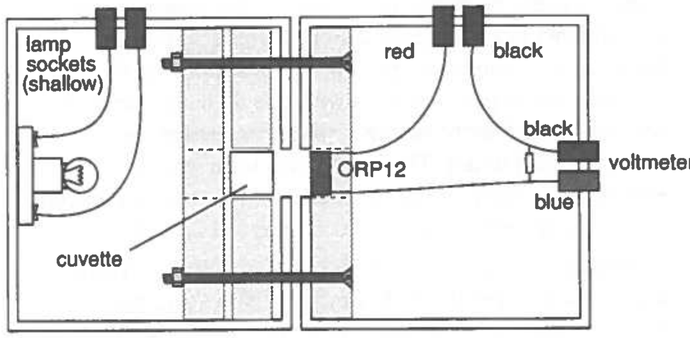


Fig. 5

A block of wood about 150 mm by about 40 mm square section is drilled axially with a 9 mm diameter hole to provide the light path. It is then sawed in half and two fillets just slightly wider than the cuvette width are glued as shown to provide a square hole to accept the cuvette.

The light path can be opened out a bit further at its ends to allow fitting of the bulb and the sensor. The circuit and three pairs of 4 mm sockets are mounted externally (at least the two for the bulb are best made shallow types).

Instead of cutting the block a circular hole may be drilled to accept a test tube in place of the cuvette. You will have then to arrange for the right distance between the tube and the sensor to catch most of the light beam. This position would be most easily found by moving the sensor to obtain the highest 'blank' reading on the meter. An old screw top from a Winchester bottle provides an excellent cover for a cuvette, although in practice we found it made little difference to the readings.

Reference

1. *Scottish Certificate of Education, Standard Grade Chemistry, Guidance on the Assessment of Investigations*, Scottish Examination Board, March 1994.

TECHNICAL ARTICLE

Magnetic Corn Flakes

Class 1B4 of George Watson's College, Edinburgh describe their investigations into this strange and wondrous phenomenon.

We have been studying magnetism. Noting the fact that *Kellogg's* list "iron" among the ingredients and the nutrition information on the side of their breakfast cereal packets, we were curious about whether or not this "iron" made the corn flakes magnetic. As a result, many of our Physics periods this term have been used up in investigating the magnetic properties of corn flakes!

We floated a corn flake on a bowl of milk and, with a strong (neodymium) magnet held closely to the corn flake, tried to attract it. The corn flake sailed across the milk, successfully guided by the magnet.

We liquidised approximately 100 g of corn flakes in water and poured the suspension into a one litre beaker. Whilst stirring this suspension with a plastic rod, we held a neodymium magnet to the side of the beaker. Lifting the magnet away briefly, we saw a dark blob which might be of iron. We were able to drag the blob up the inside of the beaker, with the magnet on the outside, and so drag it out onto a sheet of paper. The material extracted in this way looked and behaved like iron filings.

When we tried these experiments again with another brand of corn flakes, and two of bran flakes, one of them Kellogg's, we found that these other brands did not yield up magnetic iron (Table 1).

After our various investigations we eventually wrote to Kellogg's. Our letter and their subsequent reply ran as follows :

continued next column /

Cereal type	BRAND Kellogg's	Other
Corn Flakes	Iron extractable with magnet : packet states 7.9 mg per 100 g	Marshall's : no iron was extracted with magnet : packet states 14 mg per 100g
Bran Flakes	Iron extracted with a magnet : packet states 11.7 mg per 100g	Safeway : no iron was extracted with a magnet : packet states 20.0 mg per 100 g

Table 1

George Watson's College
3rd June 1994
Consumer Services Dept.,
The Kellogg Building etc.

Dear Kellogg's,

Noting that your breakfast cereals list "iron" among the ingredients and in the nutrition information : We tried to see whether our new (strong) neodymium magnets could attract them. We found that Kellogg's Corn Flakes and Kellogg's Bran Flakes could be attracted across the surface of water by the magnets.

We then liquidised 100 g or so of these cereals in distilled water and found that our magnets could extract what appears to be grains of solid metallic iron. The quantity extracted seemed to match with the information on your box; eg 6 or 8 mg from <=> 100 g of Kellogg's Corn Flakes. We dissolved the extract in hydrochloric acid and titrated it with potassium permanganate to establish that it was indeed iron.

Please can you write to us to confirm that the iron in your cereals is metallic iron and not in the form of an iron compound? Perhaps you could also explain to us why you add the iron in that form. We have found our investigations so far to be most interesting and look forward to receiving such further information as you may be able to supply.

Yours faithfully,

Class 1B4
c/o Keith Black

continued overleaf /

Kellogg's

KELLOGG COMPANY OF GREAT BRITAIN LIMITED

13th June 1994
Mr K. Black
George Watson's College

Dear Mr Black and Class 1B4,

Thank you very much for your letter regarding the iron used to fortify Kellogg's breakfast cereals.

I can confirm that the iron we add to our products is iron in its elemental form. Elemental iron powder is one of the forms of iron which may be added to white flour, which by law must be fortified with iron. The iron we use conforms with the specification stated in "The Bread and Flour Regulations 1984".

Thank you for contacting us on this matter.

Yours sincerely,
Dr. I. P. Bell,
Scientific Affairs Officer.

There is a great deal more investigative work that could be done. In particular, checking out other brands to see if we can find anyone other than Kellogg's who add metallic iron to their cereals. It has been great fun and we are hoping to do some further work on it in S2!

Acknowledgement

The idea for this investigation was gleaned by Keith Black, 1B4's class teacher. He was inspired by a splendid lecture entitled *Demonstrations to Knock Your Socks Off!*, delivered by Bob Becker of St.Louis, Missouri, at the annual meeting of the Irish Science Teachers' Association in Dundalk in March 1994.

Editor's Note

We received 1B4's article just as we were finalising the camera ready copy for this issue. It was as welcome as it was unexpected at this time in the session. We just had to make room for it.

P.S. Neodymium magnets are available from SSERC as Item 771 at £1.30 each. See page 39 of this issue.

TECHNICAL TIP

Microscopic examination of yeast cells

We recently had a request for help with practical aspects of this procedure. The context of this enquiry was of a suggested Pupil Activity described on page 177 of "Starting Science : Resource Pack One" [1]. This activity is entitled "How many in a day". It involves the addition of dried yeast and sugar to water and after twenty minutes or so examining the mixture for yeast cells reproducing by budding.

Our enquirer had a number of complaints about the procedure as illustrated in the commercial publication :

- With the usual type of microscope used for S1-S2 and Standard Grade courses, the yeast cells are far too small to see properly never mind pupils picking out those which might be budding;
- As described, the preparation is unstained and the insult of insufficient contrast is thus added to the injury of inadequate magnification;
- The amount of yeast suggested (5 g with an equal weight of sugar in 50 cm^3 of water) means that a sample straight from the resulting culture is far too densely packed with cells for convenient examination;
- The above problem combined with the omission of a cover slip means that pupils are totally confused by an excessive number of gas bubbles (carbon dioxide mainly) which many of them then confuse with the yeast cells they are meant to see.

Dealing with these problems in the same order :

- the usual specification for a pupil microscope at this level is with objectives of x4 or x5, x10 and x20 with a x10 eyepiece. Maximum magnification is thus x200. This is insufficient for yeast cells to be seen with any clarity. To be fair on the authors their illustration does show a microscope of the type used at Higher Grade and beyond and magnifying to x400 or more. This however is a pupil activity. It should have been made clear that the microscopy part of it will have to be a teacher assisted demonstration or station;

- stain the yeast cells with a vital stain (we found that methylene blue worked quite well) or use simple contrast enhancement techniques [2];

- make up the culture as directed and with the quantities suggested but - before mounting a drop on a slide - dilute tenfold i.e. 1 cm^3 to 9 cm^3 of water.

- use a cover slip and employ the usual technique of starting with the slip at an angle and letting it down gently on a mounted needle or seeker so as to allow most of the gas and air bubbles to be expressed. Even so warn the pupils about this possible confusion.

References

1. Starting Science, Resource Pack One, Fraser, A. and Gilchrist, I., Oxford Unversity Press, 1989.
2. Improving contrast, Biology Notes, SSERC, Bulletin 94, Jan. 1977.

Motion QED

The Motion QED is a Unilab instrument that measures time, speed and acceleration. This article looks at its intrinsic performance. The effects of light gates, other apparatus and experimental conditions are not considered.

Laboratory experimentation in mechanics depends on being able to measure the physical quantities length, mass, time, speed and acceleration. The Motion QED is a microprocessor based, direct reading instrument of time and of the time dependent quantities, speed and acceleration.

A suite of six programs (Table 1) can be chosen from. Three relate to the measurement of time or period. Two relate to the measurement of speed. The sixth relates to the measurement of acceleration. With one exception - momentum experiments - almost any out of the corpus of standard mechanics experiments may be undertaken.

Regarding the exception, speeds of two independently moving vehicles, as in momentum experiments, cannot be logged by QED. Either the user should use two QEDs, one per light gate, or log event times from two light gates on one QED and unscramble the data to derive the separate speeds. Although this is a limitation of the instrument, it actually works out to the user's benefit. It is much simpler interpreting data from collisions when each light gate is connected to a separate speed meter.

Description

The Motion QED is housed in an oblong metal case measuring 240 x 130 x 50 mm. The LCD display, pushbutton controls and inputs are all placed on the top surface (Fig. 1). The LCD characters are 6 mm tall. The display is comfortably read when the eye is between 500 mm and 700 mm distant. Therefore the instrument has the operational intimacy of a pocket calculator. It is very much a pupil instrument, for individual or small group work. It has not been designed to be used for laboratory demonstrations.

Power is not taken directly from the mains, but indirectly via an LT supply producing 12 V to 15 V a.c. or d.c., or from a 9 V battery. The instrument may therefore be used outdoors - for instance to study traffic, or athletics, or cycling. It is sufficiently small to be hand held. However the enclosure is not weatherproof, and its 4 mm electrical inputs are relatively clumsy for anything but laboratory operation.

Program	**Specification**
Time Interval	Measures time period between events Resolution : 1 ms Range : 99.999 s Number of measurements : 1 to 4
Speed	Measures the speed of a vehicle as it passes through a light gate, or activates two switches Resolution : 0.001 m s^{-1} Range : 99.999 m s^{-1} Number of measurements : 1 to 4 Mask or gap size : 1 cm to 10 cm by 1 cm steps 20 cm to 200 cm by 10 cm steps
Acceleration	Measures acceleration of vehicle with single mask and two light gates, or double mask and single light gate Resolution : 0.01 m s^{-2} Range : unspecified (about 50 m s^{-2}) Polarity : deceleration indicated with a negative sign Number of measurements : 1 or 2 Mask or gap size : 1 cm to 10 cm by 1 cm steps 20 cm to 200 cm by 10 cm steps
Event Timer	Measures the time at which an event happens From event times, all other quantities can be calculated Resolution : 1 ms Range : 99.999 s Number of events : 2 to 8
Average Speed	Measures the average speed of a vehicle as it travels between two light gates. The time used in the calculation is the time for the leading edge of the mask to travel between the light gates. The information on the trailing edge is not used. Resolution : 0.001 m s^{-1} Range : 99.999 m s^{-1} Number of measurements : 1 Distance between light gates : as for speed
Gap Times	Measures the time taken by the leading edge of a mask to travel between light gates Can be used to measure human reaction time using two switches Resolution : 1 ms Range : 99.999 s Number of events : 1 to 3

Table 1. QED program specification

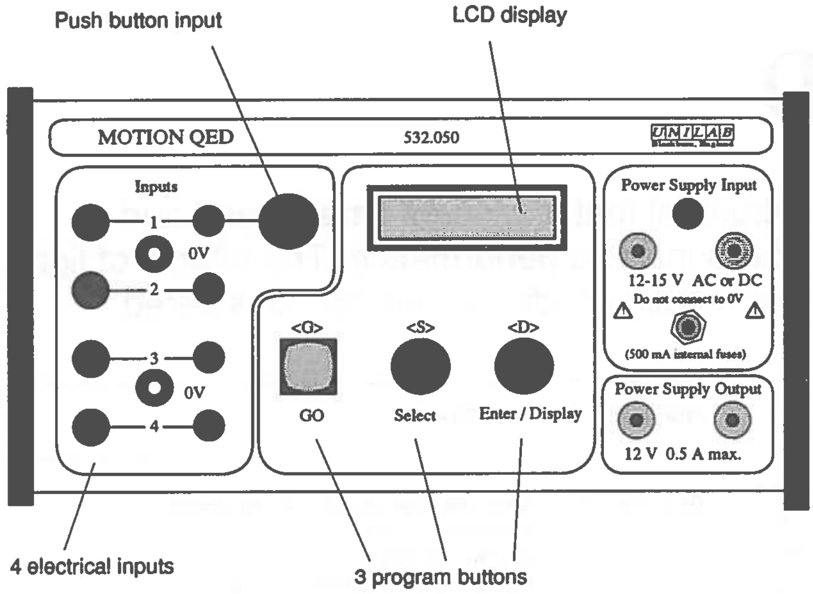


Figure 1. Motion QED : Plan of top surface

Events

The instrument waits for changes in the logic level of any of its four inputs. Any change that takes place is known as an *event*. The times of the events are stored in memory. Event times can be displayed in milliseconds or seconds using the program *Event Timer*, leaving the user to work out any derived quantities such as period, speed or acceleration. Event times can also be processed automatically to calculate derived quantities in SI units by utilising one of the other five programs.

Four events are recorded if acceleration is being measured (Fig. 2). The mathematical method used by the program is shown below.

$$v_1 = (\text{mask size})/t_1$$

$$v_2 = (\text{mask size})/t_2$$

$$\Delta t = t_1/2 + t_2/2 + t_3$$

$$a = (v_2 - v_1)/\Delta t$$

The user is unable to process a set of data in more than one way. For instance if the user is running the program *Acceleration*, the only quantity that can be displayed is acceleration. The instrument is unable also to display event times, initial and final speeds, and period. These are limitations of the QED, but help to keep operations simple. Thus if the QED is being used to introduce the concept of acceleration, the teacher may wish to start with the program Event Timer so that his or her pupils must first calculate periods and speeds before getting to a value for acceleration.

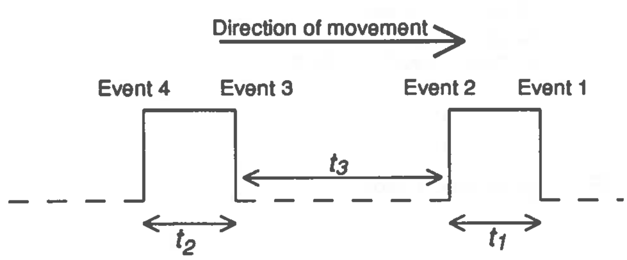


Figure 2. Acceleration measurement : logic levels and events

Programming

The programs are selected by two pushbuttons *Select* and *Enter/Display*. The Select button allows the user to cycle through a series of short menus. The *Enter/Display* button selects or locks onto the menu item being displayed.

The controls really are very simple to get the hang of. A few practice shots is all that is needed to master them. Guidance in the handbook is clear.

Inputs

There are four inputs numbered 1 to 4. These are accessed through 4 mm sockets colour coded red for live and black for 0 V or common. There is also a manual push button that operates input 1. The inputs can be wired and triggered in any order. It is not the numerical order of the inputs that is significant, it is only the sequence in which events happen that matters. This simplifies usage.

The user is warned against commoning a power supply input with the 0 V terminal of the signal input. To do so would short circuit and possibly damage the power supply rectifier. The user must therefore be especially careful when connecting earthed equipment, that is power supplies with one terminal at earth potential, to either the QED or to a light gate. The use of an oscilloscope would be similarly hazardous. The apparatus is thus at risk of harm from the accidental shorting of inputs. Admittedly the risk is slight. An internal 500 mA fuse is fitted and is likely to prevent damage.

Inputs are protected against the accidental connection of a power supply (up to 20 V).

Inputs can be operated either manually or automatically by a simple switch. Closing the switch is one event. Opening it is a second event. Because most switch contacts bounce when brought together, the software prevents a second event being recognised until a period of 3 ms has elapsed after the first event. Thus any switch bouncing is likely to be ignored and unlikely to be a nuisance. It should be noted that the microprocessor's clock continues to keep accurate time during these 3 ms dead periods after events.

For most experiments, the inputs will be connected to light gates. The QED inputs have been designed for operation with two types of light gate signal - from any of the Unilab range of light gates, or from a light gate with a TTL type output (Table 2).

Light gate type	Compatible signal	Compatible connector
Educational Electronics 6140	no	no
Harris P16750/8	no	yes
Irwin EA0381	no	yes
PASCO ME-9498	yes	no
Unilab 414.032 and 414.033	yes	yes
Unilab phototransistor 414.026	yes	yes

Table 2. Compatibility of light gates with QED

Because the inputs are triggered on events rather than on logic levels, the polarity or logic state of a light gate does not matter. This simplifies operation.

Performance tests

All the programs have been tried and found to operate without any hitch.

The accuracy of the timer has been assessed. Events are displayed to a precision of 1 ms. We found that for periods of less than 2.000 s the timer was wholly accurate with the millisecond being expressed exactly. For times between 2 s and 100 s, no detectable error was found. The readings were as accurate as our test instrument and were within 0.02%.

These tests were conducted at 20°C. The manual warns that extreme temperatures may impair accuracy. We have not investigated this.

By testing the accuracy of the speed function, and knowing that event timing is reliably accurate, we can assess whether the arithmetical processor causes errors. Our findings (Table 3) show that if events occur in quick succession, the instrument is liable to display an erroneous value. The specification records that a switch debounce delay of just under 3 ms has been built into the software. We would have expected that a period of 4 ms would

Period between events	Reading error
$t = 4$ ms	Readings are wholly wrong
$t < 25$ ms	Readings are sometimes wholly wrong, or sometimes out by 2%, but more commonly are correct to within 0.2%
25 ms $< t <$ 45 ms	Readings usually correct to within 0.2% but errors of 1% can occur
$t > 45$ ms	Errors > 0.2% not seen to occur

Table 3. Errors related to the measurement of speed

register a correct value of speed. This is not so. Wholly erroneous values of speed were found to occur for periods up to 20 ms. For periods longer than this, wholly erroneous values were never seen to occur. There was evidence of an uncertain digit error. This is biased low.

For periods greater than 50 ms, the accuracy of the speed measuring facility is reckoned by us to be ±0.2% of the reading, with 95% confidence limits, and ±1 digit.

Since acceleration is the instrument's most complex measurand, we have conducted some tests to assess how accurately it measures this. Dependence on the accuracy of timing is crucial. For instance, in the experiment to measure *g* by dropping a U-shaped card through a light gate, an uncertainty of 0.1 ms in event timing would cause an uncertainty, typically, of 0.08 m s^{-2} in acceleration. The QED's resolution is 0.01 m s^{-2}.

The accuracy of acceleration measurement depends on both internal and external factors. The internal factors are crystal frequency accuracy, electronic delays, software delays, number of bits used in the processing, the algorithm and the rounding of numbers by software when doing the arithmetic. These were tested, cumulatively, by applying signals of a mark : space : mark ratio of 3 : 2 : 1.

For the range of values up to 40 m s^{-2} the accuracy of the acceleration measuring facility is reckoned by us to be ±0.6% of the reading, with 95% confidence limits. An uncertain digit error could not be found. All readings lower than 3.00 m s^{-2} were found to be exactly right. This is very impressive!

The ultimate performance test is to find how close to the local value of *g*, 9.81 m s^{-2}, we get with QED. However by no means is this solely a test of its prowess. External factors such as light gate parallax, mask inaccuracy, the yawing of a mask as it falls and ambient lighting all can cause errors.

Because this draws in other factors, it is discussed in a separate article following on this one.

Summary

QED is an acronym for Quick and Easy Display. It certainly is a nifty instrument. Listing its positive qualities, it is easy to operate; it performs with complete reliance (except where indicated); it measures in SI units three of the basic quantities studied in mechanics; its measurements are as accurate as they need be and are certainly more accurate than any ancillary equipment that is liable to be used with it; it takes up relatively little bench space; it is quick to set up; its price, which is £103.34, is very reasonable indeed.

Set against all these qualities, we should point out that some care is required in wiring it up. Some pupils might have difficulty in correctly connecting light gates and a power supply to the QED. However this is no more than the care required of setting up many other light gate and timer systems.

Perhaps the most commonly used time, speed and acceleration measuring systems currently in use in Scottish schools are computer based. By comparison, the QED is far niftier and far cheaper than computer systems, and more accurate than some.

Verdict

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

(Code : A = most satisfactory, B = satisfactory, C = unsatisfactory)

Using QED and light gates to measure *g*

Whereas the scope of the previous article consisted of the Motion QED in isolation from other apparatus, this article looks at the performance of a complete measuring system comprising QED, light gates and masks, and the effects of ambient and experimental conditions. The test is the measurement of gravitational acceleration. How near to 9.81 m s^{-2} can we get?

A visitor to the Centre remarked recently that the value of *g* always ends up greater than 9.81 m s^{-2} whatever the method or apparatus used! This article seeks to find if this is indeed a truism. What substance is there to it?

Possible causes of error are examined one by one. These problems were described in this journal some years ago [1], when it was recommended that a large data sample be taken to allow for experimental error.

The standard experimental method was adopted wherein a double or U-shaped mask was dropped and allowed to freefall from a height of 1 cm above the light beam of a laboratory light gate. This was connected to a Motion QED programmed to measure acceleration.

Error analysis

Error inherent in QED : This is estimated by us to be ±0.6% of the reading, with there being no evidence of an uncertain digit error. The error seems to be caused by the numerical processing. Usually the processor throws out a reading that is exactly right. If however it generates an error, the reading is more often higher than it should be and to this extent it is systematic. However the manner in which the error occurs is more like a random error, and this is how we regard it. If measurements are repeated and readings averaged, the instrumentation error in the mean will be less than ±0.6%.

The QED reads acceleration to two decimal places. In a single measurement of *g* the instrument error, with 95% confidence limits, is ±0.06 m s^{-2}.

Random measurement error : If repeated measurements are made under similar conditions, the spread in readings (Table 1) indicates the cumulative effects of many possible random happenings - instrumentation error, irregular photogate response, fluctuations in mask width, mask falling skewly, mask turning during fall, variation in gap between mask and photosensor, change in ambient lighting and so on. The conditions which were maintained constant through the series were : dropping mask from same position 1 cm above and out from photosensor; same leading edge of mask; same side of mask facing photosensor.

The data (Table 1) has been analysed using the range method discussed in Bulletin 178. Confidence limits for the uncertainties throughout this article are 95%.

Acceleration	9.82	9.80	9.73	9.91	9.83
readings (m s^{-2})	9.96	9.78	9.91	9.92	9.94

Mean value (x_m) 9.86 m s^{-2}
Range (w) 0.23 m s^{-2}
Sample size (n) 10

Uncertainty in mean value
(95% confidence limits) $= 2\,w/(n-1) = 0.05$ m s^{-2}

Uncertainty in a single reading
(95% confidence limits) $= 2.3\,w/n^{1/2} = 0.17$ m s^{-2}

Table 1. Analysis of set of 10 readings of *g*

The uncertainty in a single measurement from this set of ten readings is ±0.17 m s^{-2}, which is vastly greater than the ±0.06 m s^{-2} uncertainty of the QED (for values of around 10 m s^{-2}). It shows the influence of linking additional apparatus to QED and of random happenings during experimentation.

The uncertainty in the random error is greatly reduced by taking many readings. For instance the uncertainty in the mean value of this set (Table 1) of ten readings is ±0.05 m s^{-2}. For some sets of ten readings the uncertainty in the mean is ±0.02 m s^{-2} (Table 4).

Error in mask width : If a double mask whose nominal width is 50 mm has an error of 1.0 mm in one limb (Fig. 1), or 2%, then the acceleration reading will be out by 2% or 4%, depending on whether the erroneous section leads or trails (Table 2). The error is high or low depending on the direction of movement.

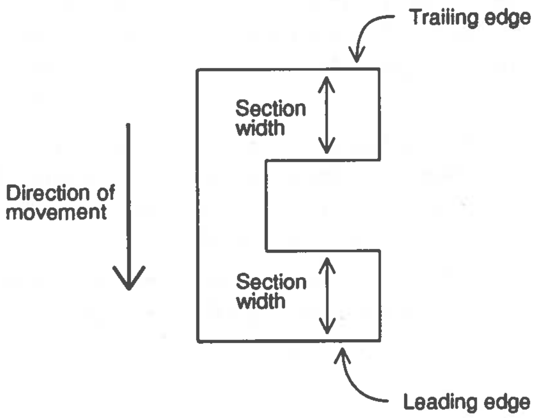


Figure 1. Double mask for acceleration measurements

The error can be partially allowed for by reversing the mask and averaging. Because of its asymmetry, the error is not completely cancelled by averaging. However it would nonetheless be good practice to alternate the leading section and average.

For instance one of the experimental masks we used had a nominal width of 49 mm in both sections. The actual widths were probably just slightly out, giving different values of acceleration for alternate leading edges (rows 3 and 4, Table 2). If these values are averaged, the mean is close to the theoretical value (row 5, Table 2).

If both widths are exactly equal, and have a common error of *x*%, reading low, then acceleration will read high by *x*%.

It was pointed out in Bulletin 178 that plastic rulers can be inaccurate by up to ±0.5 mm. This may be a source of error.

The edges of masks may not be parallel, or may be ragged. An uncertainty of ±0.5 mm in a 50 mm double mask can cause a worst case error in the computed acceleration value of ±4%.

The program in the QED and some other computer software only allows the user to enter mask width in 1 cm steps. If using such software and wishing to be as accurate as possible, some care in cutting the mask to the exact size is called for.

Leading width (mm)	Trailing width (mm)	Mean value of acceleration (m s^{-2})	Theoretical acceleration (m s^{-2})
50.0	49.0	10.19 ± 0.03	10.19
49.0	50.0	9.70 ± 0.05	9.63
49.05 ± 0.1	48.95 ± 0.1	10.07 ± 0.06	
48.05 ± 0.1	49.05 ± 0.1	9.96 ± 0.07	
49.0	49.0	10.01 ± 0.04	10.01

Table 2. Showing the effect on acceleration readings when a mask has dissimilar or wrongly sized sections. The value of width used in the calculations is 50.0 mm. The mean values may be affected by other systematic errors.

Mask size : The smaller the mask width, the larger the uncertainty (Table 3). The QED manual recommends using a large mask to measure *g*. It advises that 4 cm is the minimum size. This seems sound advice.

Width (mm)	30	50	70
Mean value of *g* (m s^{-2})	10.17	9.89	9.88
95% confidence limit in mean (m s^{-2})	±0.05	±0.04	±0.03
95% confidence limit in a single measurement (m s^{-2})	±0.26	±0.18	±0.14

Table 3. Showing the effect on the uncertainties of acceleration readings with different sized mask widths. The mean values may be affected by other systematic errors.

Light gate type : The value of *g* depends not only on the type of light gate, but on the actual light gate used (Table 4). Different samples of the same model of light gate give different results. The rise and fall times of light gates has not been investigated. Some simple light gate

Light gate	Mean value of *g* (m s^{-2})
PASCO ME-9498 sample 1	9.91 ± 0.03
PASCO ME-9498 sample 2	10.05 ± 0.03
Unilab 414.032 pre1990	10.10 ± 0.03
Unilab 414.032 post 1990	9.91 ± 0.03
Unilab 414.033	9.86 ± 0.02
Unilab phototransistor 414.026	9.94 ± 0.03

Table 4. Showing the effect on acceleration readings with different light gates. The two PASCO light gates are different samples of the same model. Unilab changed the design of 414.032 around 1990. The mean values may be affected by other systematic errors.

sensors comprise only a phototransistor and resistor. Because phototransistors have capacitance, there may be a significant *RC* delay.

The rise and fall time of the PASCO light gate is specified to be under 200 ns.

Parallax : Ideally the light gate phototransistor should register a change of state when the edge of the mask is exactly crossing the axis of symmetry (Fig. 2).

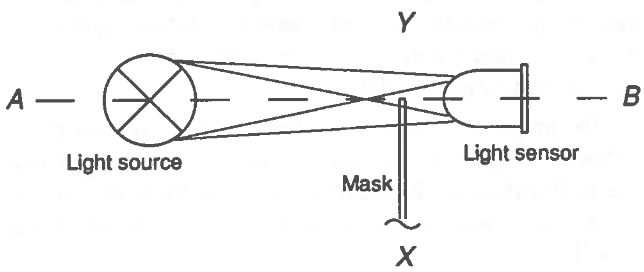


Figure 2. Light gate parallax

If the change of state does not occur till the *Y* side of the light gate axis *AB* (mask moving from *X* to *Y*) then the apparent width of the mask is less than the actual width. For instance if the actual width is 50 mm and there is a parallax error of 1 mm, the apparent width would be 48 mm. The value of acceleration would then be 4% too high.

The parallax error is systematic. It may be the largest source of error in such apparatus systems.

The diameter of the aperture on Unilab light gate sensors is about 1.2 mm. If there is a parallax error, then from the diameter it is less than 0.6 mm.

The aperture on the PASCO light gate is a tapered slot 13 mm long. The width by the phototransistor is about 2 mm. The value of the parallax error may then be 1.0 mm. Depending on mask width, this may result in acceleration values which are too high by several percent. This seems to be borne out (Table 5).

	Aperture unmodified	Aperture reduced to 1 mm
PASCO sample 1	10.05 ± 0.02	9.77 ± 0.03
PASCO sample 2	10.23 ± 0.03	9.88 ± 0.05

Table 5. Showing the effect of parallax on acceleration readings. The mean values may be affected by other systematic errors.

If two bits of black tape are stuck to the aperture to reduce the width to 1 mm, the values of acceleration are seen to diminish by about 3%.

Position of mask : The value of acceleration depends on whether or not the mask is dropped near to the light gate sensor, or near to the light. This is a parallax effect. The dependence is more pronounced when there is a large aperture at the sensor (Table 6).

Mask position	near to sensor (m s^{-2})	near to light (m s^{-2})
PASCO sample 1	10.05 ± 0.02	10.13 ± 0.04
PASCO sample 2	10.29 ± 0.05	10.52 ± 0.06
Unilab 414.032	9.89 ± 0.04	9.95 ± 0.03

Table 6. Showing the effect on acceleration readings of the drop position relative to the sensor and light source. The mean values may be affected by other systematic errors.

Ambient lighting : The ambient light level affects different light gates in different ways. The PASCO and Unilab light gates work satisfactorily across a wide range of ambient light levels. However a strong light directed at the photosensor can prevent operation. This might happen if a white or light coloured mask reflecting a lot of ambient light into the sensor is used, or if the light gate sensor faces a large white surface or direct sunshine.

Incompatible light gates : Light gates from Educational Electronics, Harris and Irwin are not properly compatible with QED. They may sometimes switch the inputs, but if so may not give wholly reliable results.

The PASCO light gate is electrically compatible with QED, but the light gate connector (Fig. 3) needs adapting to link with the 4 mm sockets on the QED.

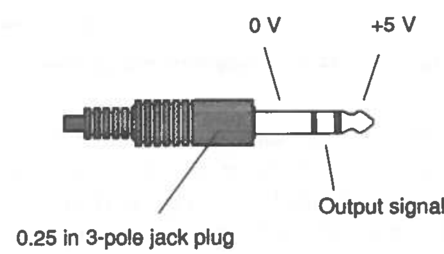


Figure 3. Connector from PASCO Photogate ME-9498. This plug fits into a Standard Stereo Jack Line Socket, Rapid Electronics part number 20-0195 at 28p. Use one of these sockets wired to leads with 4 mm plugs to connect the Photogate to the QED.

Summary

A number of small and apparently innocuous errors can lead to a significant error in the value of *g* obtained by dropping a double mask through a light gate. The most significant sources of error are inaccuracies in the mask widths and parallax. The former can throw the value of *g* high or low. The latter probably throws the value high and may be the root cause of the anecdotal evidence that the error is usually biased high. QED instrumentation errors are insignificant.

Reference

1. *Experimental errors - the measurement of g*, Bulletin 133, SSERC, November 1982, pp 10-15.

Dynamics trolleys

The new PASCO Dynamics Cart is assessed and summarily compared with traditional trolleys, with Unilab's Bogie and with a linear air track. We describe the typical performance to expect from the PASCO Cart in standard experiments.

The PASCO dynamics cart is being widely advertised in science journals. How well does it perform? Is its performance markedly superior to that of other trolleys?

Because the features and performance of traditional trolleys are well known - too well known - they are not described here in the same depth as the PASCO Cart.

Sets of new laboratory trolleys have been obtained from suppliers for comparison (Table 1) (Fig. 1). Trolleys from Griffin, Harris and Irwin are supplied either singly or in pairs. Trolleys from PASCO are obtainable as single items but, because they have been designed to run on a specialised slotted track, are more usefully purchased in the form of the Introductory Dynamics System, which includes trolleys, track and accessories. The pair of Unilab trolleys (or bogies) are part of, indeed the vital part of, the Collisions Kit. They are not sold singly nor separately.

Traditional trolleys

The trolleys from Griffin, Harris and Irwin are of traditional design with wooden frame, spring plunger and three large wheels (Table 2). Griffin fit roller skate wheels. The wheels on the other two types are standard industrial parts. All the trolley types are stackable, by which arrangement the mass is varied.

The plunger springs within both the Griffin and Harris trolleys can store a considerable amount of energy. When this is released it is conceivable that an injury, perhaps to the eye, could be caused. This might happen, for instance, if a trolley with cocked spring were held up to the eye for close inspection. No such injury however has ever been reported to us.

The metal end plates on the Griffin trolley have not been rounded off. The sharp corners could conceivably cut the skin.

Force is applied to these trolleys by pulling with one or several stretched elastics. This is impossible to apply accurately because the spring constant of elastics varies so much and because it is difficult to maintain constant stretch. A further disadvantage is that it is not possible with elastics to pull a trolley through a light gate so as to measure acceleration.

Manufacturer	Product name	Order code	Description	Price (£)
Griffin	Dynamics Trolley	XBH-292-B	1 trolley	30.70
Harris	Dynamics Trolley	Q38200/2	1 trolley	36.60
Irwin	Dynamics Trolley	RA3482	2 trolleys	35.73
PASCO	Dynamics Cart (2 versions) :			
	Plunger Cart	ME-9430	1 plunger cart with mass	49.00
	Collision Cart	ME-9454	1 collision cart with mass	49.00
	Introductory Dynamics System	ME-9429A	Plunger and Collision Carts, 1.2 m track, 0.5 kg masses, Super Pulley, magnets, springs, Friction Block, Rod Clamp, Fixed End Stop, Adjustable End Stop	206.00
Unilab	Collisions Kit	650.570	2 bogies 2 lengths track wooden cube 20 x 10 g masses spare cork and Velcro	23.48

Table 1. Descriptions, suppliers, order codes and prices of dynamics trolleys

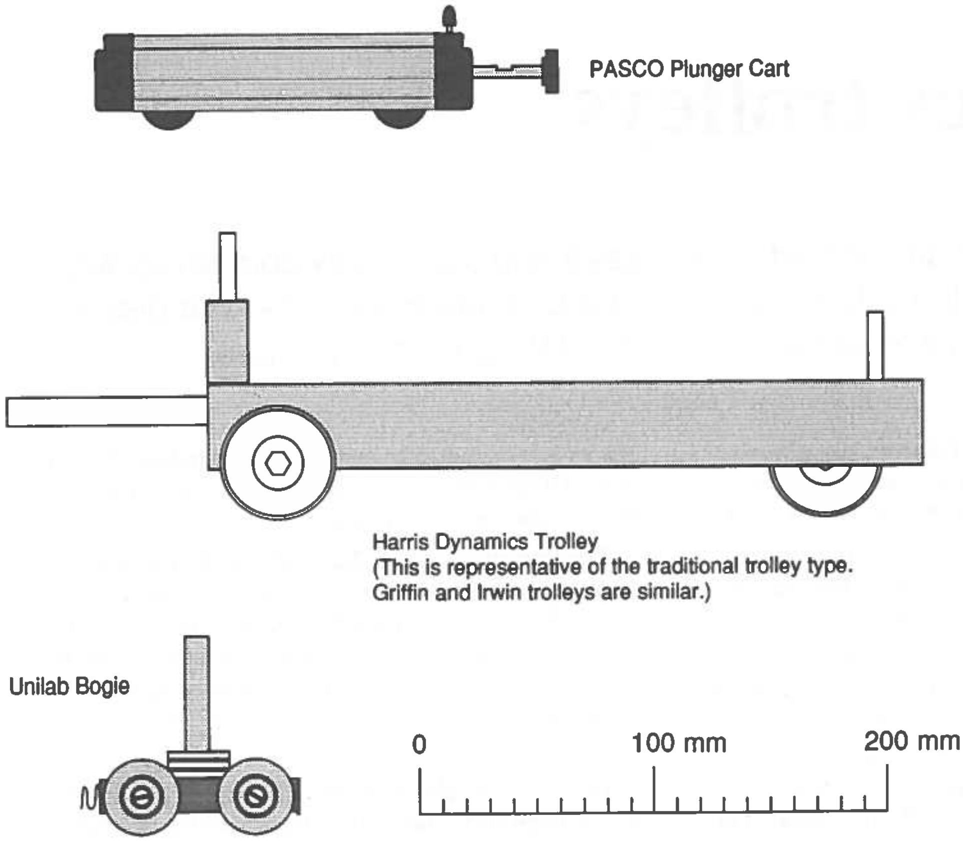


Figure 1. Trolley types, side elevations, drawn to scale

Unilab Bogie

Possibly it is unfair of us to compare this product with dynamics trolleys. Unlike the Bogie, they all purport to be used in physics education whereas it has been designed for mathematics education and may not be suited for use in physics. Although the catalogue indicates that it is "a simple and easy to use kit for work on momentum, collisions and the coefficient of restitution" and "a simple but effective means for doing both qualitative and quantitative work", do not be misled into believing that the Bogie is a low cost substitute for a dynamics trolley. It is nothing of the sort and, by placing the Bogie in the Mathematics section of their catalogue, and by not including it in the Timing and Motion section, Unilab are indicating that it has nothing to do with physics. However

Trolley	Description	Runway	Spring plunger	Collision facilities	Mass (kg)	Dimensions L x B x H (mm)
Griffin	3 wheeled wooden vehicle, stackable	Plane surface	3 position	None	0.82	305 x 145 x 50
Harris	3 wheeled wooden vehicle, stackable	Plane surface	1 position	Cork and pin	1.06	303 x 144 x 90
Irwin	3 wheeled vehicle, stackable, plastic frame with wooden battens	Plane surface	3 position	Velcro pads	0.78	310 x 130 x 55
PASCO	4 wheeled vehicle, stackable, extruded aluminium body with high-impact end pieces, wheels designed to run on rails, slots, or plane surface	Slotted track	3 position	Velcro pads, magnetic repulsion	0.50	168 x 87 x 50
Unilab	4 wheeled vehicle with polypropylene base, not stackable	Ridged plastic tracking	not provided	Velcro pads, cork and spring	0.07	80 x 40 x 85

Table 2. Dynamics trolley specifications

we have had enquiries on the Bogie from physics teachers and we have seen some use the Bogie in physics experiments. Some note on its relevance therefore seems timely.

The little four wheeled Unilab bogie is very much smaller than traditional trolleys. Its mass can be increased by slotting steel washers over its vertical stanchion. A card can be fastened to this with Blutac or tape to interrupt a light beam. The bogie runs better when loaded - that is to say, frictional deceleration is much less.

The track supplied with the Collisions Kit is a strip of flexible plastic 1200 mm long by 36 mm wide. The centre of the strip is raised by 6 mm. This prevents the bogie from leaving the track. Because the track is flexible, it can be formed into an inclined plane with horizontal run-off, or into a potential well. The track should be fastened with Blutac or tape to a plane surface for linear alignment.

During collisions experiments, the track certainly helps to ensure that two bogies meet head on. Each bogie has a Velcro tab, the function of which is that colliding bogies should stick together. In practice, however, this seldom happens. The Velcro is not really much use. At the opposite ends from the Velcro, one bogie has a spring and the other can be fitted with a cork. When trolleys collide in this way, because of the sizes of static and dynamic friction, the results you would expect if friction were negligible just don't happen. The results are so disappointing that they are not even good enough for a rough and ready qualitative demonstration of the conservation of momentum.

In inclined plane experiments, because friction is relatively large and depends on speed, the Bogie does not travel with constant acceleration when running down an inclined plane of uniform gradient (Table 3). Therefore we suggest that the Bogie is unsuited for studying constant acceleration.

In summary the Unilab Collisions Kit has very limited uses in school physics education. It can be used to study complex dynamical relationships, but is not capable of portraying the simple, idealized relationships required of elementary physics education. Its purpose in mathematics education is the generation of data for pupils to analyse. In this context, because the underlying physics principles are not being interpreted, it does not matter that these principles are complex.

Distance (cm)	Acceleration ($m\ s^{-2}$)
20	0.99 ± 0.03
40	0.90 ± 0.04
60	0.83 ± 0.04
80	0.72 ± 0.05
100	0.61 ± 0.07

Table 3. Acceleration versus distance travelled for Unilab Bogie loaded with 4 x 10 g masses on inclined plane. Value of $g \sin\theta$ is 1.44 $m\ s^{-2}$.

We are therefore being a little naughty in comparing this product with dynamics trolleys. It does not pretend to serve this function and perhaps this is the point physics teachers should note.

PASCO Carts

The design of the PASCO trolley - known as a cart - is radically modern. The extruded aluminium body is relatively lightweight. It has high impact ABS plastic endpieces, tough enough to withstand without damage falls from benchtop height to the floor.

The cart's mass is 0.50 kg, which is convenient for ready reckoning[1]. A 0.50 kg iron bar is supplied with each cart. Either one or two bars can be fitted into a recess on the top surface. PASCO carts do not therefore need to be stacked to vary the mass.

The four wheels are fitted on good quality bearings that have extraordinarily low friction. On a smooth, plane, horizontal surface the cart just runs and runs! The wheels are spring loaded so that they can retract into the body of the vehicle. This prevents the wheels being damaged by excessive overloading, such as an attempt to use the cart as a roller skate, or from the impact of a fall.

Although the cart runs on any smooth surface, it has been designed to run on a track with parallel slots. The wheel rims are angled. Because one slot is wider than the other, the two wheels on the one axle have different points of contact. One sits on the bottom of the wider slot. The other makes contact between the wheel rims and the corners of the narrower and deeper slot (Fig. 2). This causes a small but significant amount of frictional resistance to movement. The typical deceleration on a horizontal Cart Track is 0.05 $m\ s^{-2}$. But on a smooth level surface it is only about 0.02 $m\ s^{-2}$.

The design of the Cart Track and wheels would seem to be a reasonable compromise between two conflicting desires : extremely low friction and the constraint of a linear alignment system.

[1] But can any youngsters outside the Far East still do this?

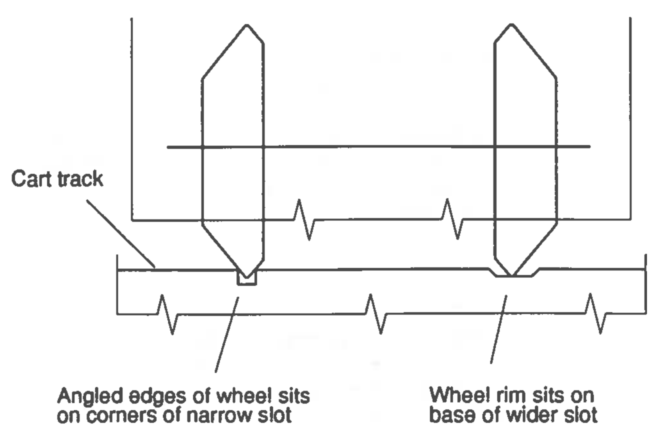


Figure 2. Transverse section through Cart and Track showing points of contact between wheels and Track

A slight amount of wear in the rims of the tough ABS plastic wheels takes place. This wear still has a negligible effect on performance after one year's usage. We cannot predict for how long the effect might remain insignificant.

There are two versions of the Cart. The Plunger Cart has a three position spring plunger for momentum and energy experiments. It also has Velcro pads fitted to the end pieces so that colliding carts stick to one another. Colliding carts were found to adhere reliably. The track's linear alignment system undoubtedly helped.

From a safety viewpoint, the potential energy within the compressed spring of the Plunger Cart is not high enough to cause injury. The energy is many times lower than that in the plunger springs of traditional trolleys. This lower spring energy is a beneficial consequence of the PASCO system's relatively low friction and low mass.

Trolley	Parts and accessories	Order code	Scope or function
Griffin	Dynamics Trolley (single)	XBH-292-B	Kinematics and momentum experiments
	Elastic Cords	XBH-360-D	Acceleration and force experiments
	Stackable Mass	XBH-420-A	Force and momentum experiments
	Flat Ended Steel Springs	XBH-460-S	Mechanical oscillations experiments
	Spring Holders	XBH-480-E	(to fit springs to trolley)
	Trolley Runway (with 6 levelling feet)	XBH-531-C	Provides smooth, flat, inclinable surface
Harris	Dynamics Trolley (single)	Q38200/2	Kinematics and momentum experiments
	Elastic Cord with Eyelets	Q38260/9	Acceleration and force experiments
	Springs	Q38220/8	Mechanical oscillations experiments
	Spring Holders	Q38230/0	(to fit springs to trolley)
	Trolley Runway (2.4 m)	Q38240/3	Provides smooth, flat, inclinable surface
	Trolley Runway (Short) (1.5 m)	Q38250/6	
Irwin	Dynamics Trolleys (pair)	RA3482	Kinematics and momentum experiments
	Momentum Trolley	EE0281	Acceleration, force, momentum and energy experiments
	Elastic Accelerating Cords	EK0281	Acceleration and force experiments
	Momentum Track (3 m) with Catapult	EM0281	Momentum and energy experiments
PASCO	Introductory Dynamics System	ME-9429A	(*items within Introductory Dynamics System are italicised*)
	Plunger Cart	ME-9430	Cart with spring plunger for explosion experiments
	Collision Cart	ME-9454	Cart with magnets for elastic collisions
	0.5 kg bar mass (supplied with each cart)		Doubles mass of Cart, 2 masses can be placed on each Cart
	Track, 1.2 m length		Provides accurate linear alignment and uniform gradient, light gate (Photogate Head ME-9498) fits to any part of track with Photogate Bracket 003-04662
	Fixed End Stop and Levelling screw		Easy to level track or to compensate for friction
	Adjustable End Stop	ME-9469	Either repulses or clamps cart, can be fitted to any part of track
	Super Pulley with Clamp	003-04319	Acceleration and force experiments
	Neodymium Magnets (for Plunger Cart)		Elastic collisions with Plunger Cart fitted with magnets
	Harmonic Springs	632-04978	Mechanical oscillations experiments
	Friction Block		Friction experiments
	Rod Clamp (for tilting the track)		Inclined plane experiments (fits into clamp stand)
	2.2 m Track with End Stops and Feet	ME-9453	Long track for larger scale demonstrations
	4.2 m Track (requires pair of End Stops and pair of Adjustable Feet)	ME-9480	Very long track for large scale demonstrations
	Adjustable Feet (pair)	ME-9470	For levelling 2.2 m and 4.2 m Tracks
	Picket Fence (fits Cart)	648-04704	Mask for operating light gate
	Photogate Head	ME-9498	Light gate
	Photogate Bracket	003-04662	Attaches Photogate Head to any part of track
	Ballistic Cart Accessory	ME-9486	Projectile experiments, Accessory fits on Cart
	Drop Rod Accessory	ME-9487	Projectile experiments, fits on Ballistic Cart Accessory
	Bernoulli Accessory	ME-9481	Demonstration of Bernoulli's Principle, Accessory fits on Cart
	Friction Cart Accessory	ME-9457	Friction experiments, Accessory fits on Cart
	Fan Cart	ME-9485	Demonstration of Newton's Laws of Motion, vector components of forces (*the Fan Cart is not an accessory of the standard Carts; it is a separate vehicle that runs on the Cart Track*)
Unilab	Collisions Kit	650.570	(*Items within Collisions Kit are italicised*)
	Bogie with cork and velcro pad		Acceleration and momentum experiments
	Bogie with spring and velcro pad		
	2 lengths track, 1.2 m each		
	40 mm cube		Inclined plane experiments
	20 x 10 g masses		Momentum experiments

Table 4. List of parts and accessories for dynamics trolleys

The Collision Cart end pieces are also fitted with Velcro pads. In addition, they have, at each end, sets of powerful neodymium magnets so that pairs of carts repulse. These collisions are very nearly elastic. However magnetic collisions were not found to work every time because at high speed one of the carts could be knocked off its track. By repeating the event, a good collision can eventually be obtained.

There is one design flaw related to the spring plunger and cart track. No wholly suitable thrust block has been provided for energy experiments. The Adjustable End Stop has too much give to the spring's thrust. The Fixed End Stop is sufficiently resilient, but cannot make contact with the spring when fully compressed because of an obstructing bumper. There should be a fitment that can be added to the Fixed End Stop to meet this need.

In conservation of energy experiments, a significant amount of potential energy is transformed into heat energy during the firing of the plunger spring. This is the one dynamics relationship found in the system that does not behave in a near-ideal fashion. This imperfection is not unexpected.

In dynamics experiments, force is applied to the cart by attaching thread to a weight suspended from a Super Pulley - a PASCO component with low friction and low moment of inertia that is included in the Introductory Dynamics System. The Super Pulley clamps to the end of the Cart Track. This arrangement has been found to give very satisfactory results, there being good agreement between theory and practice.

There is a wide range of accessories for the PASCO Cart (Table 4). Applications include conservation of momentum and energy, Newton's Laws of Motion, inclined plane, friction, simple harmonic motion and projectile experiments. All these applications can be studied quantitatively. To a large part, the strength of the system is its width of application.

Cart track

The extruded aluminium track has a single foot at one end by which the track (1.2 m version) can be levelled, or adjusted for friction compensation. A measuring tape marked in millimetres runs along the track for accurate positioning. Both sides of the track are slotted to accept peripheral fitments. These include a means of attachment to a clamp stand for inclined plane work, an adjustable end stop fitted with neodymium magnets, and photogate brackets. By means of the last named, light gates may be fitted to the track. This is particularly useful for inclined plane experiments, or indeed any repositioning of the track, because the light gates move with the track and remain in correct alignment.

The track was found to sag slightly and be slightly twisted (Table 5). The effect of a 1 mrad gradient on a 0.5 kg cart is equivalent to the gravitational force on a suspended 0.5 mg mass pulling on the cart, or an acceleration of 0.01 m s^{-2}. By comparison, the frictional deceleration is 0.05 m s^{-2} typically. In nearly every experiment, the effect of this sagging is negligible. Allowance can be made by working on that section of track which is nearly horizontal.

Comparative tests

All types of trolley were compared by measuring their frictional decelerations on a smooth horizontal surface. A range of values were obtained for fast and slow speeds. The typical deceleration is the mean value at slow and moderate speeds.

The PASCO Cart was found to be the trolley with the lowest frictional deceleration (Table 6). As explained earlier, the optimum running conditions are a smooth, plane surface. However when the cart runs on its track, friction is two or more times greater.

Of the traditional trolleys, the Harris one fared nearly as well as the PASCO Cart running on its track. All of the other trolleys performed significantly less well.

The cart race test (Table 7) confirms these findings. However the test does not have integrity because we were unable to find a totally level, smooth surface sufficiently long to conduct a fair race. Our race track was a vinyl covered floor. This had very slight undulations, but overall was reasonably horizontal.

Position (cm)	Gradient (mrad)	Camber (mrad)
10	-2.1	-0.8
20	-1.5	
30	-1.4	-0.4
40	-0.8	
50	-0.5	0.2
60	0.1	
70	0.2	0.5
80	0.6	
90	0.7	0.8
100	0.8	
110	1.2	1.5

Table 5. Distortion in PASCO's 1.2 m Cart Track

Trolley	Trolley mass (kg)	Typical deceleration (m s^{-2})	Range of decelerations (m s^{-2})
Griffin	0.82	0.14	0.09 to 0.26
Harris	1.06	0.07	0.05 to 0.13
Irwin	0.78	0.16	0.11 to 0.23
PASCO (on benchtop)	0.50	0.02	0.02 to 0.09
PASCO (on cart track)	0.50	0.05	0.04 to 0.11
Unilab, unloaded	0.07	0.47	0.35 to 0.64
Unilab, 60 g load	0.13	0.28	0.24 to 0.35
Linear air track	0.21	< 0.01 0.001 at 0.2 m s^{-1}	0.0007 to 0.008

Table 6. Comparison of frictional deceleration of trolleys coasting along a horizontal, smooth surface. The linear air track in the comparison is model SF-9214 from PASCO and 432.100 from Unilab (same type).

Trolley type	Mean distance (m)	Off course veer rate (cm/m)
Griffin	0.93	< 5
Harris	2.20	< 5
Irwin	1.12	< 5
PASCO	4.03	12
Unilab, unloaded	0.66	< 5
Unilab, 60 g load	0.81	< 5

Table 7. Cart race test : the mean distance travelled across a smooth flat floor after release from rest at the top of a 15 mm high inclined plane. The rate at which the trolleys veered off a straight line course is also shown.

The ability of trolleys to travel straight was also tested. Except for the PASCO Cart, all ran fairly straight. The tendency for the PASCO Cart to veer from a straight course is only significant over a long distance of several metres. For distances of 1 m or less, the veer rate is less than 5 cm/m. This is no worse than the performance of other types of trolley. Moreover, since the PASCO Cart has been designed to operate mainly on a track with guide lines, it is normally constrained to run in a straight line and veering cannot occur. Therefore, when running on its track, its linear alignment is perfect - certainly far superior to any traditional trolley.

PASCO advertise their carts as being better than an air track in some conditions. The typical deceleration of an air track vehicle is about an order of magnitude less than a cart on a cart track (Table 6). So for absolute performance, an air track is still the clear winner. However, for many applications, the amount of friction on carts is not high enough to be significant. To this extent, the assertion is justified.

Examples of the performance of the PASCO Cart are given in the next section.

Examples of performance

Newton's Second Law of Motion : How well does the experimental value of acceleration agree with the theoretical value?

A Super Pulley was fitted to the end of the track and the track levelled so that the 50 cm stretch next to the pulley was horizontal. The cart was pulled by thread attached to a mass carrier suspended from the pulley (Fig. 3). Acceleration was measured with a Unilab Motion QED and two light gates. Friction was compensated by suspending paper clips totalling 2 g from the pulley.

Value of acceleration from experiment :

Experimental values in m s^{-2} :
0.51, 0.51, 0.52, 0.51, 0.51

Light gate parallax uncertainty :	± 2% of reading
Mean value of acceleration :	0.51 m s^{-2}
Uncertainty in mean value :	± 0.01 m s^{-2}
Measured value :	0.51 m s^{-2} ± 0.01 m s^{-2}

Value of acceleration from theory :

Mass of cart and mask (M) :	1006.7 g
Suspended mass (m) :	55.4 g
Uncertainty in friction compensation :	± 1 g

Acceleration (best value) $= m\,g\,/\,(M + m)$
$= 55.4 \times 9.81 / (1006.7 + 55.4)$
$= 0.51$

Uncertainty in theoretical value : ± 0.01 m s^{-2}
Theoretical value : 0.51 m s^{-2} ± 0.01 m s^{-2}

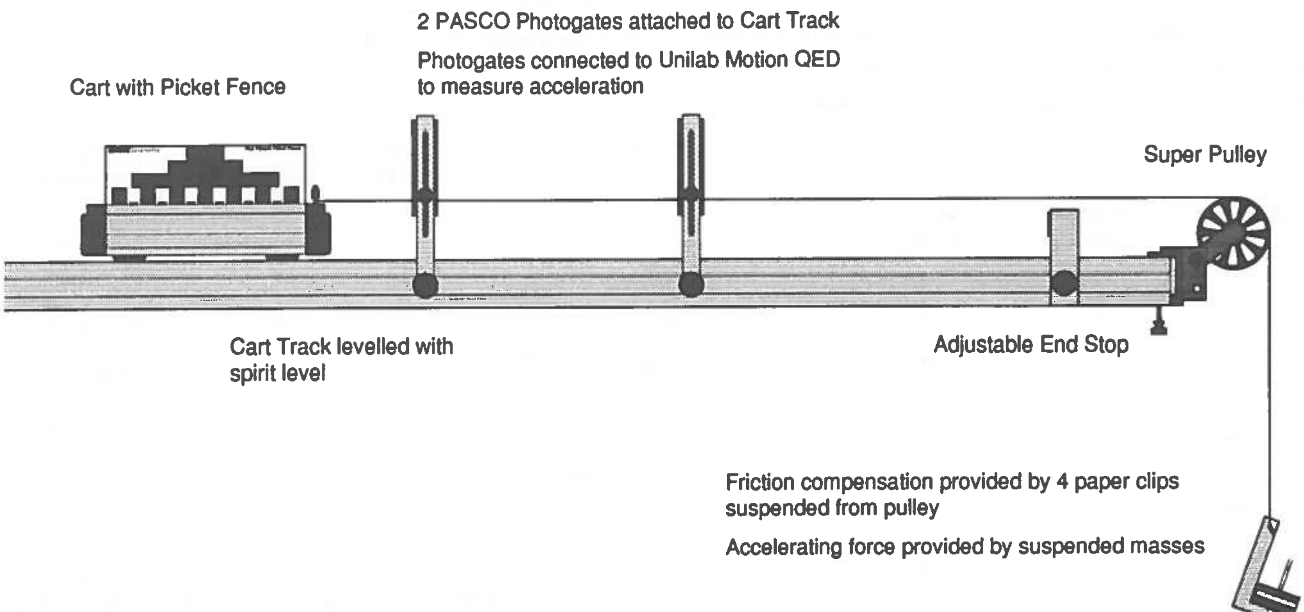


Figure 3. Apparatus to compare experimental value of acceleration *a* with theoretical value *F/m*

Comments :

- There is therefore excellent agreement between the experimental and theoretical values of acceleration.
- Friction compensation is vital for good correlation, but getting it is tricky and may take some time to achieve.

Collisions with a stationary trolley : The levelling screw on the track was finely adjusted so as give the track a gentle tilt in order that friction was compensated. The Velcro pads fitted to the end pieces of the carts caused the carts to cling together in a collision. Velocities before and after the collision were measured with a QED and two light gates (Table 8).

m_A (kg)	m_B (kg)	u (m s^{-1})	v (m s^{-1})	$m_A u$ (kg m s^{-1})	$(m_A + m_B) v$ (kg m s^{-1})
0.5	0.5	0.434	0.215	0.217	0.215
1.0	0.5	0.692	0.461	0.692	0.691
1.5	0.5	0.690	0.515	1.035	1.030
0.5	1.0	0.530	0.169	0.265	0.253
0.5	1.0	0.784	0.262	0.392	0.393
0.5	1.5	0.489	0.119	0.245	0.238
0.5	1.5	0.868	0.217	0.434	0.434

Table 8. Momentum experiment results with PASCO carts : Collisions with a stationary trolley

Comments:

- Carts always stick together. This form of collision is completely reliable and works for a large mass into a small mass as well as for a small mass into a large mass.
- Friction compensation is necessary. Without compensation, momentum appears to degrade by around 5%.
- Momentum before and after the collision usually agrees to within 1%.
- If the initial launch velocity is less than 0.5 m s^{-1}, then frictional deceleration may be quite noticeable because the velocity after the collision may be very low.
- Because the trolley mass and bar mass are both 0.5 kg, momentum quantities can readily be expressed in SI units rather than in arbitrary units, as is the custom with other types of trolley.

Exploding trolleys : The track was adjusted until it was set horizontal by means of the levelling screw and a spirit level. The effect of frictional deceleration on both trolleys would be roughly similar and balance out. One Plunger Cart and one other cart were used (Table 9).

m_A (kg)	m_B (kg)	v_A (m s^{-1})	v_B (m s^{-1})	$m_A v_A$ (kg m s^{-1})	$m_B v_B$ (kg m s^{-1})
0.5	0.5	-0.175	0.177	-0.087	0.088
0.5	0.5	-0.398	0.395	-0.199	0.197
0.5	0.5	-0.571	0.565	-0.285	0.283
0.5	1.0	-0.667	0.332	-0.333	0.332
0.5	1.5	-0.709	0.238	-0.355	0.357

Table 9. Momentum experiment results with PASCO carts : Exploding trolleys

Comments:

- Disagreement between the momenta of carts never exceeds 1.5%.
- If using the Motion QED, two instruments would be preferable, one to measure the velocity of each cart.

Elastic collisions : The track was adjusted until it was set horizontal by means of the levelling screw and a spirit measure. Some degradation due to friction could be expected (Table 10). Ideally two Collision Carts should be used. However we used two Plunger Carts, one fitted with PASCO neodymium magnets, the other fitted with SSERC neodymium magnets. Initially cart *B* was at rest and cart *A* was projected at it.

m_A (kg)	m_B (kg)	u_A (m s^{-1})	v_A (m s^{-1})	v_B (m s^{-1})	$\Sigma(m\,u)$ (kg m s^{-1})	$\Sigma(m\,v)$ (kg m s^{-1})
0.5	0.5	0.442	0	0.434	0.221	0.217
0.5	0.5	0.555	0	0.520	0.277	0.260
1.0	0.5	0.495	0.119	0.625	0.495	0.432
1.0	0.5	0.581	0.101	0.709	0.581	0.456
0.5	1.0	0.529	-0.112	0.315	0.265	0.259
0.5	1.0	0.568	-0.085	0.355	0.284	0.312
0.5	1.5	0.513	-0.224	0.248	0.257	0.260

Table 10. Momentum experiment results with PASCO carts : Cart *A* projected at cart *B*, which was initially at rest; because of magnetic repulsion, carts spring apart

Comments:

- Velocities are significantly affected by deceleration.
- During some collisions at high speed, one of the carts bounced out of the slots in the track. Perhaps this was caused by using imperfectly aligned, non-PASCO magnets.
- If using the Motion QED, two instruments would be preferable, one per light gate. These should be sited on either side of the point of collision.

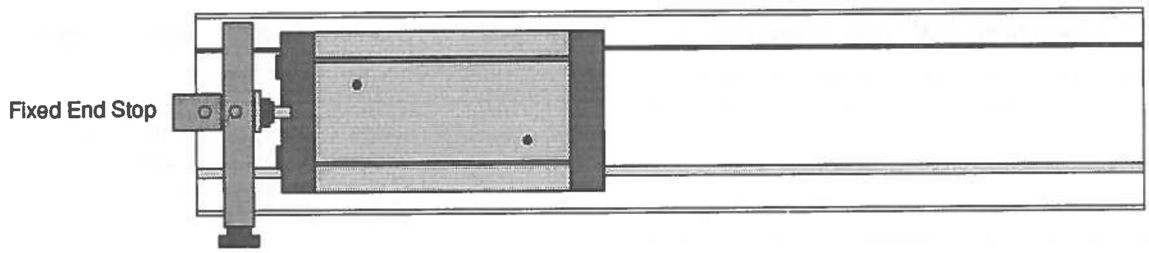


Figure 4. Thrust block for energy transform experiments : Plan view

Energy experiments : The spring constant of the Plunger Cart spring was measured by standing the cart upright and loading the spring with masses by 100 g steps to 2 kg. A force versus extension graph was plotted from which a value for the spring constant was obtained. Knowing this, the potential energy of the compressed spring at each of its three positions could be worked out.

A thrust block was contrived by placing the Adjustable End Stop hard up against the Fixed End Stop. A coin was used as a spacer to allow the plunger spring, when fully depressed, to make contact with the thrust block. The Velcro pads on the Plunger Cart would otherwise preclude this happening. The coin was taped to the middle of the Adjustable End Stop (Fig. 4).

The track was tilted slightly to compensate for friction. The Plunger Cart was placed against the thrust block, the spring released and the ensuing speed measured with a QED and light gate (Table 11).

Plunger position	m (kg)	v (m s^{-1})	$\frac{1}{2} m v^2$ (J)	$\frac{1}{2} F x$ (J)
1	0.5	0.280	0.020	0.021
2	0.5	0.603	0.091	0.119
3	0.5	0.887	0.197	0.297
1	1.0	0.199	0.020	0.021
2	1.0	0.444	0.099	0.119
3	1.0	0.657	0.216	0.297

Table 11. Energy experiment results with PASCO cart : Stored energy of plunger spring is transformed into kinetic energy

Comments:

- A linear relationship pertains between the load and extension of the plunger spring. The spring constant works out at 0.8 N mm^{-1}.
- A significant amount of potential energy (about one third) is not transformed into kinetic energy when the spring is released from its fully compressed state.

Simple harmonic motion : A cart was held in tension at the centre of the track by a pair of Harmonic Springs connected to either ends of the track (Fig. 5). A load was suspended by thread from a Super Pulley and attached to the cart. By varying this load and noting the displacement, a load versus extension graph was drawn and the spring constant for the system found.

The load was then removed, the cart displaced and allowed to oscillate. The period of oscillation was measured and compared with the system's theoretical oscillation period [$2\pi (m / k)^{-1/2}$, where m is the mass of the cart and k is the spring constant] (Table 12).

Cart mass	Period of oscillation	
	Experimental	Theoretical
(kg)	(s)	(s)
0.5	1.79	1.74
1.0	2.49	2.46

Table 12. Simple harmonic motion results with PASCO Cart : Experimental and theoretical values of period compared

Comments:

- There is a linear relationship between load and extension. The fact that it is linear is important because it implies that when the system oscillates, the oscillations will be simple harmonic. The oscillations can then be analysed by the usual means. The spring constant is found to be 6.55 N m^{-1}.
- There is good agreement between experimental and theoretical values.

Inclined plane : This is used to study constant acceleration, vector components, and other matters. In this trial, a cart was repeatedly run down the Cart Track, which was at an incline of about 8°. By measuring the cart's acceleration at different points on the incline (Table 13), the dependence of friction with speed can be found. From this, we can assess whether or not the apparatus is suitable for studying constant acceleration.

Distance (cm)	Acceleration ($m\ s^{-2}$)
20	1.42 ± 0.03
40	1.38 ± 0.03
60	1.34 ± 0.03
80	1.32 ± 0.04

Table 13. Acceleration versus distance travelled for PASCO Cart on inclined plane. Value of $g \sin \theta$ is 1.44 $m\ s^{-2}$.

Comments:

- Frictional forces are certainly significant, but are relatively small.
- The apparatus would seem to be suitable for studying constant acceleration, but is not perfect.

Summary

The PASCO dynamics cart has been tested and compared against other dynamics trolleys. In all respects except price, the comparison bears in its favour. Although on a feature by feature basis, the Cart is superior, it is the combination of features which single it out for commendation:

- friction is significantly less than with most other trolleys
- vehicles are precisely aligned when running on the track
- the track surface is almost perfectly plane
- collisions between trolleys are near to ideal
- standard accessories such as magnets, Velcro pads, spring plunger, harmonic springs, picket fence, light gates and pulley wheel are all compatible and work reliably
- there is a range of further accessories, such as for projectile motion
- a trolley mass that is in multiples of 500 g is arithmetically convenient

In general, there is good correlation between experimental results and theoretical expectations. Where there are differences, these are not unexpected. They are therefore excusable.

What we have not so far mentioned is that the PASCO system feels good to work with. It is modern, state of the art engineering. You expect it to perform well, as indeed it does, and therefore it encourages you to use it and to experiment. You feel that the apparatus will be an aid rather than an impediment to your understanding of physics. And without doubt it can help that understanding. If only more physics apparatus could meet this requirement!

The combination of Unilab's Motion QED together with PASCO's Introductory Dynamics System and Photogates is specially recommended for studying linear motion. However the PASCO Photogate requires a home-built connector from jack to 4 mm plugs (see page 26), its parallax error is larger than it might be and Unilab's new light gate (414.033) gives more accurate results.

Verdict

Griffin Dynamics Trolley	C
Harris Dynamics Trolley	B
Irwin Dynamics Trolley	C
PASCO Dynamics Cart (both types)	A
PASCO Introductory Dynamics System	A
Unilab Collisions Kit	C

(Code : A = most satisfactory, B = satisfactory, C = unsatisfactory for use in Scottish school physics)

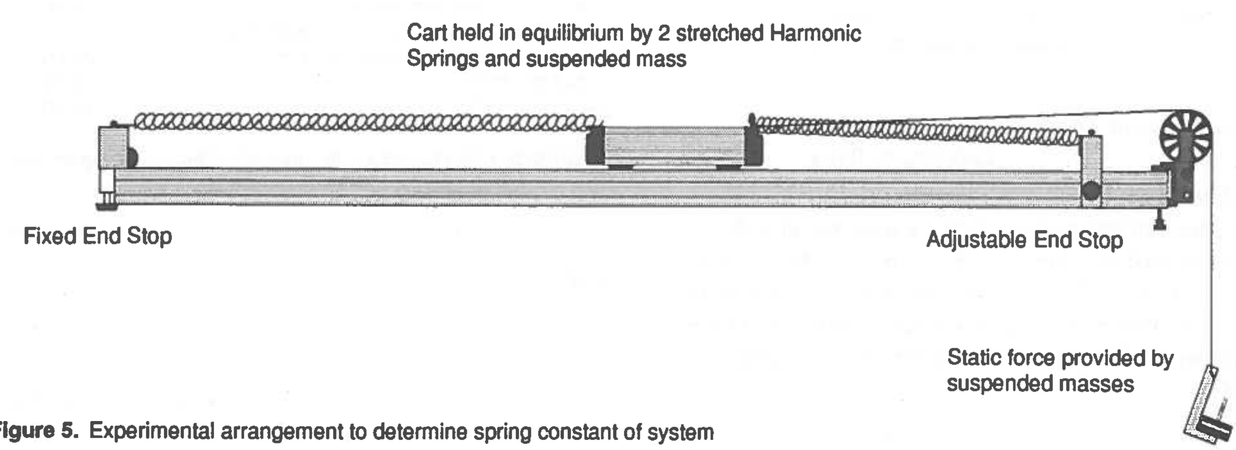


Figure 5. Experimental arrangement to determine spring constant of system

NOTICES

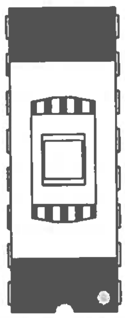
Graphics Competition

The more astute of you may have noticed that your Bulletin conveniently arrived long after the May deadline for entries. No this was not a cunning plot to rig the competition but a curious time compression phenomenon which arises when a Bulletin is created from the chaos of scientific matter floating around at SSERC.

Therefore we are playing it extra safe and will give you 'til the end of September to generate your works of scientific art!

P.S. - Dr. J.S. Clark of Stonelaw High School, the only entrant so far, gets the pick of 3 discs from the *Graphics Libraries* for enthusiasm. The Bulletin is obviously read as soon as it arrives in school!

Schools Chip Set



The Centre has been asked by Edinburgh University to act as the distributor of sets of Schools Chips to Scottish schools. This is an interim measure until a proper system of commercial distribution is established by the University and Motorola. The offer to be described is open to any Scottish school and is not restricted to the group of pilot schools.

By agreement with the University, the Centre is charging schools £4.00 (plus VAT) per Chip Set to cover its costs. This charge includes £2.00 towards the cost of breadboard and the remainder to cover SSERC's costs in testing each chip, and for packaging, postage and invoice processing. We trust that this charge will be accepted as reasonable and fair. It may worth considering that the eventual full commercial price of a Chip Set could be very much higher than £4. To anyone who might be interested our advice is buy now.

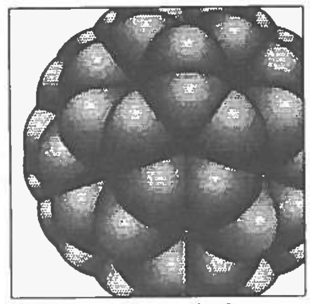
Please note that the Centre is also the distributor of two Edinburgh University texts on the Schools Chips. Post and packing will be charged at £2.00 per document on top of the prices shown:

Semiconductor Teaching Chips : Volume 1 : Teaching Support Material : £4.50

Semiconductor Teaching Chips : Volume 2 : Laboratory Work : £5.00

Both texts are essential for any first-time user of the Chips. Much of the material in these texts has already been distributed by Edinburgh University to the 100 pilot schools and by the Centre as part of its in-service training materials. However the bound volume format could prove useful material for home study by members and pupils or as a reference source.

TRADE NEWS



Buckybox kits

In Bulletin 174 we provided templates for the construction of card models of either C-60 or C-70 bucky-balls. These were based on the work of Professor R. H. Good of the California State University. A number of items are now available commercially from Dynamic Enterprises Ltd. which give the opportunity of some practical work on fullerenes.

Their *Buckybox Kit* contains samples of graphite and diamond, a magenta solution of pure C-60, 2.5 g of carbon with a high fullerene content and four chromatographic columns. Also included is a software package with structures for 70 large and complex molecules from buckminster fullerene through vitamin B12 to various alkenes. The usual 3-D specs are provided. This software is for IBM, or compatible, PCs with a 386 or 486 processor, but versions are also available for other machines, including Archimedes and Nimbus.

You may feel that you already have several of the above items anyway and that you can do your own extraction of soot, followed by chromatographic separation and identification by IR or UV spectroscopy. In that case you may not wish to pay £95 plus £3 post and packing for a complete kit. However many of the more specialised bits and pieces can be ordered separately. These are as shown in Table 1 together with their prices:

Item	Price (£)
Manual with instructions for a range of experiments including spectral data	20.00
Carbon rich in fullerenes (includes 4 chromatographic columns with packing)	35.00
Calibrated standard sample of pure C_{60}	30.00
Graphite sample	3.00
Diamond sample	15.00
Molecular visualisation software (IBM compatible)	39.00
4 pairs of glasses for use with the 3-D software	6.00
6 special filter papers	2.50
Cochrane carbon molecular kit to build C_{60} and C_{70} as well as graphite and diamond	8.00
Molymod carbon molecular kit to build C_{60} and C_{70} as well as graphite and diamond	28.00
Special tee-shirts	9.50
Special labcoats	19.50

The Buckybox Kit version 2.1 includes all of the above apart from the Molymod kit and the tee-shirts or labcoat.

Table 1

Soft- and hardware news/

Soft- and hardware news

SSERC Graphics update - Looks like great news for users of Mac's, IBM PC's and compatibles out there who have looked on enviously at Arc users of our Graphics Collections CD-ROM. SCET (Scottish Council for Educational Technology) are currently beavering away (sorry Kim!) converting the Arc graphics plus a whole lot more, drawn in the last six months, to Mac format. We see also in an impressive insert called Co-ordinate IT in the latest issue of Archimedes World that *Oak Draw for Windows* is now available from Oak Solutions. They say that PC Windows(TM) users can enjoy file compatibility with Archimedes Draw users. We will keep you posted on these useful developments.

New IT in Science publications by Roger Frost. *IT in Secondary Science* looks at the many opportunities to use science software, and tools such as word processor, graphics, database and spreadsheet applications in science. It also includes ideas for the science curriculum as well as IT tools for assessment.

Datalogging and Control sets out to illustrate the many aspects of science which can be explored with sensors. It is a practical guide and bank of ideas showing what datalogging and control is and where it fits in to the work of the science teacher.

Both of the above publications are available at £14.50 each from ASE (Booksales).

LogIT News - You can now see what your LogIT is up to when out in the field with *CheckIT*. Available from Griffin, Cat. No. CRD 150 560M at £59.90 it allows you to monitor sensors in the correct units whether logging is being carried out or not. For just under £300 Griffin now offer an *All-in-One* pack containing sensors, CheckIT, power pack, software and link lead. Other new developments include software and leads to display and transfer data to the Acorn Pocket Book and Psion Series 3 pocket computers, *Insight* on the Mac and a Windows version on the PC, PC Heart & Breathing Monitor and Fitness Analysis software and finally a free *LogIT Information Service*. Contact Griffin for further details.

Data Harvest News - Also under development at Data Harvest (Educational Electronics) is Archimedes software for the *Motion Sensor* and software to link the Acorn Pocket Book to the Sense & Control datalogger. Contact them for up-to-the-minute info or watch this space.

Philip Harris News - The First Sense sensor's big brothers, the *SensorMeters* form part of what they now call *System SM* (the rest is the DLplus datalogger and software options for the three main computer platforms). These do all that the Blue Box sensors and the S-Range meters did before and are capable of operating in stand-alone or datalogging modes. To make full use of the SensorMeters with the DLplus you need to have version 2 of the DLplus 32 or the new 128K version. To upgrade you have to buy 4 Sensormeters, for which you get 4 vouchers or fork out £49.50.

Finally, did you know that Philip Harris give special dispensation to UK primary and secondary schools enabling the single user version to be freely copied for use within that educational establishment? Now you do!

Surplus Equipment Offers

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

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

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

Cash / Cheque with orders

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

Motors

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

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

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

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

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

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

621 Miniature motor, 1.5 V to 3 V d.c., open construction, ideal for demonstration, dimensions 19 x 9 x 18 mm, double ended output shaft 5 mm x 1.5 mm dia. 20p

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

732 Motor with gear box, high torque, 1.5 V to 12 V d.c., 125 r.p.m. at 12 V, dimensions 40 x 40 x 28 mm, shaft 10 mm x 3 mm dia. with key. Suitable for driving buggies, conveyor belt, or any other mechanism requiring a slow drive £6.00

773 Tachometer (ex equipment) £2.25

625 Worm and gear for use with miniature motors, nylon worm and plastic gear wheel. 35p

378 Encoder disk, 15 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole. 75p

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

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

New motor stock

785 Precision motor with optical shaft encoder, 0.25 to 15 V d.c., no load current and speed 20 mA and 7,700 r.p.m. at 15 V, stall torque 11 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 1.9 V/1000 r.p.m. Suggested application - tachogenerator. Data on shaft encoder section available on application. £15

786 Precision motor with attached but electrically isolated tachometer, 0.15 to 12 V d.c., no load current 20 mA and 5,700 r.p.m. at 12 V, stall torque 96 mNm, 13 segments. Overall body length including tachometer 99 mm. Output shaft 19.5 x 4 mm dia. Back EMF constant 2.1 V/1000 r.p.m. Offload output voltage from tachometer 11.73 V d.c. with 12 V applied to motor. £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

Miscellaneous items

629 Dual tone buzzer with flashing light, mounted on small p.c.b. The unit has a PP3 battery clip and two flying leads for switch applications. 55p

710 Sonic switch and motor assembly. First sound starts the motor, a second reverses the direction of rotation, a third sound stops the motor. Driven by 4 AA cells (not supplied). 45p

715 Pressure gauge, ca. 40 mm o.d. case, 25 mm deep and 33 mm dia. dial reading 0 to 4 bar (i.e. above atmospheric). With rear fitting for $^1/_8$" BSP. Suitable for use as indicator for pneumatic circuits in Technological Studies. 75p

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

165 Bimetallic strip, length 10 cm;
high expansivity metal: Ni/Cr/Fe - 22/3/75
low expansivity metal: Ni/Fe - 36/64 (invar) 15p
166 Ditto, but 30 cm length. 40p

385 Pressure switch, operable by water or air pressure. Rated 15 A, 250 V (low voltage operation therefore possible). Dimensions 2" x 3" dia. 65p
419 Humidity switch, operates by contraction or expansion of membrane. Suitable for greenhouse or similar control project. Rated 3.75 A, 240 V. 75p

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

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

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

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

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

782 Toggle switch, panel mounting, 3 Amp rating, SPST, mounting bush 0.468 inch, flattened black 18 mm toggle. 50p

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

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

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

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

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

742 Key switch, 8 pole changeover. 40p

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

688 Croc clip, miniature, insulated, red. 5p

759 Ditto, black. 5p

741 LES lamp, 6 V. 15p

770 LES lamp, 12 V. 15p

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

691 MES battenholder. 20p

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

730 Battery holder, AA-type cell, holds 4 cells, PP3 outlet. 20p

729 Battery connector, PP3 type, snap-on press-stud, also suitable for items 692 and 730. 5p

724 Dual in line (DIL) sockets, 8 way 5p
760 14 way 7p
776 16 way 8p

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

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

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

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

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

727 Hose clamp, clamping diameter from 8 mm to 90 mm, 101 uses - securing hose to metal pipe, tree to stake, joining wooden battens for glueing, etc. 30p

731 Re-usable cable ties, length 90 mm, width 2 mm, 50 per pack. 12p

612 Beaker tongs, metal, not crucible type, but kind which grasps the beaker edge with formed jaws. £1.20

752 Shandon chromatography solvent trough. £1.00

Components - resistors

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

737 Ditto, 22 Ω, lin., 36 mm dia. 30p

329 Ditto, 33 Ω, lin., 36 mm dia. 30p

330 Ditto, 50 Ω, lin., 40 mm dia. 30p

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

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

420 resistors, 5% tolerance, ¼ W :
1R5, 4R7, 5R6, 6R8, 8R2, 10R, 15R, 22R, 33R, 47R, 56R, 68R, 82R, 100R, 120R, 150R, 180R, 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R, 1K0, 1K2, 1K5, 1K8, 2K2, 2K7, 3K3, 3K9, 4K7, 5K6, 6K8, 8K2, 10K, 12K, 15K, 18K, 22K, 27K, 33K, 39K, 47K, 56K, 68K, 82K, 100K, 150K, 220K, 330K, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M. Per 10. 6p

BP100 Precision Helipots, Beckman, mainly 10 turn. 10p-50p

Components - capacitors

695 Capacitors, tantalum,
4.7 μF 35 V, 15 μF 10 V, 47 μF 6.3 V. 1p

696 Capacitors, polycarbonate,
10 nF, 220 nF, 680 nF, 1 μF, 2.2 μF. 2p

697 Capacitor, polyester, 15 nF 63 V. 1p

698 Capacitors, electrolytic,
1 μF 25 V, 2.2 μF 63 V, 10 μF 35 V. 1p

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

Components - semiconductors

322 Germanium diodes 8p

701 Transistor, BC184, NPN Si, low power. 4p

702 Transistor, BC214, PNP Si, low power. 4p

717 Triac, Z0105DT, 0.8 A, low power. 5p

725 MC74HC139N dual 2 to 4 line decoders/multiplexers 5p

699 MC14015BCP dual 4-stage shift register. 5p

711 Voltage regulator, 6.2 V, 100 mA, pre-cut leads. 10p

Sensors

615 Thermocouple wire, Type K, 0.5 mm dia., 1 m of each type supplied: Chromel (Ni Cr) and Alumel (Ni Al); for making thermocouples, see Bulletins 158 and 165. £2.20

640 Disk thermistor, resistance of 15 kΩ at 25°C, β = 4200 K. Means of accurate usage described in Bulletin 162. 30p

641 Precision R-T curve matched thermistor, resistance of 3000 Ω at 25°C, tolerance ±0.2°C, R-T characteristics supplied. Means of accurate usage described in Bulletin 162. £2.90

718 Pyroelectric infrared sensor, single element, Philips RPY101, spectral response 6.5 μm to >14 μm, recommended blanking frequency range of 0.1 Hz to 20 Hz. The sensor is sealed in a low profile TO39 can with a window optically coated to filter out wavelengths below 6.5 μm. Data sheet supplied. For application see SG Physics Technical Guide, Vol.2, pp 34-5. 50p

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

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

503 Kynar film, unscreened, 28 μm thick, surface area 12 x 30 mm, no connecting leads. 55p

504 Copper foil with conductive adhesive backing, makes pads for unscreened Kynar film to which connecting leads may be soldered. Priced per inch. 10p

506 Resistor, 1 gigohm, ¼ W. £1.40

Opto-electronic devices

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

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

Other components

We also hold in stock a quantity of other electronic components. If you require items not listed above please let us know and we will do our best to meet your needs, or to direct you to other sources of supply.

Items not for posting

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

Glassware

657 Screw cap storage jar, plastic cap, 4 oz., wide neck. 10p

663 Flat bottom round flask, 250 ml. 50p

664 Flat bottom round flask, 500 ml. 50p

747 Quickfit vented receiver, 10 ml. 20p

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

Chemicals

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

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

668 500 ml dodecan-1-ol. 50p

670 500 g Keiselguhr acid, washed. 25p

672 500 g Magnesite native lump. 25p

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

676 500 g quartz, native lump. 25p

677 100 g sodium n-butyrate. 25p

678 500 g strontium chloride AR. 25p

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