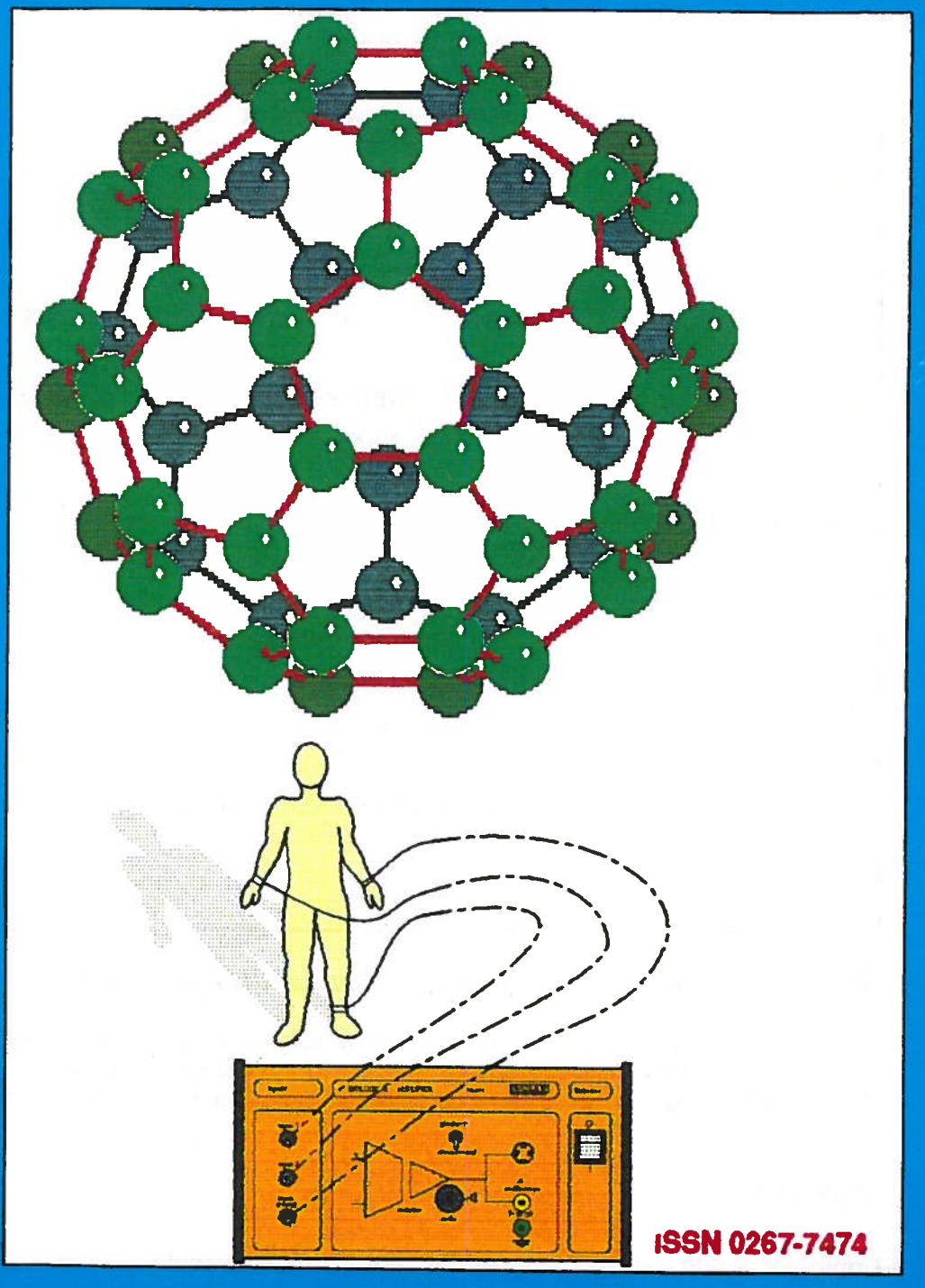
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE

Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences



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Contents

Front cover illustration : C-60 Buckyball and Unilab Biological Amplier set up for ECG work.

Note : Buckyballs are molecules of carbon, first synthesised in May 1990. Because the basic shape of these molecules resembles the geodesic dome invented by the American designer and philosopher R.Buckminster Fuller, the C-60 molecule was named buckminsterfullerene, or buckyball for short.

OPINION

Running risks

Most of us scientists and technologists can appreciate, and react to serious problems, or - to use *mediaspeak* - even so-called crises, in restricted ways. We discuss the issue theoretically, on some impersonal plane. It may then be that some minor but real inconvenience makes trouble for us in a more immediate and personal way. The practical significance and the real enormity of the problem is then brought home because we realise that our minor inconvenience may be being multiplied manyfold.

In recent years we at SSERC have attended a number of meetings on "Crisis in British science and engineering..." or some such theme. Oft times these meetings and conferences have touched on a number of related issues such as science and technology education, the public understanding of science, general standards of scientific and technological literacy etc.

We have jumped up and down and stamped a literary foot. We have metaphorically foamed at the mouth. All done, I suspect, in the absence of any real passion. Until now that is.

What has made the problem of British scientific illiteracy real to us was a most prosaic, and - I admit it - apparently trivial, episode. Trading as a company in our own right from April of this year we were refused insurance cover on the SSERC van. We even had only a part refund on our premium.

Why was this? Because, honest souls that we are, we declared on the proposal form that we occasionally carry a few small, sealed radioactive sources and tiny amounts of flammable, toxic or corrosive chemicals.

The broker had explained the position to the primary insurer and they were happy to accept the risk. It was when that insurer tried to arrange underwriting insurance with a second firm that the trouble started. This was for secondary cover against the unlikely event of our van's involvement in a major crash or fire. Most general insurers lay-off their bets at higher odds to specialists in this way.

We then explained at length that our loads presented insignificant chemical risks even when compared to the average delivery at a local DIY store. As to the risk from ionising radiations our occasional carriage of one or two, small sealed sources was, we explained, as nothing compared with a vanload of smoke detectors going to a security firm.

Our own broker and the underwriter of the primary risk bearer were sympathetic to our arguments. Neither of them, for instance, had known that smoke detectors contain radioactive material. The senior underwriter of the re-insurer however was adamantly unhelpful. Radioactivity was radioactivity and he would have none of it thank you very much.

Eventually after a lot of to-ing and fro-ing our broker found a more rational set of insurers and we again have cover, isotopes and all.

In June of this year parliamentary time was devoted to a House of Commons debate on British science and technology [1]. Although during the life of the last Parliament there had been other adjournment debates on this topic, this was the first since 1985 which was held in the Government's own time.

Repeatedly during this latest debate the point was made that too few MPs have any background or interest in science or technology. A number of speakers widened that point to take in senior administrators, managers and company executives. "Hear, Hear!" say we, although we realise in this context that by no means are we coining a phrase.

We have come round a bit towards another view expressed more than once in that Commons thrash. We used to gnash our teeth with the best of them over the numbers of young people who receive a scientific or engineering training and then suddenly change horses for a general business or professional career. "What a waste!" we said. We are now by no means so sure about that.

Scientific and technological illiteracy would seem to run deep in the generalist streams of decision making and managing. Maybe it's no bad thing that we lose the odd science and engineering graduate - yea even a physicist or two - to the ranks of management and accountancy. It could be worth the risk even if it only marginally improved their standards of scientific and technological literacy.

It would be an especially good thing if more than the odd MP, senior civil servant or lawyer knew their Becquerel from their elbow[1].

Reference

1. *Science and Technology*, House of Commons Official Report (Hansard), Vol.209, No.26, Thursday 11th June 1992, HMSO.

[1] Or, for that matter given our recent experiences, even one particular Lloyds broker.

INTRODUCTION

Sponsorship

This bulletin issue, as for number 173, has been sponsored by Scottish Enterprise. Readers interested in knowing more of the purpose, objectives and priorities of Scottish Enterprise are referred to an editorial piece which provided the *Foreword* to that previous issue.

If you have specific enquiries on Scottish Enterprise training activities and Business Education partnerships then please contact your nearest Local Enterprise Company (LEC). If need be you can obtain a list of LEC names and addresses from Scottish Enterprise itself at the address given on the outside back cover of this bulletin.

Annual Meeting dates

Technology Teachers

The Technology Teachers' Association (TTA) Annual General Meeting will be on Saturday, 7th of November, 1992. Note that this year sees a change of venue. The AGM will be held in Coatbridge High School, Lanarkshire. It is proposed that the informal part of the programme prior to the annual business meeting will be as follows:

09.30 - 10.00	Reception, registration and coffee.
10.00 - 10.45	Guest speaker
10.45 - 14.00	Exhibition (Lunch 12.45 - 13.30h).

The TTA is gaining a reputation for the quality of its Guest Speaker slots. It has pulled off a couple of *coups* in recent years with Mr (*Go on - make my day - call me Frank*) Pignatelli in 1991 and Jim (*silver tongue, fareweil tae Govan*) Sillars last year. We have no idea as yet of the identity of their guest for 1992. We will certainly be booking our places - if only to find out whether they will go from the sublime to the ridiculous (and not necessarily in that order either).

Science Education

The U.K. Association for Science Education (ASE) 1993 Annual Meeting will be held at Loughborough University from Saturday the 2nd to Tuesday the 5th of January 1993.

The ASE Scottish Region Annual Conference will run from Monday the 5th to Wednesday the 7th of April 1993. The venue is to be the Scottish Agricultural College at Auchincruive, Ayr. As potential exhibitors we have already received an outline of the proposed programme structure and were impressed with some of the novel approaches adopted by the Local Organising Committee.

The conference will be held entirely on weekdays, so avoiding organisational problems of weekend working for college and exhibitors' staff. The programme is to be based on 90 minute *slots*. There should thus be ample time between talks and lectures to allow participants to visit the exhibitions, chat informally and have, rather than grab, a cup of tea or coffee.

It bodes well for the 1993 conference that the local committee have so obviously already given its organisation much thought. If they sustain that approach, then Auchincruive could be *"the place to be in '93"* (Groan!).

Staff development : SSERC courses

Following circulation of details of our course programme for the 1992-93 session, we now have a heavy schedule of bookings mainly from the advisorate and particularly for Series B : Health and Safety, courses.

We still have a little slack for the Spring and Summer terms in 1993 in a few subject areas. We would be particularly interested in hearing from neighbourhood groups and others interested in technical support for curriculum revisions such as those affecting the Higher courses in science and technology subjects and other *new* areas such Graphic Communications and RDG 3's work on Environmental Studies at 5 - 14.

For more detail please contact the Director of SSERC in the first instance.

Science, technology and safety

Both in the "Opinion" and "Safety Notes" sections of this issue we deal with the business of estimating risk. Here we have a specifically educational point to make.

Ever since the passing of the Health and Safety at Work Act we have remained bemused at the apparent lack of imagination in educational circles as to the possibilities of integrating risk assessments into the general business of teaching.

Most teachers and advisers have spotted that safety should not be separate and special and that precautions (control measures in *COSSH-speak*) should be mentioned to students as and when necessary or demonstrated by example.

What fewer seem to have grasped is that the whole business of risk assessment is part science, part applied science and part technology. It involves the gathering of data, possibly from measurements, the judgement of the reliability of evidence and the evaluation then choice of alternative solutions to problems. This applies as much to environmental impact assessments as to health and safety. The disciplines relevant to such activities are set to

become increasingly important. We are amazed that no-one yet seems to have grasped the positive educational opportunities so presented.

This piece was in part triggered by the somewhat facetious remark of a reviewer. This was in his review of our booklet on COSHH risk assessments for novel and project work. Tongue in cheek (and one cerebral hemisphere in neutral?) he suggested that the whole SSERC approach was so thorough, care was needed to prevent the risk assessment becoming a project in itself.

Out of the mouths.....?

No Comment

"To describe it as a dog's breakfast is insulting to the culinary tastes of the canine fraternity."

Howard Davies, Director General of the CBI on the Youth Training programme.

"We must not produce people who understand all about the sun, the atmosphere and the rotation of the earth, and still miss the radiance of the sunset."

Alistair MacFarlane, in his Principal's Address at the 1991 Heriot Watt University graduation ceremony.

"It is now suspected that Einstein may well have been assassinated. Prime suspects are the Mafia and the CIA.

Why was Einstein killed? A currently popular theory is that he knew too much. At the time of Albert's death however Heisenberg was widely reported as being unsure of the whole business".

Anon. - contemporary student *wit*(?).

Safety Notes

New regulations

In the last issue [1] we gave advance warning of new leglislation needed to implement six EC (European Community) Directives on health and safety at work. These directives are part of the European Commission's action programme on health and safety which in turn is an integral part of moves toward a single European market.

The UK's own Health and Safety Commmission (HSC) and its executive arm (HSE) is treating this development as an opportunity to further their own ongoing modernisation of existing British law.

All of the six directives have to be implemented by the beginning of 1993, each by means of one set of regulations. These will cover:

General Health and Safety Management
Work Equipment Safety
Manual Handling of Loads
Workplace Conditions
Personal Protective Equipment
Display Screen Equipment

As indicated in our earlier article, most of the requirements of the regulations are not really new. Rather they will clarify that which is sometimes implicit rather than explicit in current health and safety law. Those already complying with the spirit of the Health and Safety at Work Act, and in more practical terms with the regulations linked to it, should not find the new requirements more onerous.

Some of the approaches in the new regulations are however novel. Notable in this respect are some aspects of health and safety management, manual handling of loads and the use of display screens. Also likely to impinge on science and technology departments is much of the detail of the regulations on personal protective equipment (PPE) which of course cover such matters as eye protection.

The HSE plans to publish a good deal of guidance on the new regulations. Included in that guidance will be two new approved codes of practice (ACoPs). In due course we will inform readers of the availability of these. Meantime:

Health and Safety Management

One result of the framework directive undoubtedly will be a greater emphasis than ever on systems for the general management of health and safety at work.

HSC watchers like ourselves have seen the steady development of this trend over a number of years.

Evidence of the importance placed on this aspect of health and safety by the Commission and Executive even in areas like education is afforded by one of their latest publications. And, there is another in the pipeline.

Just out is guidance in this area for the higher and further education sectors. The Education Services Advisory Committee (ESAC) of the Health and Safety Commission has published practical guidance on policy planning, inspection, monitoring and auditing [2]. On the way shortly is a parallel document for the school sector.

The higher and further education document is useful for its emphasisis on the need for an effective, action based, management framework. ESAC is to be especially congratulated for the way it has sought to define and distinguish terms such as inspection, monitoring and auditing which hitherto have been used sloppily and interchangeably.

This is an area of development in our own advisory and consultancy service. We would be pleased to assist any Scottish EA officers who wish to plan ahead to meet the likely new requirements in this area.

References

1. *1992 and all that*, Safety Notes, Bulletin 173, SSERC, April 1992.

2. *Health and safety management in higher and further education : guidance on inspection, monitoring and auditing*, Health and Safety Commission, 1992, HMSO.

HSE Enquiries

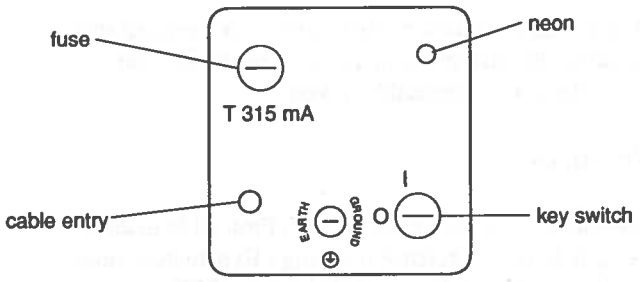
Note that from 1st of June this year the HSE Public Enquiry Service has been centralised at the HSE's Sheffield Information Centre. The telephone enquiry service is available from 9.00 am to 5 pm Monday to Friday. A new *Freeleaflet Line* will also operate from that date. Please see the list on the inside rear cover of this issue.

Note also that the telephone number of the HSE Edinburgh office in Belford Road has been changed and is now 031 247 2000.

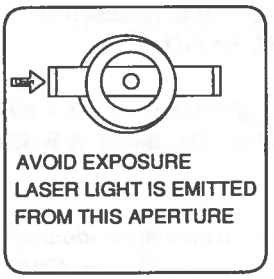
Electrical safety

Obsolete Griffin laser

We have had enquiries from schools concerned that their Griffin laser had failed a routine maintenance test of electrical insulation. The laser is an obsolete model, XFV-530-010F, which the company withdrew from the market around 1981 because it was proving to be unreliable. Drawings of the front and rear panels are shown as an aid to identification (Fig.1).



REAR PANEL MARKINGS



FRONT PANEL MARKINGS

Fig.1 Front and rear panels of faulty Griffin laser
(Note legends are white on black on the laser itself)

We have examined a sample and found that there is a 470 kΩ resistor connected between the earth conductor and one terminal of the bridge rectifier across which live and neutral are applied. British Standards specify that the insulation resistance between live conductors and the enclosure should be 2 MΩ minimum at 500 V. Clearly, because of its design, the laser is bound to fail such an insulation test.

If you have this laser, the question then is what to do about it? It might be argued that Griffin supplied you with goods which are of such construction that they do not comply with British or International Standards and do not thereby prevent, so far as is reasonably practicable, danger. You might then have a right in principle to return the laser to Griffin and obtain a part refund. However the Electricity at Work Regulations didn't exist at the time of purchase. Your claim would have to rely on vague general duties under Section 6 of the HSW Act and consumer protection leglislation. In addition you will have had at least eleven year's usage out of the device. It is doubtful that you would be able to claim anything significant.

Even if you decide not to pursue the matter you are bound to withdraw such a laser from service because we cannot see that it can readily be modified to bring it into reliable and safe operation.

Gamma source storage

Introduction

Here we provide an estimate of the risks arising from storage of gamma sources near to or in a classroom. The article is based on the reply to an enquiry we had as to the siting of a storage cabinet of radioactive sources. Behind the enquiry lay concern that pupils in a nearby classroom might receive a dose that was significant and, thereby, unacceptable.

Estimate of annual dose

The following estimate is based on gamma sources stored within a locked steel cabinet mounted on an internal, single leaf, brick wall. It further assumes that pupils nearest to the cabinet sit no closer than about two metres from the opposite side to the wall. Estimate values are taken from the Explanatory Notes [1].

Taking the separation from the source to a pupil to be 2 metres, the dose rates to the pupil from Co-60 and Ra-226 nuclides, each of 185 kBq activity, are

Co-60	17 nSv h^{-1}
Ra-226	11 nSv h^{-1}

Taking the fractional transmissions of the wall to be 50% and of the lead castles to be 75%, the doses rates are reduced to

Co-60	6.4 nSv h^{-1}
Ra-226	4.1 nSv h^{-1}

For a pupil sited in the room 6 periods a week and 38 weeks a session, at 40 min periods, the number of hours of exposure a year is 152 h. The separate annual doses received from each source are therefore

Co-60	973 nSv	(round off to 1000 nSv, or 1 μSv a year)
Ra-226	627 nSv	(round off to 600 nSv a year)
total	1600 nSv	

Estimate of risk

Reporting in 1985, NRPB [2] [3] reckoned that an effective dose equivalent of 50 μSv a year "corresponds to an annual risk of harm to the individual of about 1 chance in a million (a risk of 10^{-6} per year)".

If we assume a linear relationship between dose and risk, the risk from an annual dose of 1.6 μSv is 3 chances in 100 million, or 3×10^{-8}.

The report advises that "effective dose equivalents up to 50 μSv per year, i.e. 1% of the annual dose limit for members of the public, are insignificant as far as the individual is concerned". It recommends that "the effective dose equivalent received by an individual from all practices may be disregarded if it does not exceed 50 μSv per year. Individuals can justifiably regard such annual doses to themselves or to their families as being no cause for concern."

From recent analysis of the fate of Japanese World War Two atomic bomb victims, NRPB [4] revised their risk estimates by a factor of 3 upwards, but have not, so far as we are aware, revised downwards their 50 μSv level of 1985 at which they reckoned the risks to be insignificant. Even if this level were lowered threefold, the risk to a pupil from an annual dose of 1.6 μSv would be well beneath it.

Comparative risk estimates

From analysing the risks of different environmental factors and occupational practices it has come to be recognized that there is a risk of harm from almost everything and anything. Considering risks to the general public, a Royal Society Study Group [5] judged that an annual risk of 10^{-4} (1 in 10 000) is unacceptable, whereas a risk that was ten times less at 10^{-5} (1 in 100 000) is probably acceptable. This judgement should be compared with the estimate of harm to pupils exposed to gamma radiation in the site considered.

Another relevant risk comparison is the risk with that from radiation of natural origin. The average annual effective dose equivalents in the UK from radiation of natural origin is

Source	(μSv)
cosmic radiation	250
earth gamma rays	350
radon decay products	1200
thoron decay products	100
other internal radiation	300
total	2200
(Co-60 source	*1)*

Thus the risk of harm to the individual from natural background radiation stands at about 4.5×10^{-5} per year.

Summary

Schools have a duty to site stores of radioactive sources such that employees and pupils do not receive a dose that presents a significant risk. In the exercise above, we have shown that the worst case risk to pupils is about 3×10^{-8} from two gamma sources sited on the opposite side of a brick wall two metres from their desk. This risk is many orders of magnitude less than that posed by natural background (4×10^{-5}) and is well below the limit (10^{-5}) set by a Royal Society Study Group on the level of risk acceptable for members of the public.

If the siting of a store causes concern, we suggest that you analyse the risk in the manner shown to find out whether the risk is acceptable to you.

References

1. *Gamma radiation*, Sections 34-37, Protection against ionising radiation in science teaching : Explanatory notes on local rules for teaching establishments (SED Category C only), SSERC, 1987, 11-13.

2. *Small Radiation Doses* to Members of the Public, ASP7, NRPB, 1985, HMSO.

3. *The Significance of Small Doses of Radiation to Members of the Public*, Fleishman, A B, Chilton, NRPB-R175, 1985.

4. I*nterim Guidance on the Implications of Recent Revisions of Risk Estimates*, Chilton, NRPB-GS9, 1987.

5. *Risk Assessment : a Study Group Report*, Royal Society, 1983.

Outmoded SOED circulars

Recent enquiries from advisers and health and safety officers have raised questions as to the status of two Scottish Office Education Department safety documents. They were reviewing the contents of departmental safety files and wished to know if two particular SOED Circulars were any longer useful or relevant. These are SOED circulars 766 (1970) [1] and 825 (1982) [2]. The first relates to the educational use of lasers and the second to carcinogenic substances.

Laser guidance

The problem with the SOED's guidance on lasers is that at 22 years old it is seriously outmoded. In our view it is also unnecessarily restrictive. For example we have recently been demonstrating some interesting and exciting ways of teaching geometrical optics with the use of a low-powered laser. The published SOED guidance has proved less than helpful in that regard and puts a needless block on the wider use of these techniques.

Carcinogens

In the second case, that of the advice on carcinogens, the leglislation on which this twelve year old circular was based itself was effectively repealed four years ago. The relevant regulations have been superseded by provisions made as a sub-set of the COSHH Regulations. The leglislative basis for Circular 825 has thus disappeared but the circular itself has not been withdrawn formally.

Action suggested

We are anxious not to be entirely negative in our comments. Both circulars contain a deal of information and practical guidance which remain useful to schools. However currently they lack relevance or technical veracity. Circular 825 in particular has some useful features but no legal status.

It has been suggested to SOED officers that 766 and 825 should either be withdrawn formally or properly updated so that they may again be sensibly included in basic safety files. A Departmental response is awaited.

References

1. *The Use of Lasers in Schools, Colleges of Education and Further Education Establishments*, Circular No.766, SED (now SOED), 1970.

2. *The Use of Carcinogenic Substances in Educational Establishments*, Circular No. 825, SED, as revised, 1982.

TECHNICAL ARTICLES

Higher Grade Human Biology

Instrumentation Part II

This is the second article in a short series describing practical work for the new Human Biology syllabus at the Higher Grade.

Introduction

In Part I [1] we provided both a rationale and an overview of opportunities for the application of modern instrumentation to the teaching of the new course in Human Biology. Specific examples were provided of the application of pressure transducers and piezoelectric devices.

Here we deal with applications of modern instrumentation techniques to the teaching of parts of Topic 3 - *Life Support Mechanisms* and of Topic 4 - *Biological Basis of Behaviour* [2].

Cardiovascular and neural physiology

Electrocardiograms (ECGs) are specific syllabus entries under *Transport Mechanisms* in sub-section 1c)i of Topic 3. Reflex actions and their supression are dealt with in Topic 4 - *Biological Basis of Behaviour.*

Safety

We last wrote in any detail on these subjects in Bulletins 145 and 163 respectively [3, 4]. Then, one major concern had been with the safety aspects of deliberately attaching electrodes to the human body and the remote but real possibility of electric shock from any ancilliary, mains-powered, displays etc.

Another worry was with the unpredictable effects of what is known as *biofeedback.* It was feared that in observing aspects of their own physiology, student subjects might so influence their own behaviours as to cause themselves harm.

In the intervening period these fears apparently have proved largely groundless.

In the first case any relevant modern educational equipment tends to be battery driven and electrically isolated by optical means from any peripheral mains devices. With such well-designed equipment the risks of shock are insignificant especially when compared to the potential educational benefits.

In the second instance any effects of biofeedback appear to have been grossly overestimated. Only for a minority of activities and for pupils with specific medical conditions, does there seem any real potential for harm.

Background theory

Good theoretical accounts of those aspects of human physiology described here are provided by a number of standard texts such as those of Green [5], Tudor [6] and Pope [7] the latter two being particularly and admirably concise. For the convenience of readers, teachers or students, the main points are summarised as follows.

Biopotentials

Electrical potential differences generated inside living organisms are known as *biopotentials*. Generally they arise because of differences in ionic concentrations across cell membranes. Hence the use of an additional, or alternative, term - *membrane potential.*

Biopotentials are generated in nerve, muscle and glandular cells. They depend upon special features in the differential permeability in the membranes of such cells. Some cell membranes will permit not only water but also even large solute molecules to pass. This, for example, is the case with cells lining the digestive tract. Other cell membranes, such as those of nerve fibres, permit only water and Na^+, K^+ or Cl^- ions to move through them.

Differences in the relative concentrations of these positive and negative ions are maintained across the membranes of nerve fibres by a mix of osmotic and mechanical mechanisms.

Resting potential

When at rest, a nerve fibre maintains relatively high concentrations of negative chloride and positive potassium ions inside its membrane and of sodium ions outside. This results in the establishment of a *resting potential* of about -70 mV across the cell membrane.

Action potentials

When such cells, or indeed muscle fibres or glandular cells, respond to a stimulus this potential difference goes through a series of reversible changes.

Nerve cells

In nerve fibres the membrane suddenly becomes permeable to Na^+ ions which quickly move into the cell resulting in a rapid change of membrane potential from the resting -70 mV. It drops to and then swings through zero to become positive at about +40 mV. These are termed the *depolarisation* and *reverse polarisation* stages respectively.

Equally rapidly, the membrane then becomes impermeable to Na^+ but permeable to K^+ ions.The latter leave their internal site of relatively high concentration and move out to the external membrane surface. This is termed *repolarisation.* It restores the membrane potential to the original -70 mV. The sum of these changes results in an electrical pulse, initially positive going but rapidly backing again to a negative potential.

The magnitude of this pulse is thus about 110 mV (-70 mV to +40 mV). It is known as an *action potential.*

In nerve fibre cells one whole cycle takes only a few milliseconds. It is however followed by a much slower recovery period during which the Na^+ and K^+ ions are re-exchanged and that part of the cell cannot respond to further stimulus. The entire process is summarised diagramatically in figure 1.

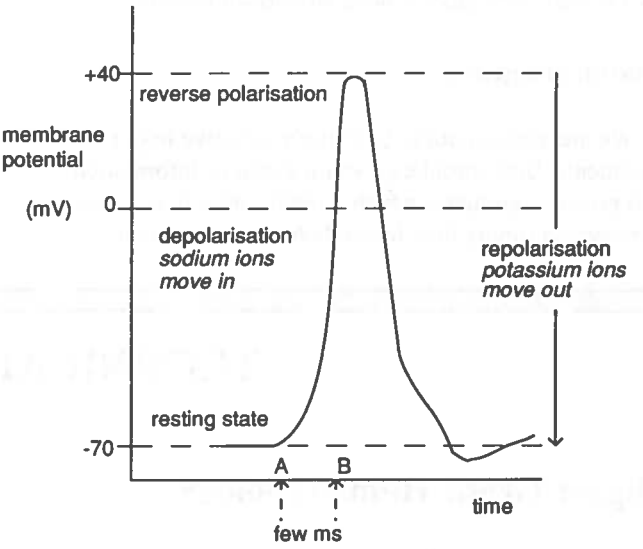
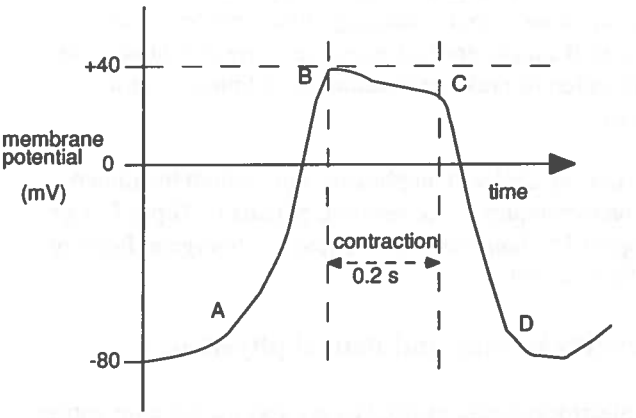


Fig.1 Action potential (nerve)

Heart muscle

The cells making up heart muscle exhibit an action potential markedly different from that of nerve and other cells. The magnitude of the change in potential is similar (-80 to +40 mv and back to -80mV) but the shape and timescale of the pulse are distinctive (Fig.2).



A - B = depolarisation (causes contraction) & reverse polarisation
C - D = repolarisation (relaxation) ABCD = one heartbeat

Fig.2 Action potential (heart muscle)

The pulse is wider, the positive part of the cycle having a duration of about 200 milliseconds. Each complete cycle, from depolarisation (which causes contraction) to repolarisation (relaxation) covers one complete heartbeat.

Propagation

Before any stimulus can result in an initial action potential it must exceed a certain *threshold* value. However, once such a potential has been triggered, the first depolarisation of any region of a fibre effectively stimulates the region adjacent to follow suit.

Thus the process is repeated down the fibre so that a wave of action potentials then proceeeds along it. By such means is a nerve signal transmitted. When such a pulse reaches the end of that individual fibre it must cross the gap (synapse) to the next. That stage is a biochemical, enzymically controlled process the result of which is the generation of an action potential in the adjacent fibre (neurone).

This mix of electrochemical and biochemical processes involved in the transmission of nerve signals explains rates of transmission which are much slower than would be the case with a purely electrical process.

Rates of propagation vary with cell or fibre type and diameter, together with a number of other variable factors. Generally transmission in muscular tissues is markedly slower than in large diameter nerve fibres - where propagation rates may be as high as 150 ms^{-1}.

Practical matters

Detecting signals

Biopotentials, as described, result also in summative changes in electrical potential at the body surface. Electrodes placed on the skin and suitable instrumentation will enable such changes to be detected and measured. Obviously changes due to activity well below the skin, such as in the heart muscle, will be heavily attenuated at the surface.

Thus action potentials with associated voltage changes originally of 100 mV or more may result in signals of only a few millivolts on the skin (4 or 5 mV at most in the case of activity in the heart). This means that once detected the signals may have to be amplified manyfold before they can be displayed.

In the past, the poor conductivity of human skin presented a significant obstacle in the detection of such signals. The high resistivity of the outer skin layers meant that areas for electrode attachment had to be clean, free of grease, sometimes hair-free (and thus shaved).

Sites were also often rubbed or even sand-papered (I still remember that bit - ouch!) to remove some of the outer layer of dead cells. Contact resistances were lowered with conductive electrode pastes or gels and by firmly taping electrodes in position (Ouch again - when the tape was ripped off!).

Another difficulty is that such changes reflect only the total result of the electrical activity of groups of cells. These may be neural or muscular or both. Only when the detected signals arise from co-ordinated activities of such groups can we make much sense of them.

The problem lies then in sorting out the signals under study from random background voltage changes on the skin surface. This *noise* results from the general sum of bodily electrical activity. The usual way round this snag is to use a differential amplifier. Even so, much still depends on the proper location of the detecting electrodes and of any others intended as *earthing* or *grounding* reference points (see, for example our figure 4).

Educational practice

Improvements in electrodes and amplifier design have largely circumvented such difficulties for educational purposes. Electrodes still may be applied with the same rigour in clinical work (Yet again - ouch!).

Electrocardiography

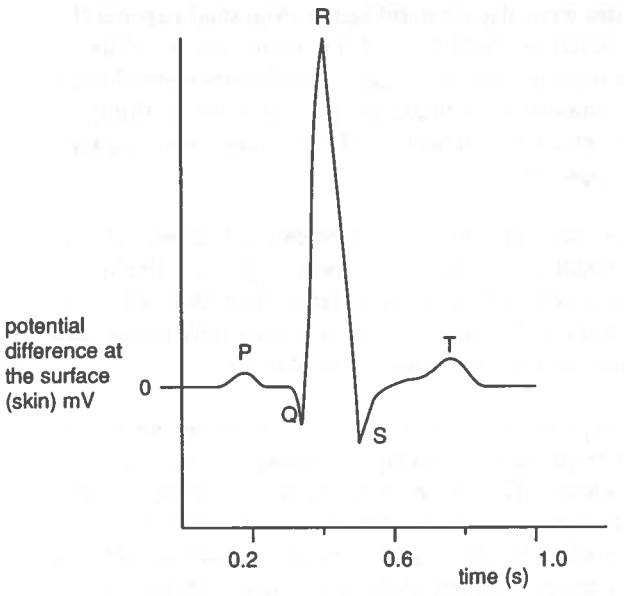
Electrocardiograms (ECGs) are recordings of the rapidly changing pattern of biopotentials which accompany the rythmic beating of the heart. Long study of such patterns from both normal, healthy hearts and from those with a range of defects has lead to the the development of a powerful diagnostic tool.

The ECG waveform

Each beat of the human heart is triggered by an electrical pulse arising in its upper right region. The function of this pulse is the synchronisation of contractions in the four chambers of the heart[1]. In turn it causes action potentials which spread from the right atrium down and across the heart.

During any one heartbeat, biopotentials thus develop between cells already depolarised and those awaiting depolarisation. It is these potentials which are detected at the surface, amplified and recorded as an ECG. A typical waveform from such a recording is represented diagrammatically in figure 3.

1. An engineering analogy is with the timing mechanism of an internal combustion engine which ensures the correct firing order of its cylinders.



P wave = depolarisation of atria and atrial contraction.
QRS pulse = depolarisation and thus contraction of ventricle
T wave = repolarisation and thus relaxation of ventricles.
QRS pulse obscures repolarisation of the atria.

Fig.3 ECG - PQRST waveform

By convention such an ECG waveform is labelled with the letters *PQRST* each of which denotes a characteristic part of the cardiac cycle (see legend for figure 3).

For educational rather than clinical purposes it is merely an acceptable approximation of such a waveform we seek to record and display. Affordable and reasonably reliable equipment for such study purposes has been on the educational market for a number of years now.

Suitable equipment

At the school and non-advanced FE levels our first recommendation for work on ECGs has to be Unilab's *Biological Amplifier* (Cat. no. 743.001) At the time of writing this cost £108.47 including three large area electrodes, with adjustable straps, and a cassette recorder lead (fig 4).

Also useful but less versatile is Philip Harris' *E.C.G. Interface* (Cat.no. B72970/6 at £146.73). In our view this lacks the quality and clarity of the traces achievable with Unilab's device. The Harris ECG electrode system results in smaller areas of reliable contact than the Unilab plate and rubber strap system. The Harris device is also restricted to use with software on a microcomputer (BBC B or Master only) and is single purpose, having only an ECG/ heart rate facility.

The Unilab amplifier in contrast, is general purpose allowing a range of neurophysiological work to be carried out. It also allows a range of options for the recording and display of the resulting traces (see Table 1).

To be set against such features is that, given frequent usage, the Unilab electrode straps do wear out rather quickly being prone to snap at the adjustment holes. Replacement straps are however available, see Table 1.

Overall the Unilab Biological Amplifier is a device which deserves more attention from teachers and is currently a much under-rated and under-used resource.

Also available from Unilab is a *physiological* version of their famous *big orange box* interface, so beloved by physicists. Apart from the fact that this version is instead a *big white box* (Cat.No.532.020), the major features are much the same. A significant functional difference however is that the analogue sensory inputs of the physiological version are fully isolated from its outputs. It is however of little interest in this present context since (apart from its cost) it is specifically described by Unilab as "not intended for use with human subjects".

Device	**ECG Interface**	**Biological Amplifier**
Supplier	Philip Harris	Unilab
Cat. No.	B72970/6	743-001
Price	£146.73	£108.47
Safety/ isolation	Optical fibre connection from interface output to computer analogue input	Internal opto-isolated stage in the amplifier circuit
Batteries	Y (1 x PP3)	Y (2 x PP3-P)
Electrodes & straps	3. 2 x thumb & 1 ankle. Carbon impreg-nated foam plastic	3 metal plates with 4 mm lead connections & 3 ad-justable rubber straps
Replacement straps/plates	Y (B72975/5, £21.32/set)	Y (strap - QK157, £0.63) (plate - QMAC099, £0.80)
Output	BBC Analogue compatible voltage	bipolar 1 V peak-peak
Functions:		
ECG waveform	Y	Y
Heart rate	Y (automatic)	Y (count & calculate)
Electromyograms	N	Y
Reflex action	N	Y
Display facilities:		
VDU	Y (BBC B or Master dedicated software)	Y (any suitable interface/software)
CRO	N	Y
Chart/pen rec.	N	Y
via Datalogger	N	Y (if it can accept 1 V peak-peak)
Audio output &	N	Y
save to audio tape	N	Y
Save screen-disc	Y	software dependent

Table 1 Main features ECG Devices

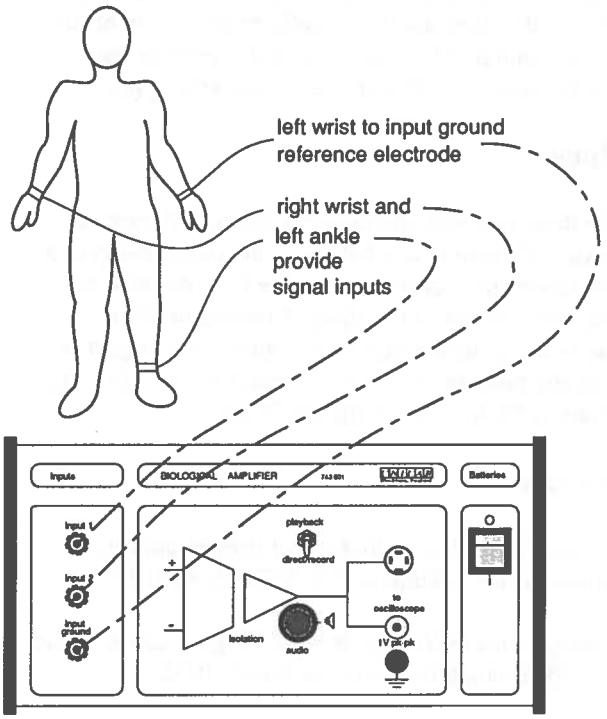


Fig.4 Electrode positions and amplifier connections

Usage

In clinical work a variety of electrode positions may be used. This is because the biopotential patterns arising from the heart vary according to electrode positioning as well as with the condition of the subject.

Signals are also apparently directional. They may be envisaged as *vectors* - having direction as well as amplitude. Analysis of these so called *cardiac vectors* against those of known heart defects is a useful diagnostic technique. This involves the use of several sets of electrode configurations which by convention are designated with *lead numbers*.

Discussion of these aspects of cardiac physiology is outwith the scope of this article[1]. The techniques described will thus be restricted to one standard set of electrode positions.

Electrode sites

For an ECG recording on the Unilab device for example the standard electrode positions are as follows:

- left wrist to amplifier *input ground*

- right wrist and left ankle to either of the two *signal* inputs

1. Computer software packages on such aspects of cardiac physiology are however available eg Harris' ECG CAL package BBC version A29590/5 £28.95.

The *input ground* terminal is connected to a *true earth* inside the biological amplifier. The amplifier thus detects and amplifies the potential difference between the right wrist and left ankle - two extremities either side of the median line of the body. Which lead, wrist or ankle, goes to the red and which to the black thus matters little. We normally connect up as shown in figure 4.

Sample results

Printouts are shown for the Unilab device with direct (Fig.5) and indirect logging via VELA for its fast data capture facilities (see Fig.6 - note - top trace is smoothed).

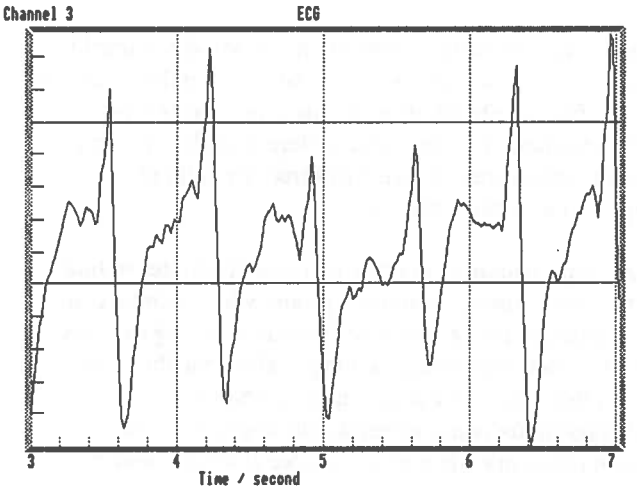


Fig.5 Bio-Amp to analogue port of Beeb

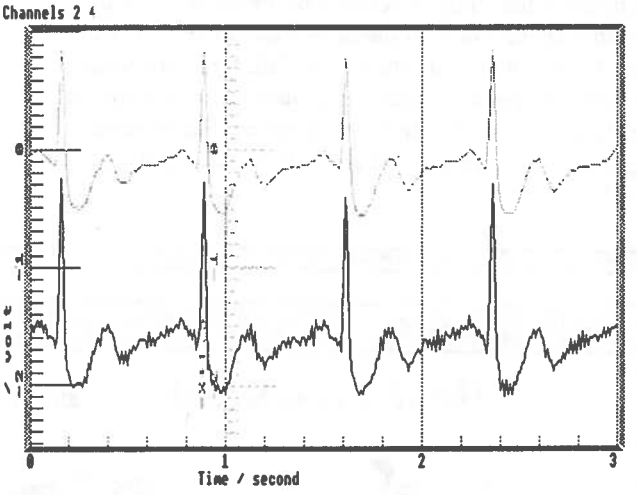


Fig.6 Bio-Amp to VELA then downloaded to Beeb

The display device was a BBC microcomputer running Philip Harris' *Datadisc Plus* software. A variety of other recording and display methods is feasible.

Unilab's own interface and *Grapher* software (ubiquitous in physics departments) can be used as may newer devices such as LogIT. Reasonably fast data

capture is needed however to ensure enough data points per heartbeat to produce an ECG of acceptable quality. We have yet to trial some more recent dataloggers in this respect.

If a permanent record or hard-copy are not required then the Biological Amplifier output may be displayed on an oscilloscope or recorded and played back on a standard audio-cassette tape.

Reflexes

Some work on the suppression of reflexes is specified in section 1b)iv of Topic 4 of the SEB syllabus for Human Biology [2].

Biopotentials also accompany nerve activity related to reflex actions, such as the human *knee-jerk* reflex. Like the signals from the heart, these too may be detected by electrodes placed at the surface. Here though, the electrode configurations are somewhat different from those employed in cardiac studies.

A useful pattern is to place all three electrodes in line on the main muscle, or muscle group, which contracts in that particular reflex response. Thus in studying the knee jerk the electrodes would be ranged along the thigh. At school this may prove impractical or potentially embarassing for some subjects. The ankle or *Achilles tendon* reflex may then prove a more amenable area of study.

Fuller accounts of such application of the biological amplifier in the study of reflex arcs are to be found in Unilab's instructions for the device and in SSERC Bulletin 163 [4]. In that account the use of VELA for fast data-capture was specified since reflex arcs are relatively fast transients. We have been looking since at the possibility of logging on more recent and portable devices such as LogIT.

Early trials indicate that the event button on this device may be used to both apply and indicate the timing of the physical stimulus. This would avoid the need for the special hammer described in our earlier writing [4].

Endpiece

The third and final article in this series will provide technical information and advice on the construction of a simple thermistor based detector. We shall describe the use of such a device in the study of responses of the human body to sudden heat loss or gain. This subject is specifically mentioned in the syllabuses for both Biology and Human Biology at the Higher Grade.

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6. *Understanding the Human Body*, Tudor, E.Mcl. & Tudor E.R., 1985 edition, (1990 reprint), Pitman, ISBN 0 85896 260 8.

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Standard Grade Technological Studies

The article describes a project in prothesis. A summary description is given of the development of designs for a jointed, flexible foot. This is intended to improve the performance of artificial legs. Diagrams of systems and subsystems are included.

Introduction

Victoria Brown is a pupil at Penicuik High School. When she was eleven years old Vicky had a leg amputated below the knee. She therefore has direct experience of the drawbacks of current designs of artificial legs. That experience gave her the idea for her final year project in Standard Grade Technological Studies.

With the encouragement and assistance of Jim Cassidy, Principal Teacher of Technology at the school, her design was then entered for the Young Inventor of the Year Competition. This competition is funded and organised by the Rotary Club of Great Britain. Vicky won the Scottish heats and then went forward to compete in the national finals. She did not win but her project was highly commended by the judges.

It is pleasing to discover a technology project, undertaken at Standard Grade, reaching the finals of such a prestigious, national competition. It is doubly pleasing to discover such a relevant and innovative, bio-engineering project carried out by a young Scotswoman[1].

The Problem

As defined by the pupil :-

After the first world war a great number of men lost limbs and were given artificial legs made of tin which used to creak and squeak. They were held on with leather straps, belts and braces. As the years have progressed increasingly sophisticated technology has greatly improved design and manufacture of artificial limbs.

Now if you need an artificial leg you receive one which stays on by a vacuum and does not need straps.

They are lightweight, look good and even have toes.

There is still one major drawback though. An artificial leg has a foot which is at right angles to the leg and does not give much when the leg is moving or walking.

1 Please note that no chauvinism (literally, nor in the modern, sexual usage) is intended - so no letters to your *vertically challenged* Editor on this one , please!

Performance Criteria

As defined by the pupil :-

The artificial leg has to perform as near normally as possible. It must be so designed that :-

Standing

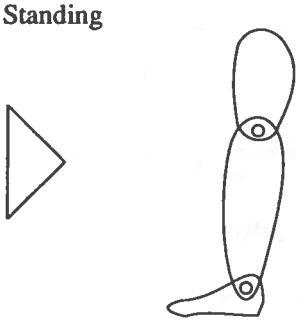


Fig.1 When standing the foot should lock in a position at right angles to the leg.

Walking 1

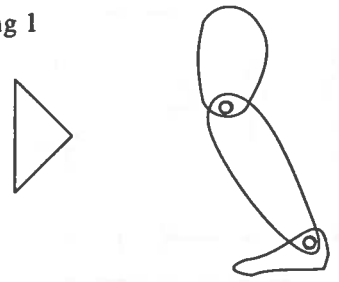


Fig.2 When you start to walk your body weight moves forward and your foot changes position, the system thus must make the foot move down to take off.

Walking 2

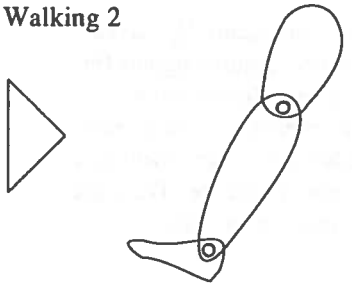


Fig.3 When the foot is in the air it has to swing through and return to a horizontal position.

Landing

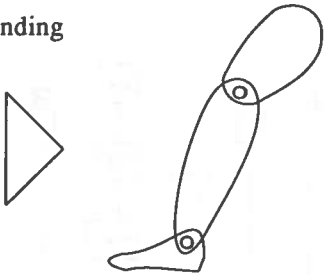


Fig.4 When the foot lands the system must make the foot move up so that the heel lands first. It then must go back to the beginning of the cycle.

The Project

Designs

Once the problem had been so defined a block diagram of the overall system was drawn. This was then broken down to a series of sub-systems, each such sub-system in turn was analysed. Where appropriate truth tables were drawn up and completed for any electronic and, or, pneumatic logic circuitry. Prototypes were built.

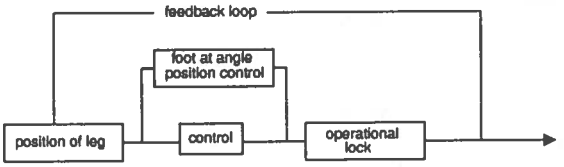


Fig.5 Block diagram of control system

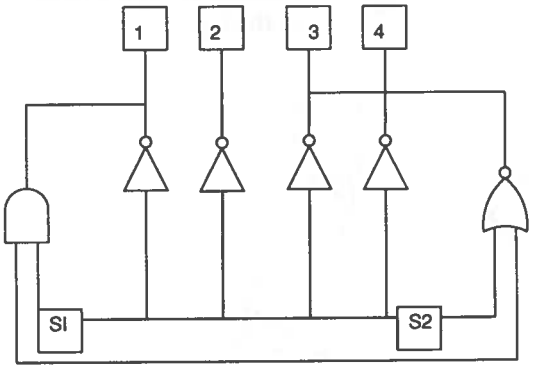


Fig.6 Early design for a control system

Building and testing

The first working model used pneumatic $^5/_2$ valves controlling double acting cylinders. Control signals for these cylinders were provided from solenoid valves which in turn were energised by means of signals from sensors in the foot. These sensors were micro-switches, one in the heel of the foot the other in the toe. The logic circuit was built up from E&L modular boards.

As a result of trialling this system, design changes were made. One early, major modification was to simplify the system by using single acting cylinders controlled by $^3/_2$ valves. E&L modular electronics boards were retained as basic sub-systems of the logic circuit.

Further evaluation and refinement

By this stage a number of significant drawbacks to the system were already apparent. With pneumatics providing the basic motive power a compressor with a reservoir is required and this hardly adds to the portability of the system. The E&L boards too are relatively bulky and more prone to faults in such a dynamic system subject to constant movement and vibration.

As a result of this critical evaluation, an hydraulic power system was substituted for the pneumatic one. This hydraulic system used components supplied by Economatics Ltd., which allowed a small scale, sealed system to be used.

The logic circuits were also redesigned. It was decided to build up circuits with discrete components on bread-board. This had twin advantages. It reduced the physical size of the circuit so improving the portability of the overall system. It also markedly improved the reliability of the circuit so that it eventually gave a fault free performance.

Conclusion

We feel that this project met both spirit and letter of the SEB requirements for such projects. Various design stages showed evidence of progression and obvious evidence of the integration of electronic and pneumatic systems. An industrial dimension was added through discussion sessions with staff of the prosthetic department at the Princess Margaret Rose Hospital. These were held to gain background information and insights as to possible commercial development of the design.

This was a relevant project. It was relevant to the understanding and experience of the pupil. It exhibited a proper mix of both top-down systems and intuitive bottom-up approaches. It may be argued that this pupil

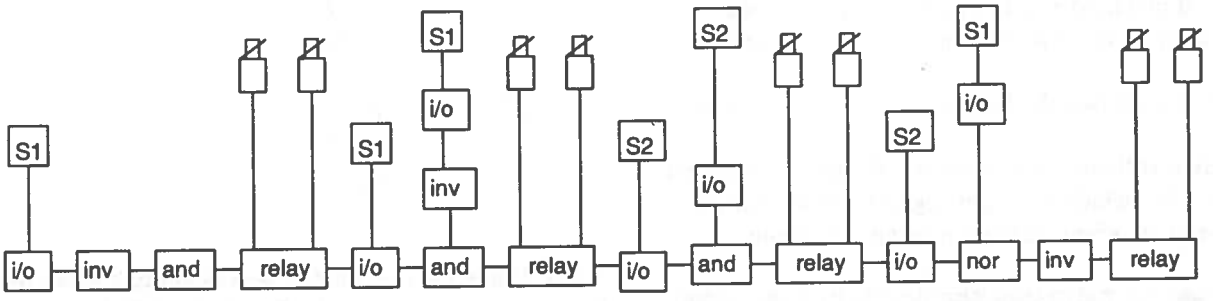


Fig.7 Electronic control using E & L boards

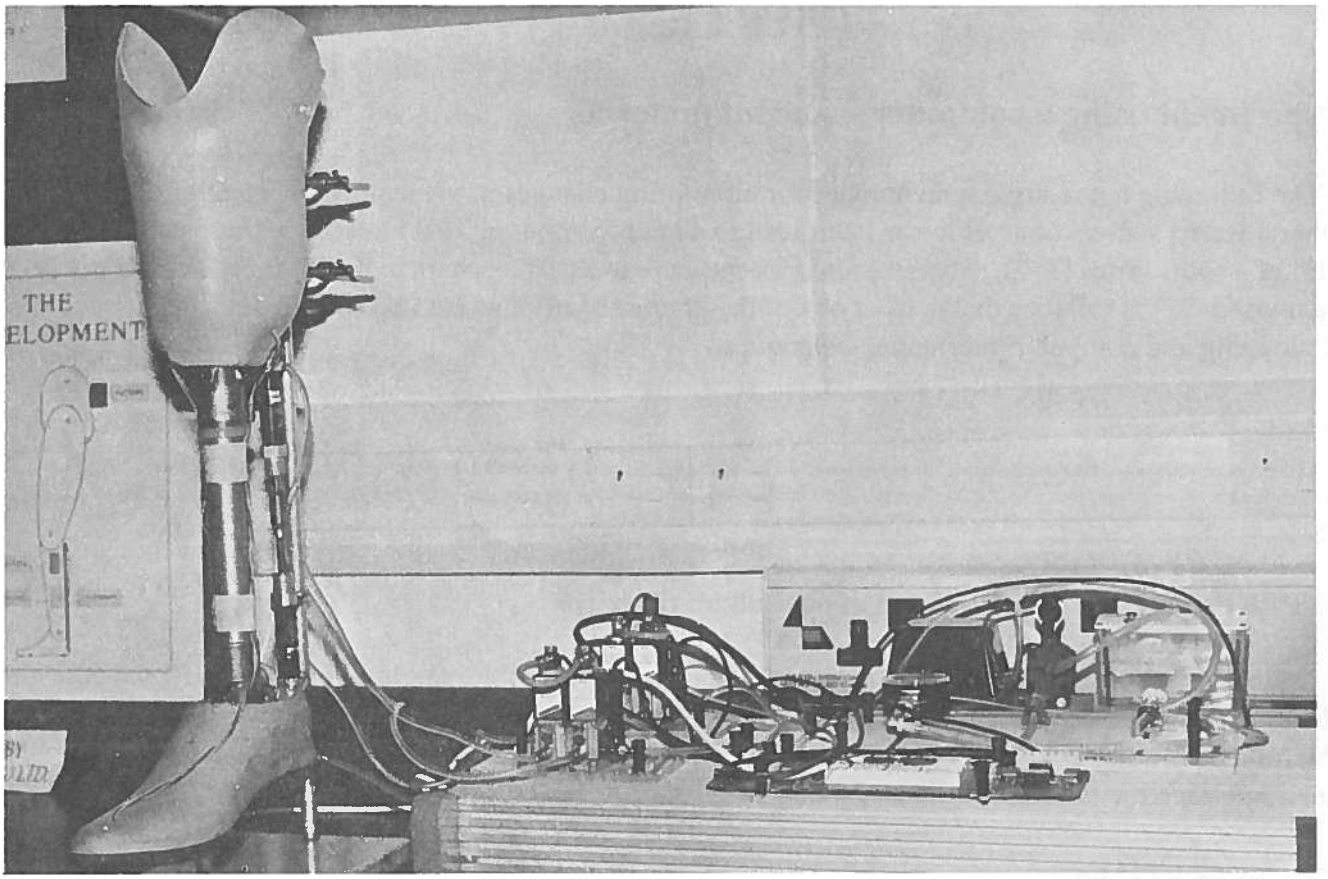


Fig.8 - limb and control system

was a special case with special, personal, interests in the problem. That may well be so but if Technological Studies is to secure a position of strength it will be because it successfully offers a broad technological education. Before that happens there must be many more 'special cases' like Vicky Brown and her project.

Endpiece

There is concern amongst those involved in teaching Craft and Design that the coffee table has become ubiquitous as a project. It would seem that there is a similar danger in Technological Studies that controlling a sliding door or some other kit based project becomes the equivalent of that coffee table.

We would argue for a move away from modelling industrial processes and practice and mere manipulation of kits of parts. We need to get back to promoting projects which have relevance to individual pupils. No matter how simple these might be, they must involve real, rather than simulated, industrial problems.

It may well be worthy of note that the outcome of the project which won the Rotary Club Young Inventor Award was a spark plug tester with potential in the commercial market place - shades of Brunton?

CSYS Chemistry

Experiment using a computer - student material

The following notes suggest techniques for monitoring changes in pH using a pH electrode and either a Harris sensor or a pH meter interfaced to a microcomputer. This material is presented as the third of a short series [1, 2]. This is an interim measure to assist teachers to meet the requirement in the revised CSYS syllabus that at least one of the practical activities is to be carried out using datalogging and computer interfacing techniques.

HAZCONS

At the concentrations used the acids and alkalis are not even defined as being 'irritating' in the CPL regulations. Splashes will nevertheless irritate the eyes. Wear eye protection; this is important if the tall constant flow device is used. For the preparation of the solution from ampoules or from concentrated solutions wear goggles and use in a well ventilated room.

EXPERIMENT D4 - Investigation of acid-alkali titrations

A manual recording and graph plotting technique is described for experiment D4 in the SCCC's Memorandum Number 16 [3]. That account should be read in conjunction with this present article. The following notes suggest techniques using a *Harris pH sensor* and probe or a pH electrode and meter interfaced with a BBC microcomputer and *Datadisc Plus software*.

Interfacing a pH meter

If your existing pH meter has suitable outputs it can be used in place of the Harris sensor with only a few differences in the method of use, mainly concerning the calibration stage. Alternatives for steps 7, 8 and 9 are given in Appendix 1. A pH meter will allow you to span from pH 0 to 14, whereas the Harris sensor is restricted to a range of 10 pH units. The output voltage from the meter must be positive and less than 1.8 V at the maximum reading. Many older pH meters are quite suitable with outputs of 0 V at pH zero to 1.4 V at pH 14. But do check first in the operating instructions and also with a multimeter as outputs from a few meters range from -0.7 V through zero at pH 7 to +0.7 V.

Constant flow - volume versus time

Datadisc Plus software enables the computer to capture data and produces a graph of *pH against time*. As the head of the titrant in the burette falls the flow rate reduces. The simplest way to provide an almost constant flow is to deliver the titrant from a wide vessel fitted with a length of glass capillary to restrict the flow rate. The drop in head in such a device is negligible. The wide reservoir can be a separating funnel of capacity greater than 100 cm^3 or a redundant plastic bottle fitted with an outlet, tap (or screw clip on rubber tubing) and capillary tubing.

The above arrangements will only give graphs of pH against time which is good enough to display the shapes of the four titration curves. Time can be related to volume in a number of ways:

(i) Appendix 2 describes one method of simply timing with a stopwatch the rate of delivery of the titrant by weighing it. A variation on this would be to use a balance with an output and appropriate software to plot mass against time (eg Oertling OB 152 and the *Balance Monitor* package);

(ii) Another alternative is to use a different software package from Harris called *Dataplot* which allows you to directly plot volume against time. Here you would carry out the original procedure as described in D4, but after addition of each 2 or 0.2 cm^3 from the burette, type in the total volume added. Pressing function key 0 makes the point plot appear on the graph. Make more additions of titrant and enter the data each time to get a succession of points. Once the graphs are completed they can be saved, printed, etc using menus and commands almost identical to those in *Datadisc Plus*.

Equipment and chemicals

BBC microcomputer and disc drive, 80 track, double sided
Datadisc Plus software
4 channel interface connecting box and leads, 4 mm
Harris sensor (or pH meter) and pH probe
magnetic stirrer assembly
pipette, 25 cm^3 pipette filler
constant flow device (see Appendix 2)
beaker, 100 cm^3, tall form
deionised water
acids: 0.1 mol l^{-1} - ethanoic and hydrochloric
alkalis: 0.1 mol l^{-1} - sodium hydroxide and ammonia solution
clamp stand and clamps

Procedure

Note that where a letter or word is enclosed in angled brackets e.g. <Escape>, <Return> etc. the computer key or keys indicated are to be pressed. Words or phrases in italics generally signify something that appears on screen or on an interface, e.g. a menu name or menu choice.

Preparing equipment

1. Remove the silicone cup from the pH probe and attach the protective skirt. Rinse in deionised water and soak in deionised water before use. If you have a pH meter, first check that the probe responds reasonably well to changes in pH before proceeding.

2. Set up the apparatus as shown in Fig.1, keeping the constant flow device clear of the beaker until you are ready to start recording.

The pH sensor should be switched off and connected to the 4 channel interface connecting box as follows:

0 V (sensor) or -ve output on pH meter ----> COM (interface unit)
1 V (sensor) or +ve output on pH meter ----> Channel 1 (interface unit)

3. Pipette 25 cm^3 of 0.1 mol l^{-1} sodium hydroxide into the beaker; this should just leave sufficient room for a small stirrer follower. If not, add a little deionised water to cover the skirt of the probe. Remove the probe and place it in a beaker of deionised water.

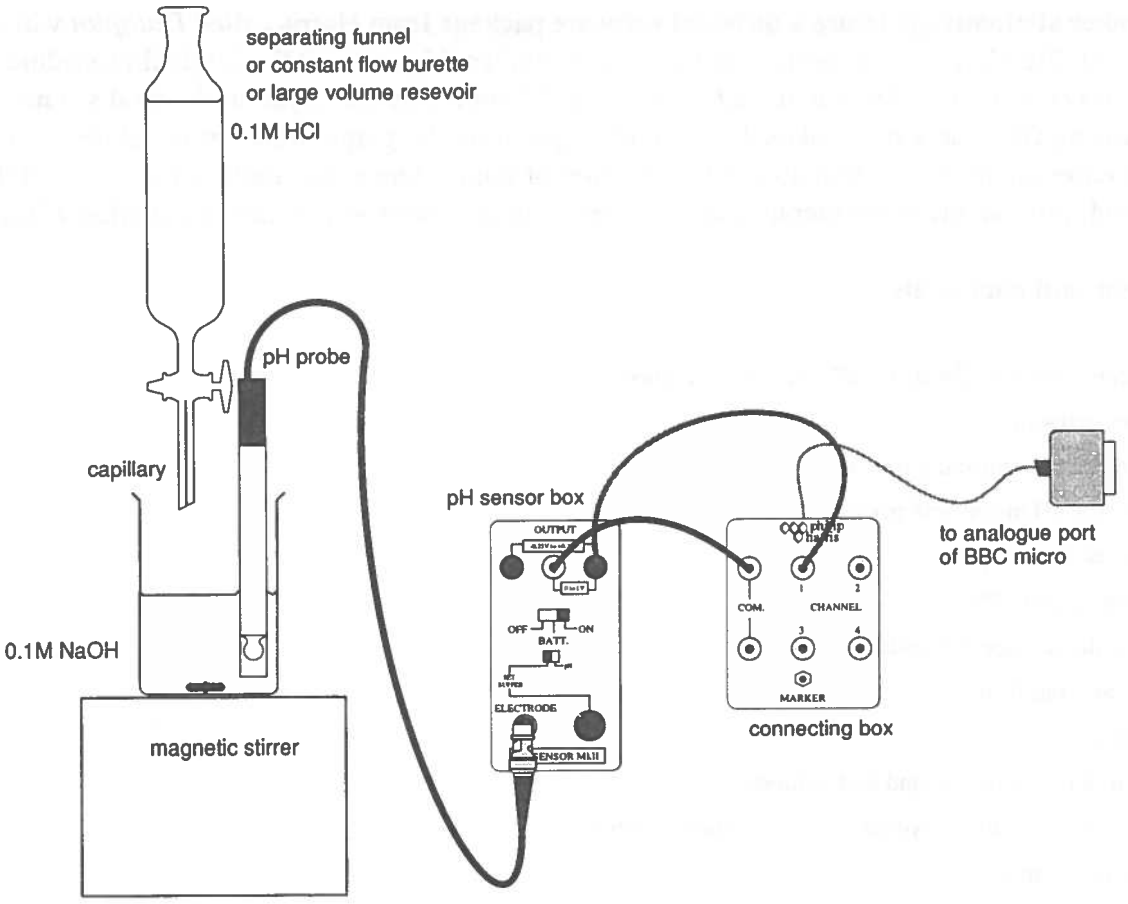


Fig.1 Titrations using Philip Harris pH sensor

4. Fill the constant flow device (or burette) with 0.1 mol l^{-1} hydrochloric acid as outlined in the instructions appended to these notes (see page 24).

5. Attach a printer to the BBC microcomputer, switch on the computer and insert *Datadisc Plus* into the main drive (usually Drive 0)

6. Load the operating programme by autobooting- hold down <SHIFT> and tap <BREAK> before releasing <SHIFT>. The *Main Menu* should appear.

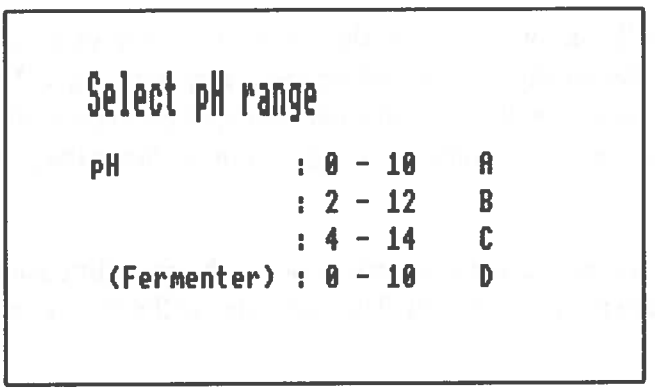
Calibration of pH sensor using Philip Harris pre-sets

7. Select <C> - Calibrate input channel
   Select <1> - Channel 1, then <RETURN>
   Select <P> - Philip Harris sensor

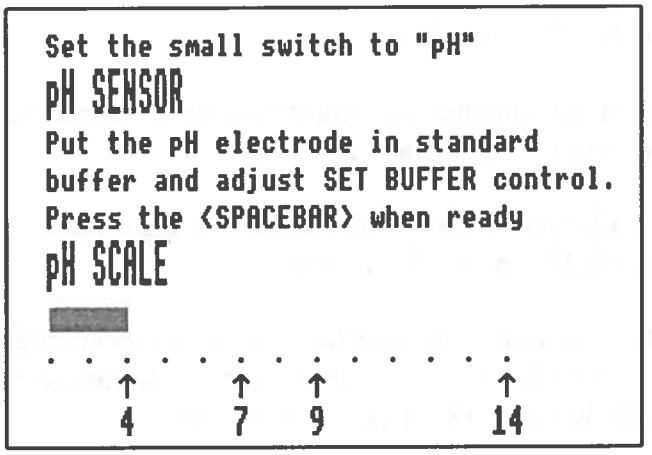
From the *Select sensor* menu choose <P> for a pH sensor.

The computer will now check the battery in the pH sensor. Move the *OFF-BATT-ON* switch to *BATT* and follow the instructions on the screen. If the battery fails, check all the connections and repeat step 7. If it fails again, replace the battery in the sensor. If the battery is fine, then switch the pH sensor *ON* and press <SPACEBAR> to proceed.

The following screen appears. (Appendix 1 shows how a pH meter can be used instead of the sensor by providing alternative steps 7, 8 and 9.)



8. Move the *SET BUFFER-pH* switch on the pH sensor to *pH*. Press <B> or use the cursor keys (arrow keys) to select pH 2-12 and press <RETURN>. The following screen appears.



9. Place the pH probe in a standard buffer solution e.g. pH 4. Remember the *SET BUFFER-pH* switch should be set to *pH*. Try rotating the *SET BUFFER* control knob and the solid yellow line at the bottom of the screen will move. Adjust this line to coincide with the pH of the chosen buffer solution i.e. 4. Press the <SPACEBAR>. The sensor is now calibrated and you are returned to the *Main Menu*. Do not move the *SET BUFFER* control knob after this.

Capturing pH data

10. Wash the buffer solution off the pH probe and then clamp it in position in the sodium hydroxide solution.

11. Switch on the stirrer and adjust to a slow speed.

12. Select <R> to record data
Select <1> to record on one channel against time
Select <1> to select Channel 1.

13. Type in the length of time for the recording as a whole number followed by <secs> or <mins>. (*Datadisc Plus* will accept <s>, <S>, <m> or <M>). Select a longer time period than you think is needed, say 2 or 3 minutes, for it is is easier to stop the logging process at any time during the

recording by pressing <ESC> than to try and rush a second recording. Press <RETURN> to enter this time period. You may care to add a suitable pH indicator at this stage.

14. Move the capillary end of the delivery tube on the constant flow device (or the burette) into position. Open the tap and simultaneously start recording the pH by pressing <SPACEBAR>. (Optional - press the *MARKER* button on the four channel analogue port connecting box if any change is seen in the indicator colour). The trace of pH against time shows the progress of the neutralisation.

15. Allow the computer time to complete the recording or cut the recording short by pressing <ESC> if you have overestimated the time needed. The computer will now reprocess the data and redraw it with a better scaling.

16. You can cycle through the options shown at the bottom of the screen by successive taps on the <SPACEBAR>, for example:

Print screen - provides a print-out of the graph *or*

Save Data - transfers your data onto another disc along with some information about it, e.g. the way it was obtained and when.

Have another formatted disc ready and follow the instructions on the screen. Once an option has been chosen by using the <SPACEBAR> press <RETURN>.

17. When you have produced a print-out, or the data has been saved on another disc, the graph will remain on the screen. Press <SPACEBAR> to cycle through the options to *New Recording* and select by pressing <RETURN>. Follow step 18 for *Yes* or 19 for *No*.

18. If the experiment was unsatisfactory and has to be repeated using a different time scale enter <Y> and then <RETURN> in answer to the question on the screen. Repeat steps 12 (from the second line) and 13 and enter a new time. Note that the first graph will be lost. Repeat the experiment from steps 14 to 17.

19. If the graph is satisfactory, enter <N> in answer to the answer on the screen. The Software will now move the existing data to *Channel 2* so that *Channel 1* is available for a new recording.

Other acid/alkali combinations

20. Plot other titration curves by again following steps 14 to 17 and 19 for each titration, involving:

ammonia solution and hydrochloric acid
ammonia solution and ethanoic acid
sodium hydroxide and ethanoic acid (all solutions 0.1 mol l^{-1})

Multiple plots

After each recording the software will move the the data to another channel to allow the next recording to be made on Channel 1. Take care to note which data is on each channel. (Four channels are available).

21. A plot of all the data captured for the four titrations can be plotted on one graph. To do this carry out steps 14 to 16 only for the last titration. Now press <U> to select *Options and Utilities* menu at the bottom left-hand side of the screen and press <RETURN>.

22. Select <2> to display *Two or more channels against time* from the *Display Utilities* menu.

23. *Channel 1* should be highlighted. To select this channel press <Y> (or <TAB> on older versions of the software), but do not press <RETURN> yet! Use the *down* cursor key to highlight *Channel 2* and then select by pressing <Y> (or <TAB>). If channels 3 & 4 were used select them in the same way and finally press <RETURN>. All the titration curves will be plotted on one graph, which can be printed or saved as before (step 16).

24. To finish this part press <M> to *Return to Main Menu.*

25. At this point a red warning will appear on the screen offering to save or delete all the data. To save it press <SPACEBAR>, have a formatted disc ready and follow the instructions on the screen. Otherwise press <DELETE>.

26. When the main menu appears press <F> to *Finish off.* If you omit this last step before switching off, the Main Menu won't appear when you next load in the software.

Comment on the pH curves produced and compare the plots obtained from each of the titrations. Try to identify the end point of the neutralisation in each titration and comment on the pH at each of these points.

Appendix 1 - General calibration method (pH meter or Philip Harris sensor box)

Most pH meters used in schools have a buffer off-set control, but no slope control. Here the software is used to emulate the hardware slope control (see reference [4]). First connect the meter or sensor box as in step 3 above and then follow the alternative versions of steps 7, 8 and 9.

7(b). From the *Main Menu*
Select <C> - Calibrate input channel
Select <1> - Channel 1, then <RETURN>
Select <G> - General calibration

8(b). **METER** - Switch on the pH meter. The solid yellow bar represents the incoming voltage. Type in <pH> and press <RETURN> as Channel 1 is to be calibrated in these units. They will be displayed on the vertical axis instead of volts. For many pH meters a pH of 14 gives an output of 1 V or 1.4 V and a pH of 0 an output of 0 V.

SENSOR BOX - Move the *OFF-BATT.-ON* switch on the sensor box to *ON*. The solid yellow bar represents the incoming voltage. Type in <pH> and press <RETURN> as Channel 1 is to be calibrated in these units. They will be displayed on the vertical axis instead of volts. Note the Philip Harris sensor box has a voltage span of 0 to 1 V representing any 10 pH units between 0 and 14.

9.(b) (i) **METER** - The first of the input levels for calibration is now requested. Place the probe in buffer pH 4 and adjust the *pH set* or *buffer set control* to make the pH meter read 4.00. Now type in <4> and press <RETURN>. Do not touch the *buffer set control* knob from now on.

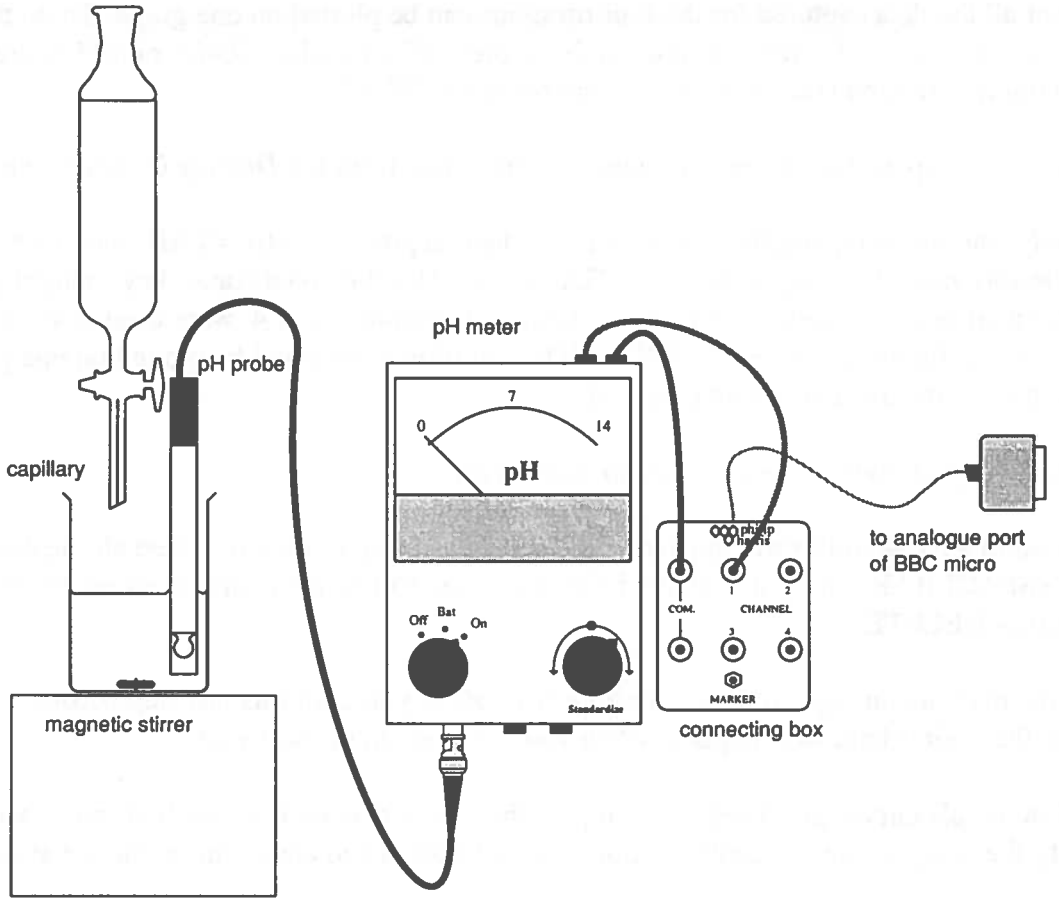


Fig.2 Titrations using pH meter

SENSOR BOX - The first of the input levels for calibration is now requested. Place the probe in buffer pH 4. Move the *SET BUFFER-pH* switch to the *pH* position. Rotate the *SET BUFFER* control knob to move the yellow voltage bar at the bottom of the screen. Where you set this depends on the 10 pH span you want to read over. Use the following table to set up the software where the buffer used is pH 4:

pH span voltage	**(V) on the bar set to read**
0-10	0.4
2-12	0.2
4-14	0.0

When the voltage is set to a suitable position type in <4> and press <RETURN>. Do not touch the *SET BUFFER* control knob from now on.

9(b) (ii) **METER** or **SENSOR BOX** - Remove the probe from buffer pH 4, rinse in deionised water and place in buffer pH 7 and the bar graph should increase. When the reading on the screen has stabilised, type in <7> and press <RETURN>. This tells the computer that this particular voltage corresponds to pH 7. The software now returns to the *Main Menu*.

Note that when you move the probe to the second buffer solution (pH 7) you may find that the METER reads a bit less than pH 7, say 6.85 or the yellow bar does not read exactly 0.7 V. Do not be

tempted to re-adjust the buffer off-set control to make it read 7. If you do it will simply read around 4.15 if you put it back in the first buffer!

The most likely cause of the above problem is the reduction in span response (or voltage output per pH unit difference) of a probe as it ages [4]. Some more sophisticated pH meters have a *slope control* which allows you to turn up the gain on the amplifier to compensate for the reduced span. If you follow the the above instructions you will have applied the necessary compensation by software instead of by a hardwired method.

If you have a meter with a *slope control* first calibrate it by itself using two buffer solutions (set at 4 in buffer pH 4 with off-set, rinse, place in buffer pH 7 and make the meter read 7.00 by adjusting the slope control. Thereafter do **not** touch the *slope control.)* Now connect it to the interface connecting box and proceed as in steps 7(b),8(b) & 9(b).

Appendix 2 - Constant flow burette and relating volume to time

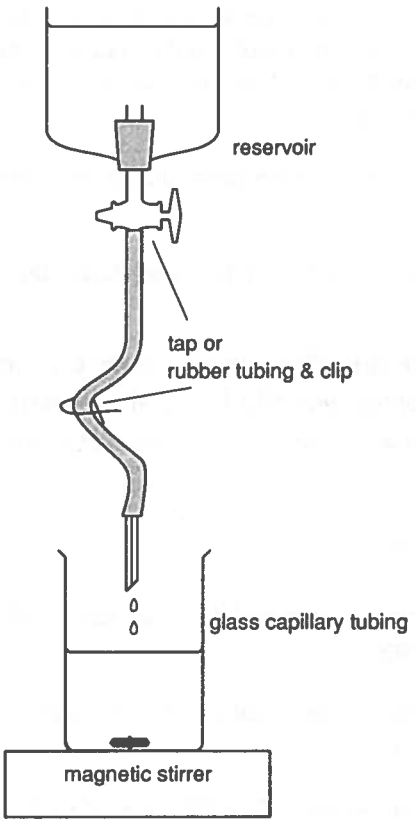


Fig.3 Reservoir model

separating funnel, 100 cm^3 fitted with rubber tubing and beaker, 250 cm^3
or wide plastic bottle fitted with bung and rubber tubing and tap
100 mm glass capillary of bore 1 mm
clamp rings of size to support funnel or bottle
stopwatch
balance

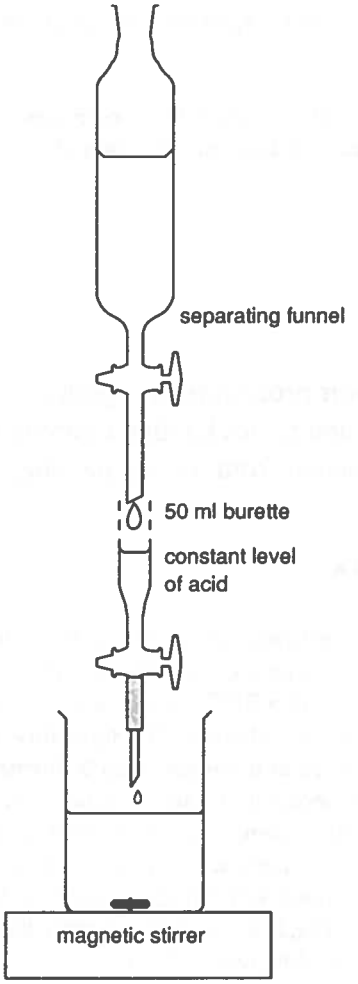


Fig.4 Burette model

burette, 50cm^3
separating funnel, 100 cm^3
stopwatch,
balance,
balance software (optional)

Procedure (reservoir model)

1. Set up the reservoir as shown in Fig.3, close the tap and fill the reservoir (or funnel) with water. Open the tap briefly to fill the tubing and close it again.

2. Point the capillary ending of the delivery tubing into the beaker placed on a balance.

3. Tare the beaker and simultaneously open the tap fully and start the stopwatch. Time the delivery of 1 g of water.

4. If required, the rate of delivery can be increased by raising the reservoir to increase the pressure head or by using a shorter length of restrictor capillary tubing.

It should now be possible to :

(a) calculate the rate of flow of acid in cm^3s^{-1}. This should enable you to interpret the final graphs as pH against volume.

(b) estimate a suitable time for the experiment, allowing excess acid to be added beyond the point of neutralisation.

Procedure (burette model)

1. Add 75 to 100 cm^3 of acid (water can be substituted for this calibration) to the separating funnel and insert it in the burette as shown in figure 4. A short length of flexible tubing on the end of the funnel outlet will protect the top of the burette from damage.

2. Close the burette tap, open the tap on the funnel slightly until the acid drips slowly at a steady rate into the burette.

3. Allow the burette to fill until the liquid level reaches the lower part of the scale, around 40 - 50 cm^3.

4. Open the burette tap carefully, until the acid drips into the beaker and adjust the the tap until the level of the acid in the burette remains constant. Adjust the rate of flow from the funnel if necessary.

5. Empty the beaker and place it on a chemical balance and then time how long it takes for the system to deliver 1g of acid. Repeat several times without altering the positions of the taps.

6. Adjust the apparatus if necessary until a constant flow is obtained.

7. Add more acid carefully to the funnel during this measurement.

The reservoir procedure is superior in being able to give a reproducible flow rate since the tap is opened fully and in not having a burette tap jet which often becomes partially blocked by small bits of debris detached from the tap packing. Procedure 2 has acid at a greater height above eye level.

Further work

Datadisc Plus software may also be used to investigate the heats of neutralisation using a temperature sensor and probe, interfaced with a BBC microcomputer in a similar way to the pH sensor and probe. The suitability of indicators for particular titrations could be investigated; to do this it may be necessary to run the titration in both directions with alkali being run into the acid. In that case alkali will be in containers at above eye level. Even greater care is required with filling procedures. The reservoir model (Fig.3) is lower than burette based apparatus and should be relatively safer.

Acknowledgement

These notes were partly based on draft materials prepared by Penny Kershaw and Barry Dunn of Fife Region whose assistance we gratefully acknowledge. Final versions will appear eventually in a revised version of Memo 16.

References

1. CSYS Chemistry, Technical Articles, Bulletin 172, SSERC, January 1992.

2. CSYS Chemistry, Technical Articles, Bulletin 173, SSERC, April 1992.

3. Memorandum Number 16, SCDS (now SCCC), 1982, under revision.

4. Use, care and maintenance of school pH meters and probes, SSERC,

Technical Tips

General introduction

In this issue we continue the experiment, begun in Bulletin 173, of publishing some technical pieces not long enough to merit a separate slot in the Technical Articles section.

Several of the ideas given an airing here did not originate in the Centre but have been sent in by teachers or technicians. This is more how it used to be in the early days of SSERC. We wish to further encourage this apparent renaissance.

The only condition of acceptance is our usual one. We reserve the right not to publish until we have tried any ideas in practice and checked that devices or circuits do what is claimed for them. That means unavoidable delay before some ideas eventually get aired. Some that we find don't work - and that we cannot develop so that they do - may be quietly, but respectfully, buried.

Radio receiver signals

Pat McKeown was not sufficiently put out by us misspelling his name in the last Bulletin to prevent him submitting to us another *McKeown's Special*. And a cracker it is! Pat, from Our Lady's High School, Broxburn, together with Tom Hamilton, PT Physics at Craigshill High School[1], sent us this idea for simultaneously displaying the modulated signal, decoded signal and filtered audio output in a radio receiver.

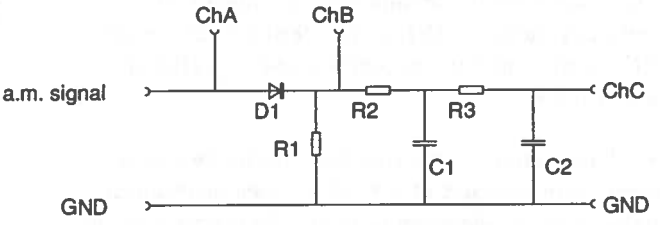
Curricular relevance includes the Telecoms Unit of Standard Grade Physics, the Radio Communications Option Topic in CSYS Physics, and the two Telecommunications Short Courses.

Using a BBC Microcomputer running *Uniscope* software, the three signals are taken to Channels A, B and C of the Unilab Interface.

An amplitude modulated signal should be produced using two signal generators [1]. For the high frequency carrier signal, use 200 Hz at 5.5 V peak to peak. For the low frequency signal, use 15 Hz at 250 mV peak to peak. An oscilloscope is required to set the amplitudes.

The decoder and pi section filter use commonplace components (Fig.1).

1 Craigshill High School in Livingstone closed in June 1992.



Component values:

diode	IN4148	(signal diode)
resistors	4K7 or 5K6	
capacitors	2.2 uF	(polyester)

Fig.1 Decoder and filter circuit

The settings on the three channels are shown on the printout (Fig.2) with a time-base setting of 20 ms per div. The *SINGLE SWEEP* mode is switched on and the trace is triggered on Channel A. The *JOIN DOT* facility has been used on Channels A and B.

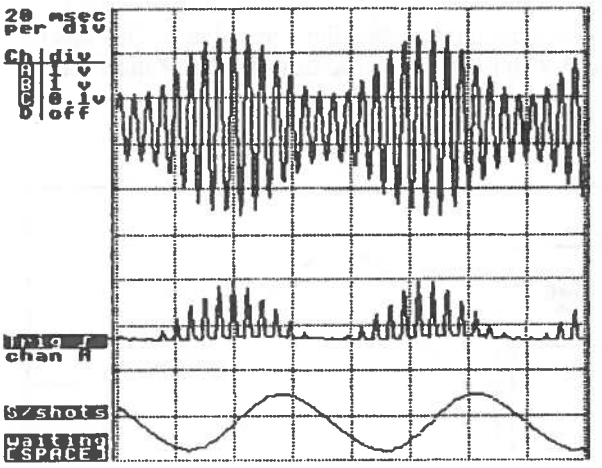


Fig.2 Printout of Uniscope screen

Reference

1. *Activity 19 - Modulation*, Technical Guide, Standard Grade Physics, Vol.1, SSERC, 1988, pp27-29.

Kynar film problems - Impulse experiment

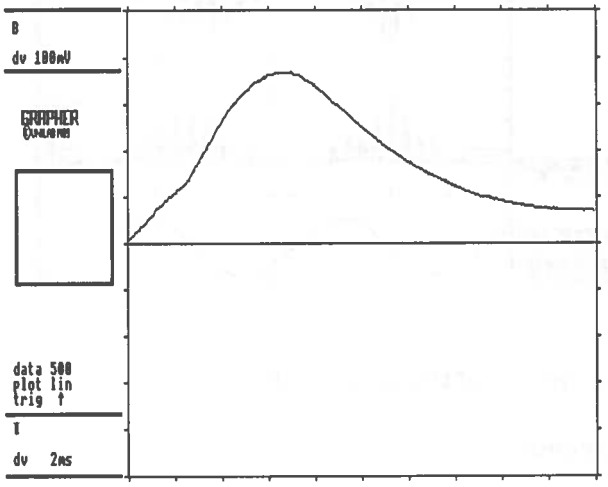
This note refers to the impulse experiment first described in Bulletin 155 [1] and referred to also in the SCCC Curriculum Support Series supporting Higher Grade Physics [2].

We have found that the film can deteriorate with age through the progressive effects of repeated mechanical damage. It should therefore be treated with great care. In particular, when being used to monitor an impulsive force, it must not be struck with anything other than a lightish blow.

It is therefore recommended that the film is always mounted on foam such as the Sensifoam material sold with it and that the maximum dropping height for a cricket ball is, say, 2 cm, or for a golf ball, say, 5 cm. These recommended heights are arbitrarily chosen. They are sufficiently large to give satisfactory force-time graphs without there being appreciable risk of damage.

If the film is in good condition, the force time plot should resemble that shown in figure 1. If however the film has been damaged, this often manifests itself in the signal being differentiated, giving a plot of dF/dt versus t (Fig.2). Presumably the physical damage introduces a resistive component to the film's impedance. This acts in concert with the film's capacitance to differentiate the signal.

Fig.1 Signal from film in good condition



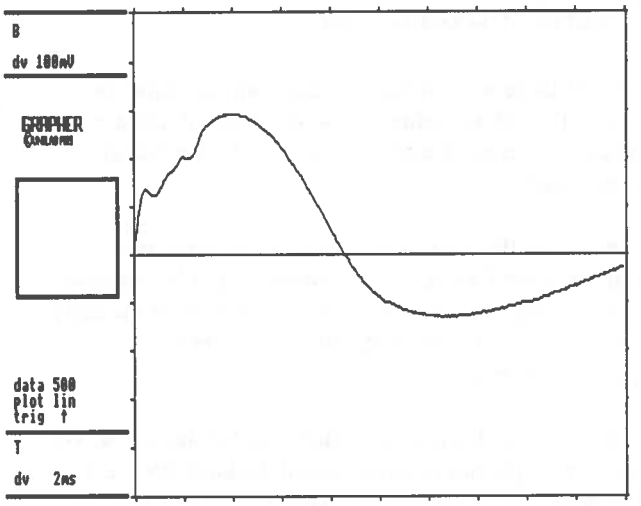


Fig.2 Signal from damaged film

If you find that your graphs resemble figure 2, then the film you have been working with has been irreparably damaged. Replacement film is available from the Centre.

As we pointed out in Bulletin 171 [3], our strain gauge method should prove more reliable as a means of obtaining force-time plots. It is in addition far more suited to quantitative analysis. However the method with Kynar piezoelectric film can be very effective and is a fascinating example of piezoelectricity.

References

1. *Force-time plots and measurement of impulse*, SSERC, Bulletin 155, January 1987, 24-31.

2. *Mechanics and properties of matter*, SCCC, Curriculum Support Series No.1, Higher Physics, 1990, 31.

3. *Capturing impulse with strain gauges*, SSERC, Bulletin 171, October 1991, 13-17.

Strain gauges in Technological Studies

A further application

Introduction.

As indicated above, Bulletin 171 carried a family of articles on strain gauges and their application. The last of those articles dealt with an application of relevance to Technological Studies at the Higher Grade [1]. We also discussed therein a possible extension of the use of a strain gauge bridge circuit to sense vibrations and, in turn, to use that data to control a motor. We have now built and trialled a simple circuit providing crude on - off motor control.

Hardware

Those with any knowledge of SSERC will realise we attempt to maximise our use both of time and materials. Whenever possible our teaching models are intended to be multi-purpose.

In this exercise we used the cantilever strain gauge model from our technological studies Case Study 2 with the dishwasher model from Case Study 3 [2]. Any small motor with an eccentric load (Fig 1) will however suffice. The *Penicuik Model*, mentioned briefly in Bulletin 171, with the addition of a second strain gauge, would work equally well. Further details of that model can be obtained from Jim Cassidy whose address is given on the inside rear cover of this present issue.

Fig.2 - Amplifier circuit

Fig.1

Circuit

Because this is introduced as an extension exercise, we would suggest that students are provided with approximate values for the various components. A circuit diagram with suggested resistor values etc. is shown here as figure 2.

At this stage of the course students should be aware of the effect of a resistor network on op-amp behaviour. The circuit for relay switching could be the same as that used in the temperature control circuit from Case Study 2 (*The fermenter*) thus reinforcing their grasp of ideas on the use of a transistor as a switch.

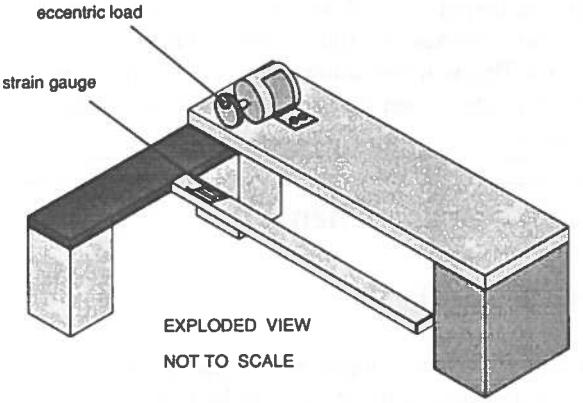
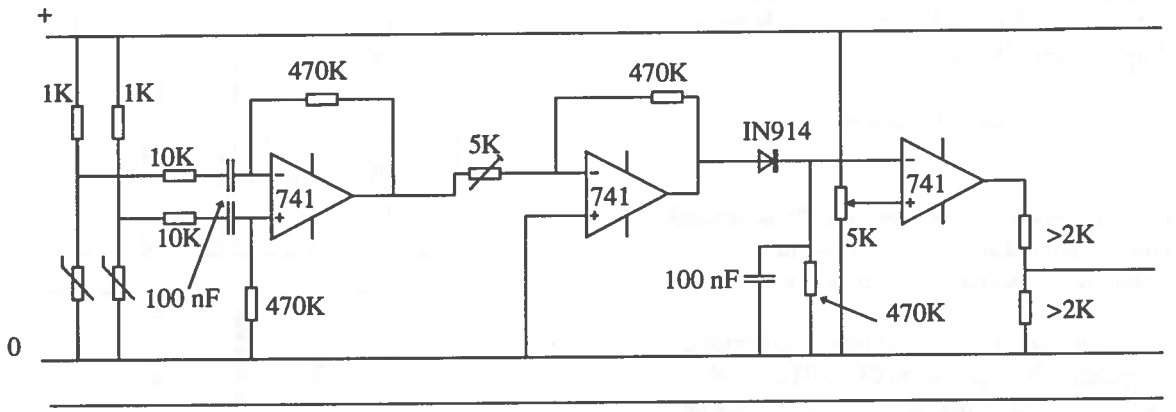


Fig.3 Out of balance load on cantilever arm

The idea is to mount an out-of-balance load on a stand. The motor end of the stand is balanced on the cantilever arm (see figure 3). Adjust the motor speed whilst the output from the comparator is monitored on an oscilloscope. As the voltage to the motor is altered so the speed will increase or decrease, causing greater or lesser vibrations from the load. If the circuit has been correctly assembled and working properly, the comparator should then switch from one supply rail to the other.



Op-amp 1 is configured as a high pass filter, a simple filter circuit which helps remove unwanted low frequency signals. This makes use of a property of the difference amplifier that only the potential difference between inputs is amplified, signals common to both being rejected. This common-mode rejection is especially useful when dealing with small signals, such as strain gauge outputs, which otherwise may be swamped by background noise.

The output from op-amp 1 is then further amplified and inverted by op-amp 2. We still of course have an a.c. signal at the output. Simple rectification is carried out with a diode and a reservoir capacitor network. Op-amp 3 acts as a comparator, the output switching a transistor in the relay circuit. Setting the 5K potentiometer provides a reference voltage.

Op-amp outputs and inputs can be monitored using an oscilloscope - perhaps we should write, must be so monitored. This will then allow that degree of *tweaking* inevitably needed to get a signal which will switch the comparator.

Conclusion

We would suggest that this additional exercise should enable students to monitor their own progress. It should provide the additional benefits of extending their skills in the choice of components, in the use of an oscilloscope and in their ability to make use of knowledge gained in prior work. This exercise has been trialled during our own in-service courses. Even with one or two hard-bitten teachers as *students*, assembly and use of this model proved a useful learning exercise.

References

1. *Strain gauges : Technology education applications,* Technical Articles, Bulletin 171, SSERC, October 1991.

2. *Higher Grade Technological Studies : Case Studies,* D.Burns, Series Editor SSERC, Published and distributed jointly by SCCC and SSERC, 1991.

Higher Grade Chemistry

Chemical egg-timers

The other, official syllabus entry, description for this activity is the study of the effect of polar bonds on physical properties!

The activity described here is an alternative to that described in the prescribed practical activities (PPAs) for Unit 5, Experiment 2, of the Higher Grade Chemistry syllabus. That uses as a method the measurement of the times taken to run the same volume of pentane and propan-2-ol out of two burettes.

In our alternative activity described here two long glass tubes are filled almost to the top with the liquids to be compared and then are sealed leaving a small bubble of air in each. All you then have to do is to invert both tubes together and compare the speed of the two air bubbles as they travel up the tubes (Fig.1).

This has a number of advantages over the burette method:

- the system is closed and there is a greatly decreased risk to health by skin absorption or by inhalation of solvents (unless of course the tubes are broken);

- the risk of flammable vapour/air mixtures forming is also greatly reduced. This is a good COSHH control measure and is particularly useful for the more volatile pentane;

- the consumption of solvent is greatly lessened with a simultaneous reduction in any amounts eventually to be disposed of;

- it overcomes the objection that the jets on the two burettes can be of a marginally different size or one of them can become slightly blocked by a small bit of debris or old hardened grease from the tap packing. Strictly the same burette should be used for both liquids and this entails emptying the burette of the first liquid and filling it with the second. And even then, the state of tap and jet could have altered between the two runs.

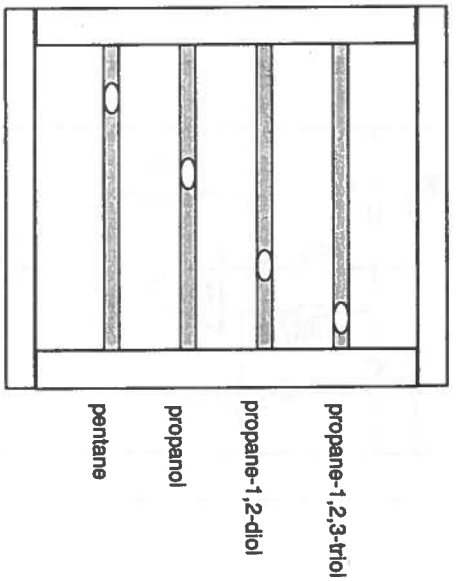


Fig.1

Can you increase the intermolecular forces even more by adding a second or even a third hydroxyl group to the three carbon spine? A good question to put to students. We thus added propane-1,2-diol and propane-1,2,3-triol to the list.

Practical use in teaching

The narrower the tube used, the greater will be the differences in air bubble speed in the four liquids. This is so to the extent that the more viscous triol, or with a narrow enough bore even the diol, will hardly move. On the other hand wider tubing produces a levelling effect in the speeds of the bubble in the two less viscous liquids. We found that a compromise based on a tube of internal diameter of 7 mm was about right. It showed up fairly sharply the difference in speed for all four bubbles. If you omit the triol then using a tube of less than 7 mm i.d. will give very striking differences between the remaining three liquids.

Another method of use is to lie the frame on its side so that the tubes are almost, but not quite, horizontal. Raise one end slightly so as to drive all the bubbles to one end and then raise the frame by about 20 degrees by the other end. Any differences in speeds are thereby accentuated.

It is wise to keep the device out of direct sunlight- this to avoid a large build-up in pressure. Pentane being the more volatile of the four liquids will escape slowly from the tube and it will need to be topped up from time to time. But, watch out for how slowly some of the bubbles may move if you use this gadget straight out of an unheated store during the winter!

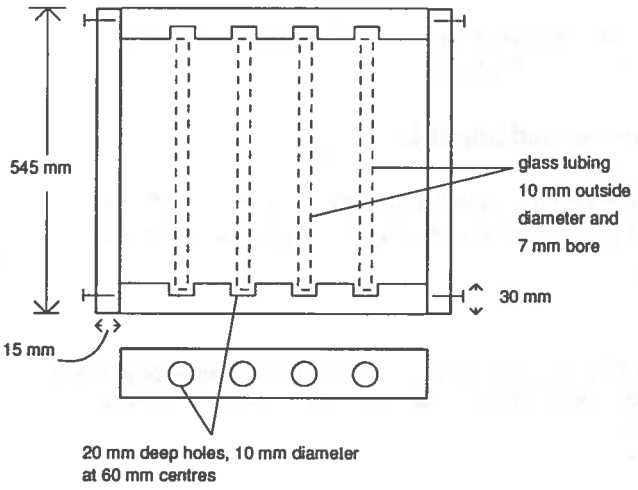


Fig.2 - Construction (not to scale)

Construction

Cut four half metre lengths of medium walled pyrex glass tubing of internal diameter 7 mm (1.5 mm wall) and fire polish the ends to remove any sharp edges. Fit a no. 7 silicone rubber bung into one end of each tube, fill to almost the top with the appropriate liquid and fit a second bung in the other end.

The support frame can be made of any scrap wood or chipboard. The dimensions used by ourselves are shown in figure 2. Most of these are not critical but the holes in the base and head of the cross pieces of the frame obviously must be just slightly larger than the diameter of the tube used at that position.

silicone bungs no. 7	SW820-26 pk of 10	£1.09 (Mackay & Lynn)
pyrex glass tubing)	TX-736-12 1.5m TWL-610-050G	£1.28 (Mackay & Lynn)
10mm (o.d.)	50x1.5m	£32.05 (Griffin)
7mm bore	C 86336/4 20x0.5m	£11.48 (Harris)

An alternative to the use of bungs at least for one end of each tube is to seal by fusion. Even some of the most experienced would probably draw back from sealing the top of a tube with pentane or propanol so close. In any case bungs have the advantage of doubling up as cushions for the ends. Other optional variations include adding a touch of colour with dye like eosin or going for the really spectacular with much longer tubes. These will be somewhat less convenient to turn over and to store.

HAZCONS (risk assessment results)

Hazards

Pentane is very volatile (with b.p. 36°C and vapour pressure 400 mm at 19°C) and extremely flammable (flash point -48°C). It is harmful by inhalation (narcotic in high concentrations) and by ingestion. It is irritating to the eyes and skin and degreases the latter.

Propanol is less volatile (b.p.97°C) and highly flammable (fl.pt. 15°C); splashes can cause severe damage to the eyes. it is very harmful if inhaled or ingested.

Propane-1,2-diol is much less volatile (b.p. 188°C) and less flammable (fl.pt. 99°C). It can irritate skin and eyes, but is of very low toxicity. (It is added to foodstuffs, including beer as an anti-freeze). Propane-1,2,3-triol with high b.p. and flash point poses no flammable or health hazard by inhalation at room temperatures. It is very mildly toxic by ingestion and can irritate skin and eyes.

Control measures

Fill the tubes in a well ventilated room in absence of sources of ignition (pentane and propanol). Wear eye protection and gloves (nitrile, pvc or latex). Once sealed in the tubes exposure is zero unless the tubes are accidentally broken. As noted above the pentane is very volatile and leaks out slowly; store as flammables away from sources of ignition. The hazards of the diol and triol are very low.

Buckyballs

Introduction

This material is based, with permission, on the work of R.H.Good, Professor of Physics at the California State University, Hayward. His original account was previously published in the *Physics Teacher* [1] wherein he declared:

"The two sexiest fields in science have intersected: buckyballs and superconductivity".

Whilst we're not sure that we agree that this is one of the "sexiest fields in science" it certainly is good fun.

We provide here a copy of a simple template designed by Professor Good. This may be reproduced, folded and taped together to produce three-dimensional models of C-60 or C-70. These *buckyballs* assist in visualising such spherical cages by making the hexagons solid whilst allowing the twelve pentagons to remain open[1].

Instructions for C-60 model

Make two copies of the template provided as figure 2. Use either heavy paper or light card stock (say 120 to 160 gsm). Copies need not be same-size but may be enlarged to make models into large mobiles. If you use any photocopier facility to reduce the size take care not to overdo it else cutting out and assembling the model may be impossibly fiddly.

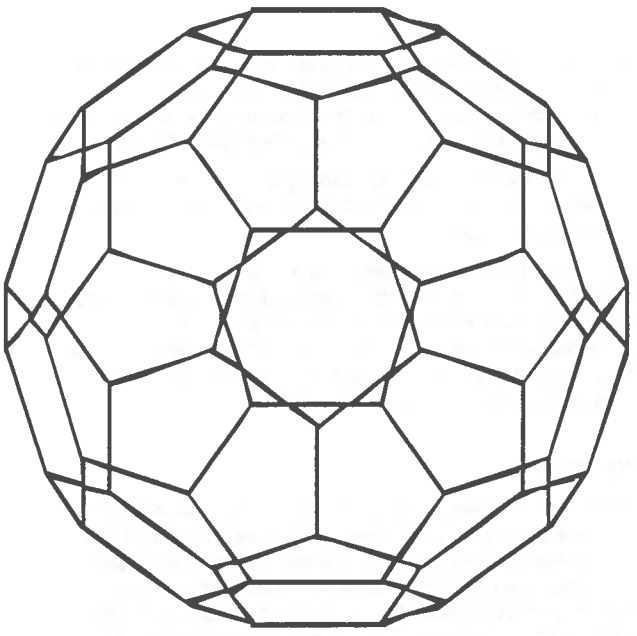


Fig.1 C-60 (buckminsterfullerene)

1. Cut out round the resulting secondary templates removing from each copy the three hexagons on each which are labelled *C-70*.

2. Use a ruler to crease the solid lines upward. Ignore the dashed lines. Then, fold each copy into a roughly hemispherical bowl shape.

3. Tape the edges together making sure as you go that each hexagon is surrounded by three other hexagons and six pentagons but that no three hexagons meet at a point.

4. The next step is to tape the two resulting bowls together. Be guided by the asterisks - the edges with asterisks being taped together. This part of the assembly is easier as a two person operation, with one holding, the other taping.

We found in our own trials that the whole of the above took an inexperienced assembler about twenty minutes.

C-70 model

Proceed along the same lines as for C-60 but cut off one hexagon from one of the two copies. That is, cut off one of the two hexagons which are labelled *Remove one of these*.

Again use a ruler but this time to crease the dashed lines downward. This is because calculations suggest that the C-70 molecule is slightly concave at these points.

Now fold and tape the two copies into bowl shapes taping these two half models together again being guided by the asterisks. At some point three hexagons meet; this is possible because of the creasing of the dashed lines.

Reference

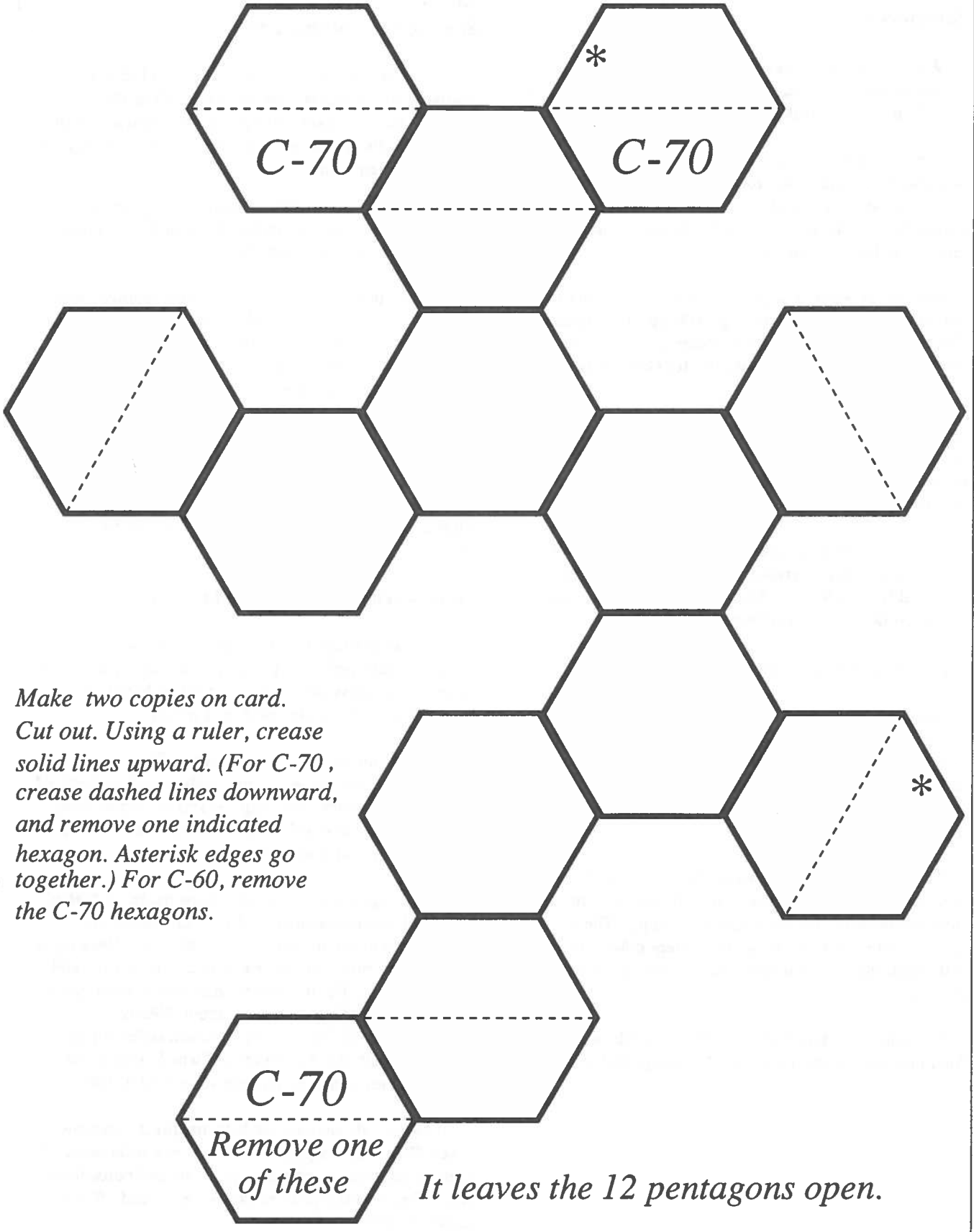
1. *Buckyballs, Anyone?*, R.H.Good, The Physics Teacher, Vol.30, January 1992.

Acknowledgements

We are most grateful to Professor R.H.Good for so readily agreeing to our using his original article in this way.

1 This according to Euler - that any such spherical cage needs exactly twelve pentagons but can have almost any number of hexagons.

Buckyball Template for C-60 or C-70



Make two copies on card. Cut out. Using a ruler, crease solid lines upward. (For C-70 , crease dashed lines downward, and remove one indicated hexagon. Asterisk edges go together.) For C-60, remove the C-70 hexagons.

It leaves the 12 pentagons open.

Trade News

Environmental Studies
Sunclocks

We have recently received details of commercially available plans for a playground project which allows the use of pupils' own shadows to accurately tell the time.

A Sunclock requires a level area of about 8 m (26 feet) in diameter. Using waterproof paint and a set of project plans you can set out a sunclock which will indicate the correct time by the use of a pupil's shadow as they stand on the sunclock's central scale.

Each set of plans, it is claimed, is printed for an exact longitude and latitude according to the specified location. The clock is also claimed to be accurate to within fifteen minutes and to adjust automatically for GMT or BST.

Possible activities based on the sunclock include: aspects of measurement and the use of grid co-ordinates in setting out the clock; demonstration of the shifting of the sun's altitude with time of year and the determination of true north without using a compass.

Sets of project plans cost £20 for a thermally bound version and £15 for a stapled finish. Further information is available from Modern Sunlocks at the address given on the inside rear cover of this issue.

Electronic rainfall gauge

Materials Advisory & Technical Services Ltd. have sent us details of a rain gauge they call *Digirain*. This is an electronic device which measures rainfall in either millimetre or inch units (switchable). It is said to be accurate to within 5% (but is readable to 0.01 mm or 4×10^{-4} " units).

The instrument has its own memory and stores rainfall data which may be read at any time. It measures through flow and therefore has no reservoir to empty. The gauge itself is mounted outdoors but the battery powered (1 AA cell) electronic digital display may be remotely sited indoors.

Digirain costs £45 including 10 m of cable, a spare filter mounting bracket and spigot, carriage and VAT.

Repairs
Skeletons in cupboards?

ESP (Educational and Scientific Products) Ltd is a company which was started up by ex-staff of Griffin (at one time a.k.a. Gerrard) Biological. This newish small firm is a useful source of supply for a range of biological sundries and equipment.

ESP is now also offering a repairs and spares service for those models and skeletons languishing in cupboards with missing parts or broken bones.

ESP will provide a quote which if not approved will result in the return of the model or skeleton to you at no charge. Typical prices range from and include: reartic-ulation of an elbow joint at £5.00, a knee joint £7.50 and a whole skull £50 (plus VAT).

ESP's target turn-round times for these orthopaedic repairs is 7 - 14 days (eat your heart out Virginia Bottomley!). You won't need your Ouija board to communicate with them either - ESP's address and telephone number are given in the address list for this issue.

Glassware fabrication and repair

A couple of firms new to us are offering to design, make or repair items of laboratory glassware. The first of these, Scotia Glass Technology is Stirling based; the other, Multi-Lab Ltd., is based on Tyneside.

Of particular interest amongst Scotia Glass Technology's services are competively priced customised items. These include such items as 100 ml conductivity flasks (conical flasks with two basal side-ports to take carbon electrodes) at £6 each.

Scotia's repair charges are also reasonable. A 500 ml filter flask can be repaired for £4.10 and measuring cylinders up to and including 1 l for £2 to £3. The snag is an overall minimum order charge of £25 plus VAT and post & packing. The basis of Scotia's fees is assumption of a total price which represents about 40% of replacement costs. That is, if you send a collection of items for repair, the replacement of which would cost £100 then they would be repaired for a total of £40.

Of Multi-Lab services we have no direct experience as yet. They claim capability to work on a wide range of items in ceramics as well as both quartz and borosilicate glass. They will fabricate as well as repair and offer to quote for specific items.

SSERC, 24 Bernard Terrace, Edinburgh EH8 9NX; Tel. 031 668 4421. (Please Note: our Fax number - 031 667 9344)

A.S.E. Scottish Region, Chairman Annual Meeting Committee, Blairbeth Cottage, 17 Whitletts Road, Ayr KA8 0JA

The Association for Science Education, College Lane, Hatfield, Herts. AL10 9AA Tel. 0707 266532

J.Cassidy, P.T. Technology Education, Penicuick High School, 39a Carlops Road, Penicuick, Midlothian EH26 9EP

Educational & Scientific Products (ESP) Ltd., A2 Dominion Way, Rustington, West Sussex BN16 3HQ Tel. 0903 773340 (Fax. 0903 771108).

Griffin and George Limited, Bishop Meadow Road, Loughborough, Leicestershire LE11 0RG; Tel. 041 248 5680, or 0509 233344.

Philip Harris Education:

2 North Avenue, Clydebank Business Park, Clydebank, Glasgow G81 2DR; Tel. 041 952 9538;

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

Health and Safety Executive, Public Enquiry Service, Information Centre, Broad Lane, Sheffield S3 7HQ Tel. 0742 892345 (Fax. 0742 892333)

HSE Freeleaflet Line Tel. 0742 892346

Materials Advisory & Technical Services Ltd., 18 Bath Road, Swindon SN1 4BA Tel. 0527 893389 (Fax. 0527 892442

Modern Sunclocks, 1 Love Street, Kilwinning, Ayshire KA13 7LQ Tel. 0294 52250 (Fax: as telephone)

Multi-lab Ltd., Tynevale Works, High Street, Newburn, Newcastle-upon-Tyne NE15 8LN Tel. 091 264 6801 (Fax. 091 229 0028)

NRPB, 155 Hardgate Road, Glasgow G51 4LS Tel. 041 440 2201

Scotia Glass Technology, Kaimes Farm, Craigforth, Dumbarton Road, Stirling FK8 3AB Tel. (and Fax.) 0786 73305

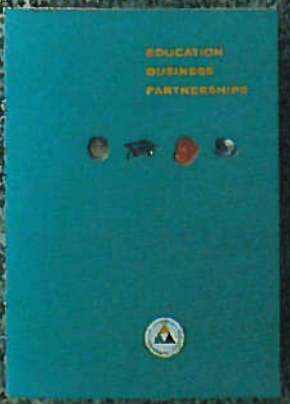
Scottish Enterprise, 120 Bothwell Street, Glasgow G2 7JP (Education Business Partnership - Willie Robertson), Tel. 041 248 2700

SCCC, Gardyne Road, Broughty Ferry, Dundee DD5 1NY; Tel. 0382 455053.

Technology Teachers' Association (TTA), Secretary, Mr.T.K. McIntyre, Glendaruel, Knocksalbert Way, Campbeltown PA28 6TD Tel. 0586 53252

Unilab Limited, The Science Park, Hutton Street, Blackburn, Lancashire BB1 3BT; Tel. 0254 681222.

HOW TO INTRODUCE YOUR STUDENTS TO THE UNIVERSITY OF LIFE.



Many businesses take a fairly uncompromising view of academia. It's all very well in its place – but it's no substitute for the University of Life.

The Education Business Partnership has been created to form closer bonds between schools, colleges and universities with business and industry. Students and businesses will both benefit.

The more students know about the realities of work – the more likely they are to find work and the more likely they are to get more out of their studies. Through work placement, mock interview experience, talks from visiting speakers and practical help with C.V. writing, students get all sorts of practical benefits.

To find out more about the Education Business Partnership call Willie Robertson on 041-248 2700 or write to him at the address below.

SCOTTISH ENTERPRISE, 120 BOTHWELL STREET, GLASGOW. G2 7JP.

Scottish Enterprise