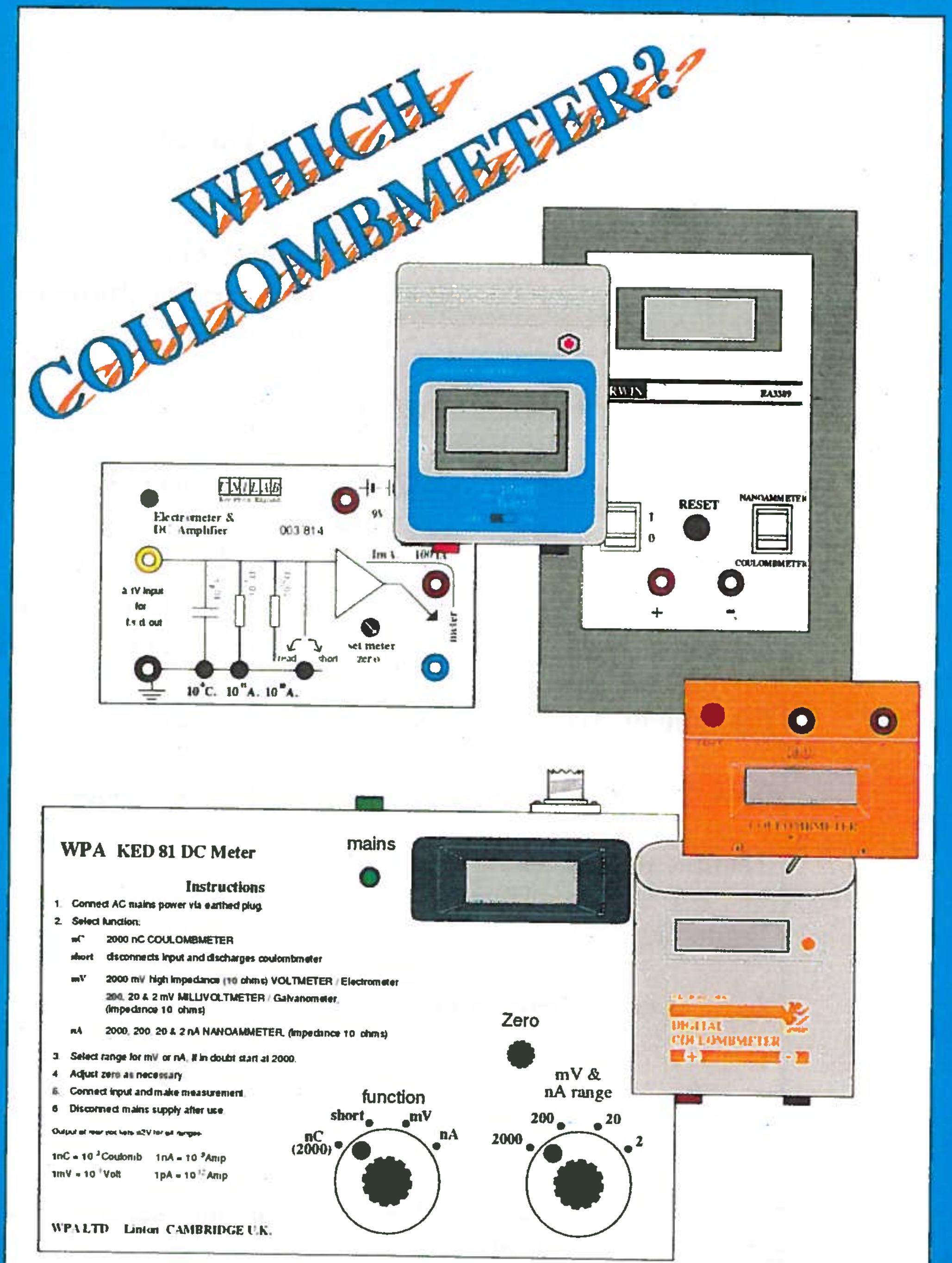
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE

Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences



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FOREWORD

Sponsorship

This bulletin issue, the second in the new cover style, has been sponsored by Scottish Enterprise. We are most grateful to staff in the Education Unit of Scottish Enterprise for their interest in and support for the work of the Centre.

This sponsorship meets the criteria laid down in Bulletin 172 which was sponsored by the Institution of Electrical Engineeers (IEE). Readers and clients should note that we only accept such support from *third party* firms or organisations which have no commercial or other direct interest in the educational equipment market.

Scottish Enterprise

Purpose

Scottish Enterprise is in business to develop the economy, enhance the skills and improve the environment of Scotland.

Through partnerships with both the public and private sectors it aims to build a stronger, more diversified economy that is internationally competitive with higher levels of skills, income and quality of life. Together with Highlands and Islands Enterprise they represent an alliance for development, with the economic interests of Scotland uniquely at heart and the authority and finance to carry through projects to meet these aims.

Objectives

Scottish Enterprise's strategic objectives include the provision of a clear vision and direction for the design and delivery of enterprise development, training and environmental action programmes. It will work to:

- help provide Scotland with the vigour and self-confidence necessary to meet the challenges of the 21st Century;

- create the conditions for success, identifying areas both of opportunity and of need, encouraging and enabling partnerships to develop and exploit them appropriately;

- through *Locate in Scotland* help to further diversify and develop the economy by attracting and assisting inward investors.

Scottish Enterprise aims to carry out its activities and meet these objectives with the minimum of bureaucracy yet maintain those controls needed to ensure public accountability.

Priorities

Scottish Enterprise has established seven statements as to those national strategic priorities which will guide its actions.

1. Training at all levels is essential to the country's economic success.
2. Industry and commerce must have access to the latest technology.
3. Scotland must be able to thrive in increasingly competitive markets.
4. Business must be able to flourish in increasingly open global markets.
5. Business needs good access to resources, whether physical, intellectual or financial.
6. Scotland must develop more high quality, high value-added products and services.
7. The physical environment must be both protected and improved.

In summary

Whilst these aims are indeed ambitious, the purpose of Scottish Enterprise can be summed up in but few words: to build a better Scotland.

If you wish to know more about Scottish Enterprise training activities and business education partnerships 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 back cover of this bulletin issue.

INTRODUCTION

Standard Grade Physics Technical Guides : Volume 2

As this Bulletin goes to press SCCC will be distributing the above SSERC publication to Scottish schools. Principal teachers of physics should ask the school office to ensure that Volume 2 does go to them. With communications an apparently weak feature of some schools' management arrangements we found that the previous volume was often mis-directed. We might have known where it would end up when we had been so foolish as to include "Technical" in the title!

We are sorry that this volume, which covers Units 3 and 4 of the Standard Grade course, should have taken so long to appear in its final, posh, bound form. The provisional versions for Unit 3 *Health Physics* and Unit 4 *Electronics* were issued as long ago as 1988. Staff shortages and new demands on our time from health and safety work, apparatus evaluation and other syllabus revisions then interfered with SSERC's publication schedules.

On the positive side, the delay has allowed a more considered approach to practical activities and the chance to distance ourselves somewhat from the early, *starter* materials. We could also take account of the recent revision of the syllabus, the reduction from eight to seven Units with re-distribution of some of the Unit 7 work to other parts of the course.

Acknowledgement - Jimmy Bell

We are sorrier and even more embarrassed over an error of omission in the acknowledgements section of the Introduction to Volume 2. In our anxiety to include all those who had assisted in its production we actually forgot to include the major contributor to half of the volume.

In 1988 when the Centre was drawing up apparatus lists and practical guides as well as searching for new premises it became clear that we could not, unaided, deliver all that was being expected of us. We were therefore mightiliy relieved when Jimmy Bell of Jordanhill College of Education took over the task of writing the provisional technical guide to Unit 4.

Unprompted therefore, we record formally here our major debt to Jimmy.

Saturday opening

Regrettably we have decided to give up Saturday morning opening. This marks a break with a tradition of almost 25 years in providing a specific service for the convenience of teachers and technicians outwith the Eastern Central Belt. Latterly there just doesn't seem to have been the level of demand for Saturday morning visits to justify our remaining open.

We haven't taken this decision lightly, not least since it sometimes provided the only relatively quiet time in a busy week when whoever was on duty could either get some work done or, alternatively and justifiably, escape the in-town, in-laws on their weekend visits.

Staff development : SSERC courses

Menus of courses for teachers and technicians in science and technology departments were recently circulated to our nominated contacts in the Scottish advisorate and to senior staff in technical resource support services. We are willing to offer any of these courses in the session 1992-93 and already are negotiating with several EAs on INSET provision for next session.

As noted in Bulletin 172 however, some Scottish EAs have begun to devolve staff development budgets to *neighbourhood* or *cluster* groups and in some cases even to individual schools. We would be pleased to supply copies of our course programmes to any such grouping or school.

Our courses have been classified into three broad categories which are:

Series A : Technical Support for curricular revisions, new practical work etc.

Series B : Health and Safety (includes technical courses on inspection, testing and monitoring techniques).

Series C : Information Technology Applications : interfacing; datalogging; control techniques; graphics handling; DTP for scientific and technical purposes; databases in departmental management etc.

Wherever possible our courses are practically based and require the active participation of course members. We are willing to tailor training courses to meet specific needs. Fees are charged on a participant per day basis.

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

Obituary - Mrs Diane Rogers

It is with much sadness that we report the death of Mrs Diane Rogers of Philip Harris Education.

Diane joined Philip Harris in 1974 as a sales representative. Her enthusiasm and her knowledge of the practicalities of teaching science led to her eventual appointment as Marketing Manager. It was in that role that we began to work closely with her. We then quickly learned to count on her as a reliable and efficient contact point within Philip Harris.

"Di" was known and respected by teachers, advisers and suppliers throughout the United Kingdom and was a popular ambassador for her Company. She will be sadly missed by all of her colleagues and by those many others such as ourselves to whom she provided so much help over the years.

Safety Notes

1992 and all that

Despite any contrary impressions at Maastricht, members of the European Community are committed to a common *Social Dimension*, the implementation of which is to run in parallel with that for the Single Internal Market. This social element is, amongst other things, leading towards harmonisation of elements of legislation on health and safety in the workplace.

Change will occur in two broad ways.

Firstly: legislation governing health and safety at work will move away from nationally drafted acts and regulations (e.g. in Britain the Health and Safety at Work etc. Act 1974 [HSAWA]) and toward agreed principles adopted on a Community-wide basis (e.g. *Framework Directives* - see below - and *Daughter Directives*).

Secondly: national product standards, such as British Standards, will be superseded by common European standards based on European Normes (ENs). Such international harmonisation of standards has been underway for some time and this often goes beyond the bounds of Europe (hence the quoting on some recent BSI documents of equivalent ISO or IEC Standard numbers).

EC Framework Directive

The Health and Safety Commission (HSC) has recently published proposals for implementing the 1989 European Community (EC) Framework Directive [1]. This Directive requires member states to introduce measures which will further improve health and safety standards. It refers specifically to assessments and remedial action to be taken by employers, as well as to requirements for training, medical surveillance and consultation with employees and their representatives.

Many of the principles stated in the Directive are already implicit in U.K. legislation in the shape of the HSAWA and more recently in the COSHH Regulations. New legislation may nevertheless be required in the U.K. wherever European leglislation is either more detailed than current British regulations or where it goes beyond our present law.

Watch this space!

Reference

1. "Proposals for health and safety (general provisions) regulations and approved code of practice". Health and Safety Commission 1991 (note that the consultation period ended on 21st of February 1992).

Electrical safety

Bayonet cap (BC) lampholders

Although there is a significant risk of electric shock from touching the live pin of a BC lampholder, we cannot recollect ever getting an accident report from a school on an injury resulting from this cause. Perhaps because the risk is ubiquitous and so well known, the incidence of harm is very low.

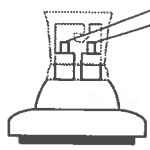


Fig.1 - Conventional bayonet cap (BC) lampholder

Clearly however there is an appreciable risk. Bench lamps comprising of batten lampholders are widely used in laboratories.

A new design of lampholder that removes this risk is therefore especially welcome. The new products, manufactured by Crabtree, come basically in two forms, a *Safety Pendant Lampholder* and *Safety Batten Lampholder*. The lampholder incorporates an automatic switch that closes when a lamp is inserted and opens when a lamp is removed. You can therefore safely touch and even press down on the exposed terminals. Only when the rim of a lamp presses down on a pair of lugs do the contacts become live. The design would therefore seem to ensure that accidental touching is safe and harmless. Only deliberate, maniacal pressing of the lugs and terminals, not easy to do simultaneously, can result in electric shock. But as they say, you can't design against idiots!

Safety lampholders are available from Crabtree distributors, such as Senate Electrical in Aberdeen and Glasgow, Ross Electrical in Dundee and Bemco Wilson in Edinburgh. Stock numbers and prices are shown below.

Safety Pendant Lampholder 5850 £1.33

Safety Batten Lampholder 5851 £3.68

Demountable transformer

Connection to the primary winding of some models of demountable transformer such as from Irwin, catalogue number EA0200, and imports from Russia, is by means of a detachable mains cord with 4 mm plugs (Fig.2 overleaf).

This is obviously unsafe and, by present standards of electrical construction, impermissibly dangerous.

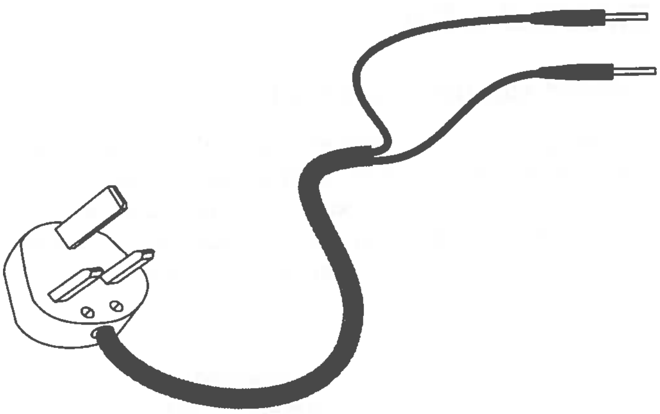


Fig.2 - Dangerous primary connection

We therefore strongly advise that, if you have such an electrical system, it is not used in this state. Either it should be modified to a reasonably acceptable standard, or it should be disposed of.

From discussions with Irwin, we understand that they are working on a means of modifying their demountable transformer. As it may take some time for these changes to be devised, and for the Centre, we trust, to give them our approval, the Irwin transformer kit may have to be out of action for some time. We understand that Irwin intend to offer an upgrading service, for which there would be a modest charge. The Centre should be able to advise schools on when to contact Irwin for this service.

As for any Russian imports, SSERC helped several schools some years ago renovate their transformers to a reasonable standard. Other schools wanting our advice on this should contact the Centre.

Radiant heaters

Because of the impossibility of adequately insulating the heater element, this apparatus (Fig.3), if operating off 240 V, is also impermissibly dangerous. We again strongly advise that it is not used and is disposed of, preferably immediately.

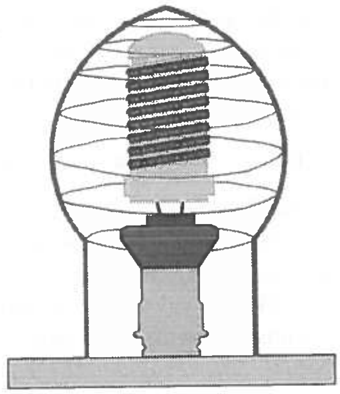


Fig.3 - Mains operated radiant heater

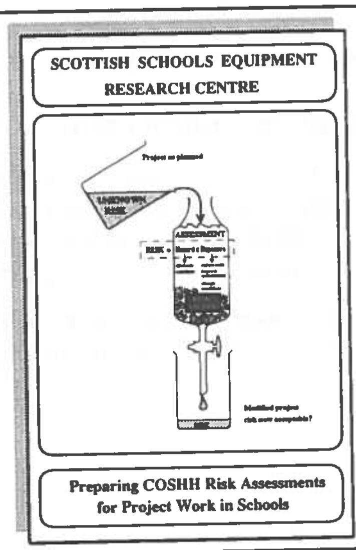
We understand that members of the British Educational Equipment Association, following pressure from the Health and Safety Executive, have now agreed to withdraw 240 V versions of this apparatus from sale.

A suitable low voltage substitute is available from Harris, catalogue number P28541/4, at £30.97. This draws 8 A at 12 V.

Why?

It used to be thought that the hazard was obvious and that in itself the hot element would prevent contact, but it is now recognised that the main risk of electric shock comes from prodding the 240 V element with a metal implement. In the event of an electrical fault caused by the element going open circuit, there is a reasonable likelihood that a pupil might poke at the cold element - not realising that it is at hazardous live.

COSHH - SSERC Publication



*** For Scottish EA establishments and Scottish independent schools currently in membership the booklet will be £4 per single copy.**

*** Discounts are available on bulk orders and SSERC/EA correspondents will receive details of these.**

*** The price to all other customers will be £7.50 per copy (including postage).**

Feature article

Preventing electric shock

By considering the effects of electric current passing through the human body, standards on safe working practices have been devised. These include levels for voltage, current and capacitance defining a regime known as hazardous live. They also include specifications for protective devices such as fuses and other forms of circuit breakers.

Introduction

Everyone knows that electricity can be dangerous, but knowing whether it's volts or amps that kill is another matter. It is generally accepted that working with live conductors powered by any reputable laboratory supply at extra low voltage, say up to 20 V, is completely safe, but touching a live mains conductor at 240 V is risky - and sometimes fatal. But why then is the Van de Graaff generator, at hundreds of times mains voltage, not also dangerous?

Electrical safety is a subject largely taken for granted. It is implicit in the safe conduct of our everyday lives. Bits of it need to be made explicit in parts of classroom teaching. Yet authoritative guidance is hidden in publications that, to most of us, are hard to come by.

The cut-off between a safe working regime and the regimes known as *hazardous live* was described in the last Bulletin issue [1]. Here in this article we describe the experimental evidence underpinning these limits. And it should provide answers to the stock question you get from children - when is electricity dangerous?

The first part of our article considers the effects of electric current passing through the human body. It is based on Published Documents [2] [3] from the British Standards Institution, which themselves are identical to recent IEC publications [4] [5]. The second part goes on to show how these provide the basic guidance on which electrical safety requirements are founded.

The evidence presented refers to all persons under normal physiological conditions, including children irrespective of age. There is no evidence that safety standards for children need to be more strict than hold for the rest of the population.

Effects of current passing through the human body

Impedance of the human body

When electric current passes through the human body the relationship between current and voltage is non linear because the impedance of the human body depends on voltage and other factors. These are the current path through the body, the duration of current flow, the frequency, the moisture of the skin, the surface area of contact, the pressure exerted on the skin and on the ambient temperature.

Simplifying the description, the total body impedance Z_T consists of two parts, the internal impedance Z_i and impedance of the skin Z_p where

$$Z_T = Z_i + Z_p$$

Electrically speaking, the interior of the human body consists of conducting fluid. The internal impedance is therefore largely resistive. It depends mainly on the current path and, to a smaller extent, on the area of contact. For instance, the internal impedance is increased if the area of contact is only a few square millimetres.

The skin, by contrast, comprises a semi-insulating layer with small conducting paths, the pores. The impedance of the skin therefore has both capacitive and resistive components. The value of the impedance of the skin depends on all of the factors mentioned above.

The skin's impedance is significant at voltages up to 50 V. It varies widely from person to person, and even for one person, depending on other conditions. Between 50 V and 100 V it diminishes and then becomes negligible as the skin resistance breaks down.

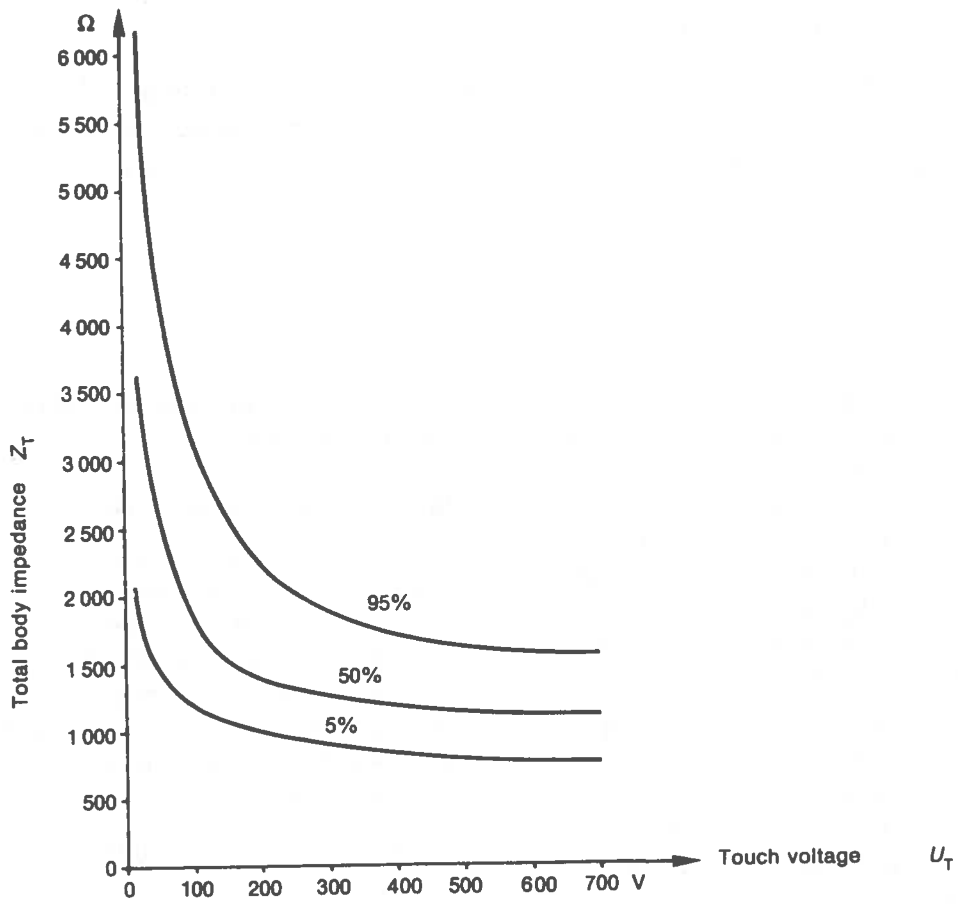


Fig.1 - Total body impedance as a function of voltage

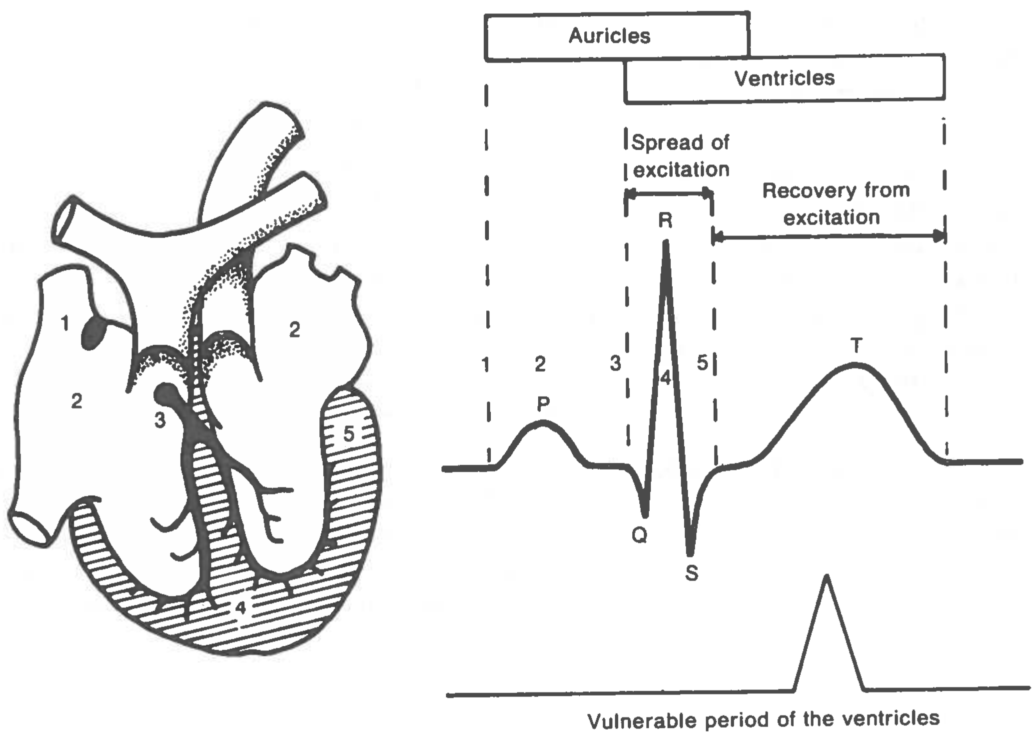


Fig.2 - Occurrence of the vulnerable period of ventricles during the cardiac cycle

Statistical values of the total body impedances valid for live human beings for the current path *hand to hand*, or *hand to foot*, are shown (Fig.1) for touch voltages up to 700 V.

In Figure 1 the 5% line shows the values of impedance not exceeded by 5% of the population. Percentile ranks not exceeded by 50% and 95% of the population are also given.

The values shown hold for dry conditions. At less than 50 V, the dry condition impedance can lessen by between 10% and 25% if the skin is wetted with water and by 50% if wetted with a conductive solution.

Above 150 V, total body impedance is only slightly influenced by humidity and the surface area of contact.

Effects of alternating current at 50 Hz

The minimum value of current which causes any sensation is known as the *threshold of perception*. This is generally about 0.5 mA, irrespective of duration.

The maximum value of current at which a person holding electrodes can let go is called the *threshold of let-go*. The value of this is about 10 mA, but it depends on several factors.

The main cause of death by electric shock at 50 Hz is an effect called *ventricular fibrillation* wherein the nerves that operate the heart muscles go into excitation. The vulnerable period for the heart to go into ventricular fibrillation is the first part of the *T-wave* in the electrocardiogram. This makes up between 10% and 20% of the cardiac cycle period (Fig.2). The numbers in the figure designate the subsequent stages of propagation of the excitation.

Blood pressure very quickly drops (Fig.3) if the heart goes into ventricular fibrillation.

The threshold of ventricular fibrillation depends on physiological and electrical factors, in particular on the pathway and duration of current flow. If current flow is prolonged beyond one cardiac cycle, the threshold falls.

If the shock duration is less than 100 ms, fibrillation is likely only if the shock falls within the vulnerable period.

Four zones have been designated in respect of the physiological effects of current passing through the human body (Fig.4, overleaf). These relate to the current path *left hand to feet*. Other current paths should be moderated by the *heart-current factor* (Table 1 below). By way of example, a current of 200 mA hand to hand has the same effect as a current of 80 mA left hand to feet.

Current path	Heart-current factor
Left hand to left foot, right foot or feet	1.0
Both hands to feet	1.0
Left hand to right hand	0.4
Right hand to left foot, right foot or feet	0.8
Back to right hand	0.3
Back to left hand	0.7
Chest to right hand	1.3
Chest to left hand	1.5
Seat to left hand, right hand or to both hands	0.7

Table 1 Heart-current factor for different paths

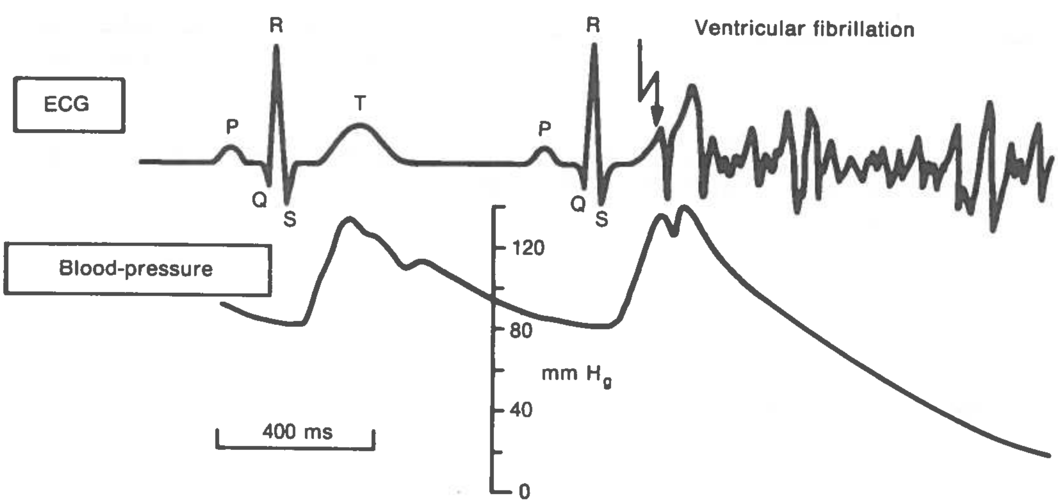
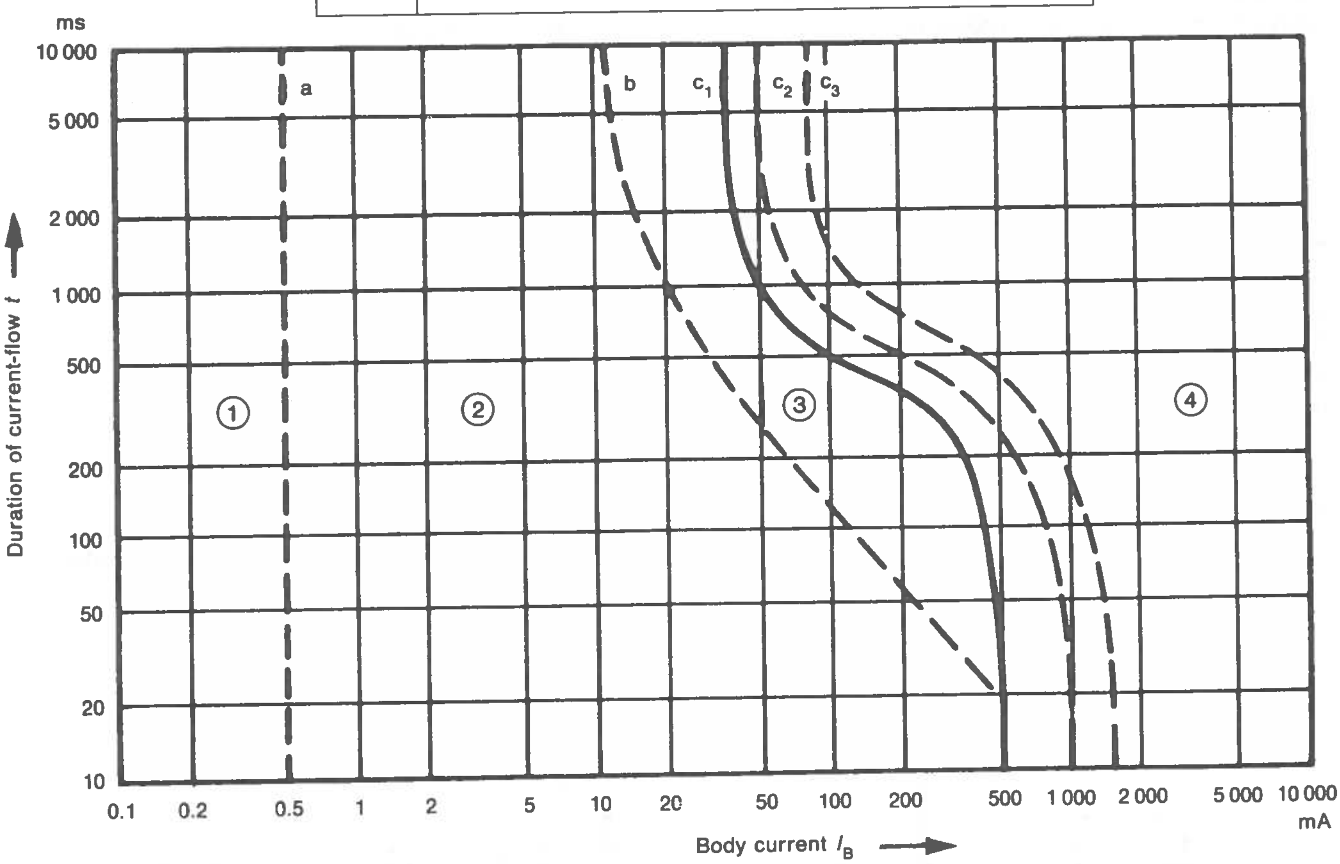


Fig.3 - Triggering of ventricular fibrillation in the vulnerable period

Zones	Physiological effects
Zone 1	Usually no reaction effects.
Zone 2	Usually no harmful physiological effects.
Zone 3	Usually no organic damage to be expected. Likelihood of muscular contractions and difficulty in breathing, reversible disturbances of formation and conduction of impulses in the heart, including atrial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with current magnitude and time.
Zone 4	In addition to the effects of Zone 3, probability of ventricular fibrillation increasing up to about 5% (curve c_2), up to about 50% (curve c_3) and above 50% beyond curve c_3. Increasing with magnitude and time, pathophysiological effects such as cardiac arrest, breathing arrest and heavy burns may occur.



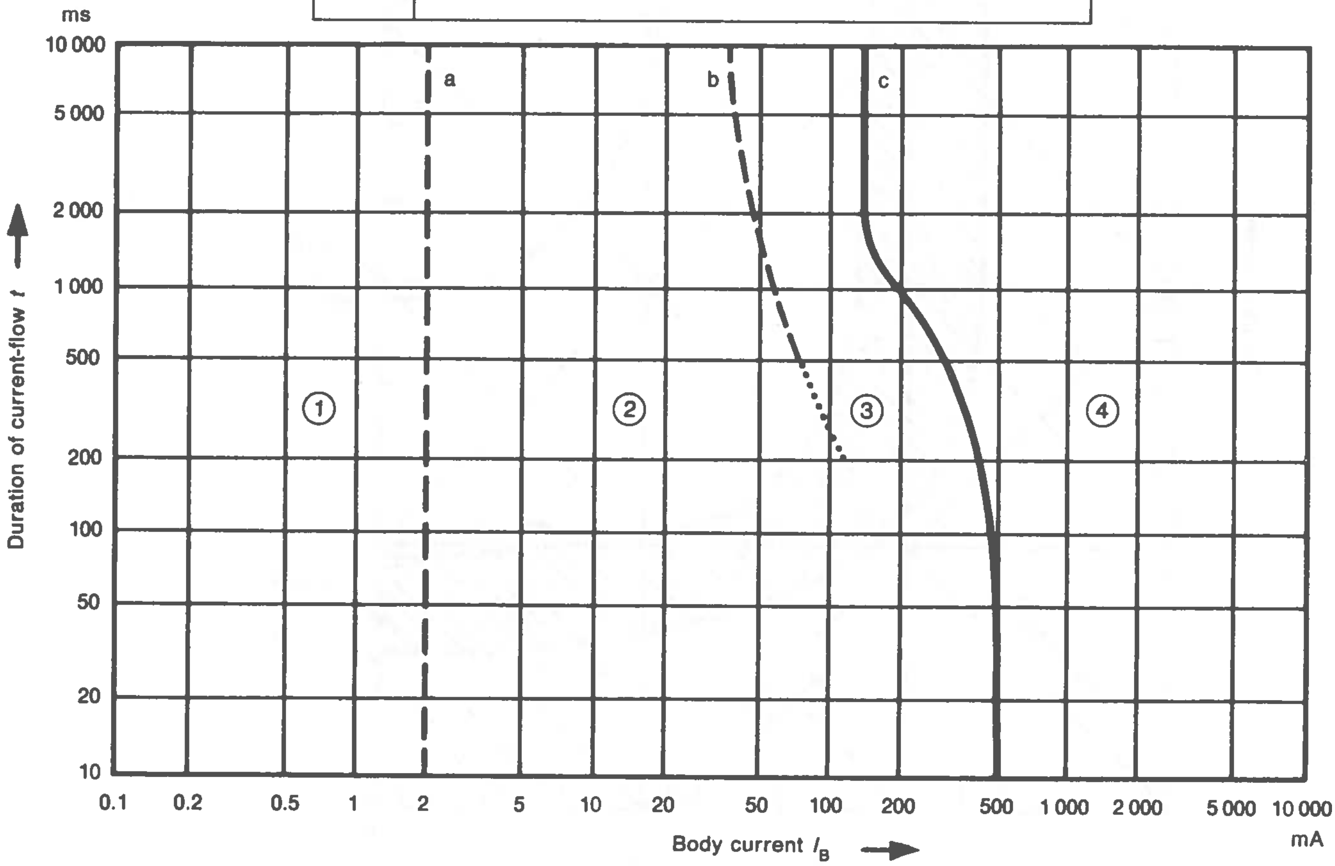
Notes 1. — As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path "left hand to feet". For other current paths, see Clause 5 and Table III.

2. — The point 500 mA/100 ms corresponds to a fibrillation probability in the order of 0.14%.

Fig.4 - Time/current zones of effects on persons of a.c. currents (15 Hz to 100 Hz)

Effects of direct current

Zones	Physiological effects
Zone 1	Usually no reaction effects.
Zone 2	Usually no harmful physiological effects.
Zone 3	Usually no organic damage is to be expected. Increasing with current magnitude and time, reversible disturbances of formation and conduction of impulses in the heart are likely.
Zone 4	Ventricular fibrillation likely. Increasing with current magnitude and time other pathophysiological effects, for example heavy burns, are to be expected in addition to the effects of Zone 3.



Notes 1. — As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet and for rising current.

2. — Boundary between Zones 2 and 3 unknown for times less than 500 ms.

Fig.5 - Time/current zones for d.c.

Accidents with direct current are rarely severe and seldom fatal. This is mainly because of two reasons.

It is much easier to let go parts gripped at d.c. than it is for a.c. The threshold of let-go is difficult to quantify, but may be around 300 mA, thirty times higher than that for a.c.

The threshold of fibrillation for direct current shock is similar to the a.c. value if the shock duration is under 200 ms. However for periods longer than one cardiac cycle, the threshold is nearly four times higher than comparable a.c. values. This is shown in the time/current graph for direct current (Fig.5) marking the boundary of *Zone 4*.

The threshold of perception is 2 mA. Unlike a.c., no sensation is felt during the flow of direct current. Only the making and breaking of current flow is noticed.

The direct current values described here are for steady, continuous currents, such as might be delivered by a battery. The risk from d.c. with an unsmoothed, full-wave rectified waveform is similar to the risk from a.c. with the same peak value.

Effects of unidirectional single impulse currents of short duration

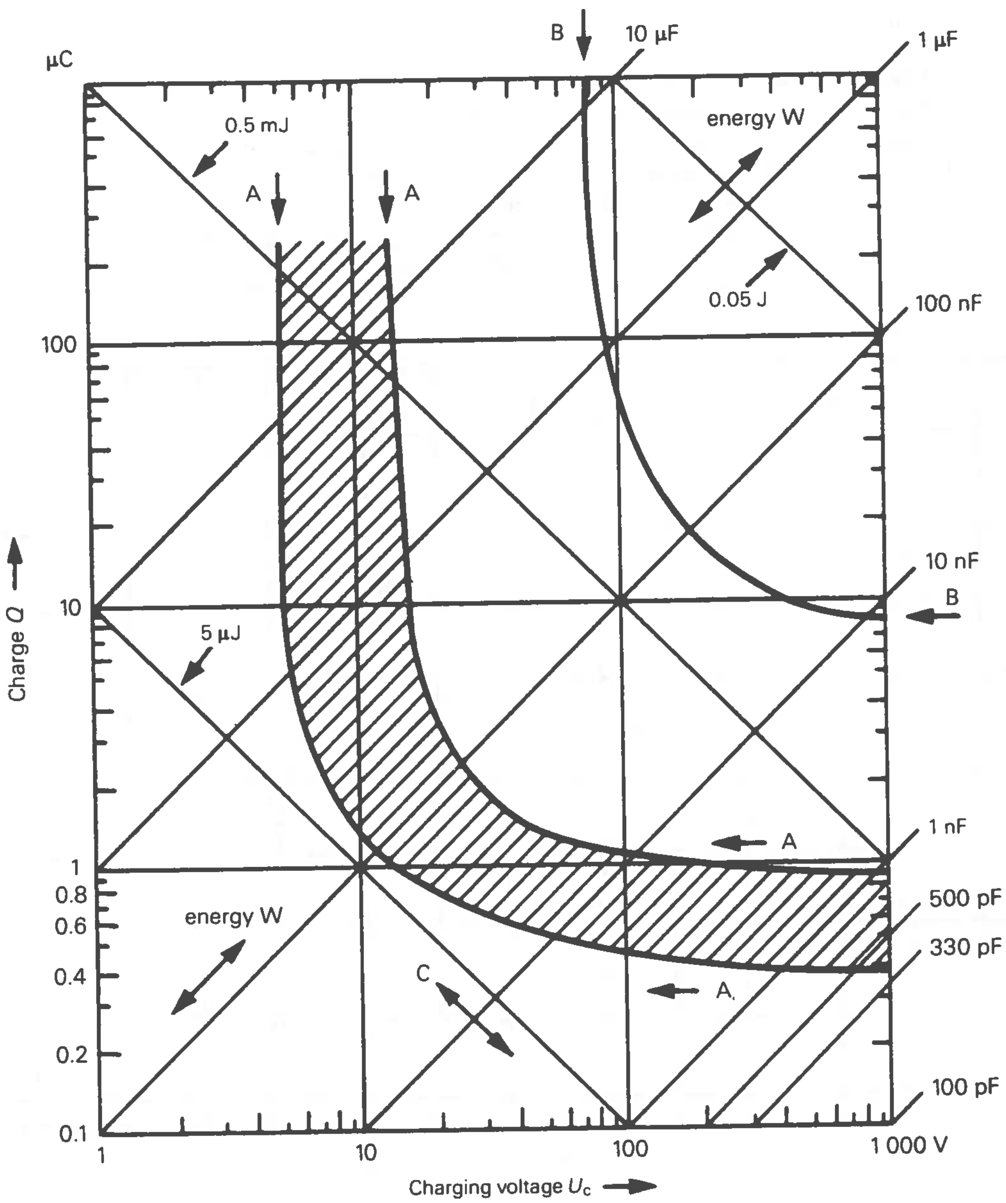


Fig.6 - Threshold of perception and threshold of pain for capacitor discharges (dry hands, large contact area)

A capacitor discharging through the body may be a source of danger if the impulse occurs during the vulnerable period.

The risk is assessed by calculating the charge which flows through the body and the energy dissipated. These quantities can be calculated in the usual way[1] from $Q = CV$ and $E = \frac{1}{2}CV^2$.

By using the values in Figure 6, you can judge whether the discharge is likely to be perceptible, disagreeable, or painful. *Zone A* marks the threshold of perception; *Zone B*, the threshold of pain.

[1] This is a simplification of the calculations used by BSI, but both methods yield similar results.

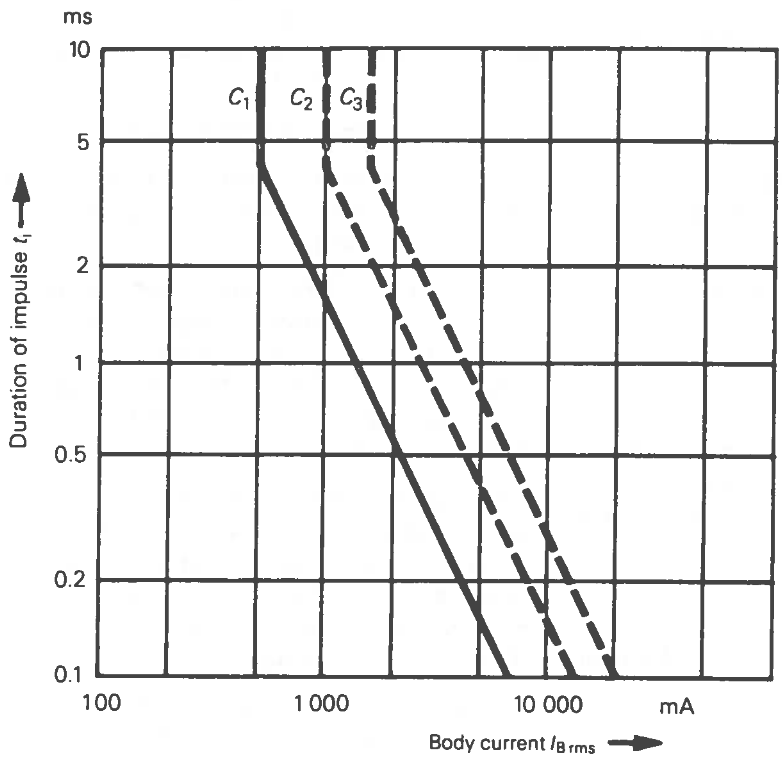


Fig.7 - Threshold of ventricular fibrillation

The curves in Figure 7 indicate the probability of fibrillation risks for current flowing in the path *left hand to feet*. To the bottom left of curve C_1 there is no risk of fibrillation. Between C_1 and C_2 the probability of fibrillation rises to 5%. To the top right of C_3 the probability is more than 50%.

Standards for hazardous live

Shock at 240 V a.c.

If you are unlucky enough to receive an electric shock from the live conductor of the mains supply, the current that would pass through your body, taking its impedance at 240 V to be 1000 Ω, would be

$I = V/Z = 240$ mA

You can see from the values in Figure 4 that such a shock may well prove fatal if the duration of current flow were to exceed a few hundred milliseconds.

Hazardous live

Standards for public safety are based on the values given above. In a recent standard [6], quoted in Bulletin 172, hazardous live is defined as shown in the next column:

"Values above the levels of *6.3.1.1* to *6.3.1.3* in normal condition are deemed to be hazardous live.

6.3.1.1 Voltage

The voltage levels are 30 V r.m.s. and 42.4 V peak or 60 V d.c.

6.3.1.2 Current

If the voltage exceeds one of the values in *6.3.1.1*, the current levels are:

- 0.5 mA r.m.s. for sinusoidal waveforms, 0.7 mA peak for non-sinusoidal waveform or mixed frequencies, or 2 m d.c., (when measured with circuits specified in the standard).

6.3.1.3 Capacitance

If the voltage exceeds one of the values in *6.3.1.1*, the capacitance levels are:

- 45 μC charge for voltages up to 15 kV peak or d.c.;

- 350 mJ stored energy for voltages above 15 kV peak or d.c."

Limits are values which, in normal practice, you stay well within. As in other spheres of health and safety, it would be considered bad practice to work right up to the edge of a limit unless absolutely required to do so.

You can see, by calculation, how these standards relate to the evidence on risks from electric shock.

AC limit

When working at the bench with uninsulated conductors at extra low voltage, the most probable path for electric current through the human body is *hand to hand*.

At the a.c. limit, which is 30 V r.m.s., the total body impedance for a percentile rank of 5% is 1650 Ω. The current I flowing through the body is

$$I = V/Z = 30/1650 = 18\,\text{mA}$$

From the heart factor of 0.4, a hand to hand current of 18 mA has a similar effect as a hand to foot current of 7 mA. You can see (Fig.4) that 7 mA is safely within *Zone 2*, where usually there are no harmful physiological effects.

DC limit

Doing the corresponding calculation for the 60 V d.c. limit, the hand to hand current I is

$$I = V/I = 60/1350 = 44\,\text{mA}$$

This has a similar effect as a hand to foot current of 18 mA, which is safely within *Zone 2* (Fig.5).

EHT supplies

To comply with the requirements of GS23 [7], the outlets of EHT supplies must be internally limited so as to be incapable of delivering a direct current exceeding 5 mA. In practice most EHT supplies have a nominal maximum rating of 3 mA. The actual maximum short circuit current is usually lower still - perhaps around 2.3 mA.

Thus in practice present models do not significantly exceed the hazardous live limit, at any voltage, of 2 mA. Their outputs are on the boundary between *Zones 1* and *2*.

HT supplies

The outlets of laboratory HT supplies, dependent on model, have a maximum voltage rating lying between 150 V and 300 V, and may be able to deliver a current of about 100 mA. Since these outputs are often unsmoothed, the risk should be assessed from the values for a.c. (Fig.4) rather than for d.c. It can be seen that the time-current point can lie in *Zone 4*, depending on the duration of current.

Laboratory HT supplies must therefore be considered to present significant risk of serious, possibly fatal, electric shock.

The Van de Graaff generator

The Griffin Senior Model (XJE-401-010Q) is the largest in the suppliers' catalogues, and thereby the one liable to be most harmful. The diameter of its collecting sphere is 250 mm. According to the catalogue, it can reach a potential of around 750 kV under dry, dust-free atmospheric conditions. This may be an overstatement. Berg [8] gives the maximum sustainable electric field for dry air at standard temperature and pressure to be 30 kV cm^{-1}. So where a is the radius of the dome in metres, the maximum potential for the dome is $3a \times 10^6$ V. By this reckoning, the maximum potential of the Griffin Senior is 375 kV.

The capacitance of the dome, using $C = 4\pi\varepsilon_0 a$, is 13 pF.

Thus the charge stored in the dome at maximum potential, from $Q = CV$, is 5 μC. The stored electrical energy, from $E = {}^1\!/_2 CV^2$, is 900 mJ.

How do these figures compare with standards? The IEC 1010 limit for stored capacitive energy at voltages higher than 15 kV is 350 mJ and is clearly broken. However this is a conservative limit. We therefore have to judge whether the amount by which we are exceeding it constitutes an unacceptable risk.

Looking at evidence on the effects of unidirectional single impulse currents of short duration, as presented in PD 6519, you can see that the data for charge, voltage, energy, capacitance and time for the discharge from a Van de Graaff all lie outwith the values presented (Fig's 6 and 7). Some extrapolation is necessary.

By extending curves A and B (Fig.6) it can be seen that the effects of a charge of 5 μC discharging from a capacitor lies well above the threshold of perception. and is close to, but below, the threshold of pain. It lies in an area where the effect is called *disagreeable*. This squares well with my own experience, having many times used such a Van de Graaff generator. The effect of its discharge is certainly perceptible, but not painful.

The values for the threshold of pain (Fig.6) lie well below the values for the threshold of fibrillation (Fig.7).

We can work out the duration of the impulse from the total body impedance. Since we are working at very high voltage and since the skin's initial capacitive charge is zero, we can count out the capacitive effect of the skin. The total impedance of the body then most probably lies somewhere between 650 Ω and 850 Ω. This gives a time constant (RC) for the Van de Graaff discharge of 10^{-8} s.

The r.m.s. value of the discharge current I_{rms} is the peak value divided by √6 (because of exponential decay). Then

$$I_{rms} = V / (Z \cdot \sqrt{6}) = 375 \times 10^3 / (650 \times \sqrt{6}) = 230\,\text{A}$$

It can be seen that an impulse current of 230 A r.m.s. with a duration of 10^{-8} s lies well to the bottom left of the limit for risk of fibrillation.

The above analysis relates to worst case conditions of the largest generator dome, very low humidity and dust-free air. Usually the charge and energy are very much less than this.

From the evidence it appears that the spark from a Van de Graaff cannot have sufficient charge or energy to hurt you - and certainly not enough to kill you, that is assuming you are a normal healthy person and don't have a specific heart illness.

Protective devices

We shall finish our article by looking at the protection afforded by fuses and other forms of circuit breaker.

The critical feature of these devices is their response time to switch off current in the event of a fault condition. In general the response time depends on the magnitude of the fault current. Only if the worst-case response time prevents any risk of fibrillation can the device be said to give you personal protection from danger.

Protective device	Delay time
Residual current circuit breaker (RCCB) or (RCD) for personnel protection	30 ms or 40 ms according to specification
RCCB for fire prevention	from 40 ms to 250 ms depending on type
Fuse, or thermal cut-out	from 100 ms to many seconds
Miniature circuit breaker (MCB)	from 3 ms to several seconds depending on current and MCB type

Table 2 Response times of protective devices

It can be seen that only the residual current circuit breaker (RCCB) of the sort specifically designed to prevent death by electric shock offers this form of protection (Table 2). With its response time of 30 ms to 40 ms, or two cycles at 50 Hz, and using the value for body current at 240 V already calculated, that is 240 mA, the current-time point lies in *Zone 2*. There is therefore no risk of fibrillation occurring. Even if the duration lasts a few extra cycles, there is still no risk of fibrillation, but you now move into *Zone 3* where harm may be caused.

However if the shock current through the body lasts for 300 ms or more, then there is a risk of fibrillation. Neither fuses, miniature circuit breakers, nor thermal cut-outs guarantee response times which react that quickly. In certain fault conditions they cannot therefore be relied upon to prevent death by electric shock.

Summary

1. The impedance of the human body depends on touch voltage. Using experimental data on impedance, the current flowing through the body can be calculated.
2. The risk of harm to persons depends mainly on the magnitude and duration of the current flow, for a specific current path.
3. The values for hazardous live published in IEC 1010-1 [6] give a satisfactory leeway for safety when working with live conductors at values below these limits.
4. Although the charge and energy of the spark from a Van de Graaff generator in worst case conditions breaks the IEC limit for hazardous live, the risk of being hurt has been shown, for people in normal health, to be improbable.
5. An RCCB designed for personnel protection has a sufficiently fast response to prevent death by electric shock in fault conditions.
6. Fuses, thermal cut-outs and miniature circuit breakers cannot be relied upon to respond fast enough to prevent a fatal shock in fault conditions.

Acknowledgement

Extracts from PD 6519 : Parts 1 and 2 : 1988 are reproduced with permission from BSI. Complete copies of the standards can be obtained by post from BSI Sales (address on inside rear cover).

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TECHNICAL ARTICLES

Higher Grade Human Biology

Instrumentation

This article is the first in a short series. It describes practical work in support of the newly introduced syllabus in Human Biology at the Higher Grade. It concentrates on applications of modern instruments and information technologies in particular, datalogging devices.

Introduction

This article was developed from a short formal presentation at the National Launch Course for Human Biology at the Higher Grade [1]. The organisers had entitled that talk "Human Biology : a Hi-tech Approach" - action to which we took mild exception. That was partly because, in the tradition of conferences and meetings, it wasn't the title we had supplied.

It worried us also because of what such a title may reveal of the collective psyche of sections of the biology teaching profession. It is almost as if an intimidating title is an essential requirement - in order that corporate task avoidance might thus be justified!

Aims and scope

Our supplied title had been "Human Biology : Applications of modern instrumentation and IT".

The aim of this present article is to indicate those parts of the Higher syllabus which sensibly lend themselves to the use of relatively modern apparatus and techniques. That may assist us to begin to close the gap between school biology and current professional practice in for example medical, paramedical and sports sciences. In so doing it is crucial that the current constraints faced both by schools and curriculum developers of restricted finance and resources, timetabling and shortage of relevant expertise are recognised.

The new syllabus offers many opportunities for the application of educational technology, in the sense of audio visual techniques and materials such as video, interactive and otherwise, computer simulations etc. The Centre has no real remit for this area of work and has only been involved to date where its own in-house development has produced software of wider application such as the SSERC Graphics Libraries. The article does not deal therefore with such general IT applications.

Educational criteria

Arguments ad-nauseam have been advanced in these Bulletin pages to support equipment evaluation and selection procedures firmly based on sound educational criteria [2].

These arguments should continue to guide sensible purchase and usage of modern instruments and information technologies.

There are many places in the Human Biology syllabus where such equipment might be applied. A significant number of those applications are probably not justifiable on educational grounds. For example, the use of an electronic sensor where simple direct observation or measurement are effective is both misguided and wasteful. There are however simple and sensible criteria which may be applied to suggested practical activities to test their suitability for applications of electronic measurement and datalogging techniques.

Such criteria for educational usage of sensors and transducers were discussed in Bulletin 161 [3]. A similar set for the application of microcomputers and other microprocessor based devices was offered in SSERC Bulletin 167 [4]. For convenience these criteria are summarised in Table 1.

Suitable practicals

In many schools Higher Grade for now at least remains a two or, at best, a three term gallop to cover content-laden syllabuses. Application of our criteria and recognising such time constraints means homing in on a relatively restricted list of worthwhile practical exercises where the use of instrumentation confers educational advantage. Such a menu is set out in Table 2.

Sequencing and novel activities

The layout of Table 2 reflects the syllabus entry sequence both of the listed topics and within any one topic. Our list and the remainder of this article depart from the SEB documents in two ways.

The first of these is that we have added a few activities filling one or two practical gaps.

The second is that in describing possible activities we have abandoned the order shown in the SEB documents in favour of an historical approach[1].

Gaps in practical work

Included in our table are one or two practicals for which the syllabus suggests only theoretical treatment. This reflects a difficulty arising from current shortages of technical expertise. This is that syllabus entries may only be theoretical merely because it was not then appreciated that a particular practical might be both technically feasible and affordable for application or simulation at school level.

One example is the lack of any practical work on pre-natal foetal examinations by ultrasonic scanning. Another is the lack of any mention of the practical

[1]This is not being suggested as a methodology for teaching students at Higher Grade but as a means to aid teachers' understanding of instrumentation.

Electronic sensors & transducers	*Microcomputers, dataloggers etc.*
"It may be particularly appropriate to select an electronic sensor when: - it is impossible or inconvenient to take direct readings, e.g. removing the sensor from the sample would affect the reading, or the sample to be measured is remote (e.g. in a tree canopy or crevice in field work); - a small inflection is sought in a gross trend or otherwise steady state; - a rapid change (a transient) has to be detected and measured; - a number of variables are to be simultaneously monitored or controlled." *SSERC Bulletin 161* *October 1988*	". . . the power of a microprocessor based device may lie, not in any one thing it can do but rather, in combinations of several or all of the many facilities it can offer." - speed of data capture allowing fast transients to be studied; - the 'patience' of devices in long term data logging; - the ability to detect minor variations in an otherwise steady state signal; - facilities for the simultaneous logging or control of a number of parameters which would be outwith the capability of a human observer; - software engineering techniques which simplify calibration and signal conditioning removing the need for some hardware components and - 'number crunching' facilities whereby the gathering, manipulation and display of numerical data enhance students' understanding. *SSERC Bulletin 167* *September 1990*

Table 1 - Criteria for applications of sensors, transducers and microprocessor based devices

Topic	Reference	Practical exercise
1. CELL FUNCTION	1 a) ii	Cell metabolism. Non competitive inhibition of enzymes e.g. of catalase by lead ions. Use of a pressure sensor and datalogging to monitor rapid initial rate of reaction.
2. CONTINUATION OF THE SPECIES	3 a	Development. Pre-natal examinations by means of ultrasonic scanning - demonstration of analogous models using Motion Sensor and electronic tape measure.
3. LIFE SUPPORT MECHANISMS	1 c) i	Transport Mechanisms. Electrocardiograms (ECGs)
	1 c) ii	Electronic sphygmomanometer
	2 b) i b	Delivery of materials to cells - influence of bile salts on lipase activity. Use of pH electrode and datalogging to follow formation of fatty acids.
	4 i	Effects of exercise on ventilatiom rates of lungs. Use of stethograph and various pressure sensors or electronic manometer and a thermistor based detector.
	4 iv	Response of body to rapid heat loss. Use of thermistor detector and datalogging.
4. BIOLOGICAL BASIS OF BEHAVIOUR	1 a) iv	Modelling of brain scans using ultrasonics (see also topic 2 ref. 3a.).
	1 b) iv	Suppression of reflexes. Use of differential biological amplifier and dataloggers.
5. POPULATION GROWTH & THE ENVIRONMENT		Many opportunities for CAL, simulations and data handling exercises.

Table 2 - Human Biology syllabus : opportunities for the application of modern instrumentation

possibilities of capturing fast transients in order to study reflex arcs, latency periods and the effects of fatigue etc.

An historical approach

This is the other reason for our scrambling of the syllabus order. One way to aid understanding of any technological development is to start with what went before, where the principles of operation are directly observable and obvious. By this means we may come to understand new principles which then prove widely applicable.

In this first article we look at developments in blood pressure measurement, at pressure sensors and their applications before ending with a possible application of an ultrasonic transducer. Future articles will provide similar, relatively simple, treatments of the principles behind electrocardiography and other transient physiological phenomena where datalogging may prove a practical aid to understanding of important biological ideas.

Blood pressure measurements

Early techniques of blood pressure measurement or sphygmomanometry involved the somewhat tricky and potentially hazardous technique of cannulating an artery. In order to prevent arterial blood entering the manometer an equal external pressure was first applied from a pressurised reservoir of saline solution (Fig.1).

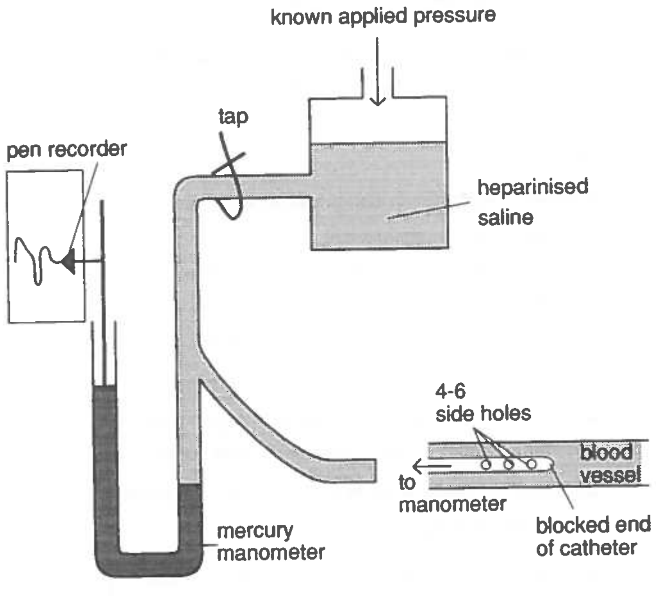

Fig.1 - Blood pressure measurement by catheterisation

In 1896 Riva-Rocci introduced his technique for indirect measurement whereby the balancing external pressure is applied by means of an inflatable cuff. Within less than a decade Korotkov had developed the now familiar method of finding systolic and diastolic pressures by listening to the arterial sounds beyond the cuff as it is slowly depressurised (Fig.2).

Until relatively recently, these pressures still had to be read from a mercury manometer until this was replaced by less cumbersome, more portable indicators.

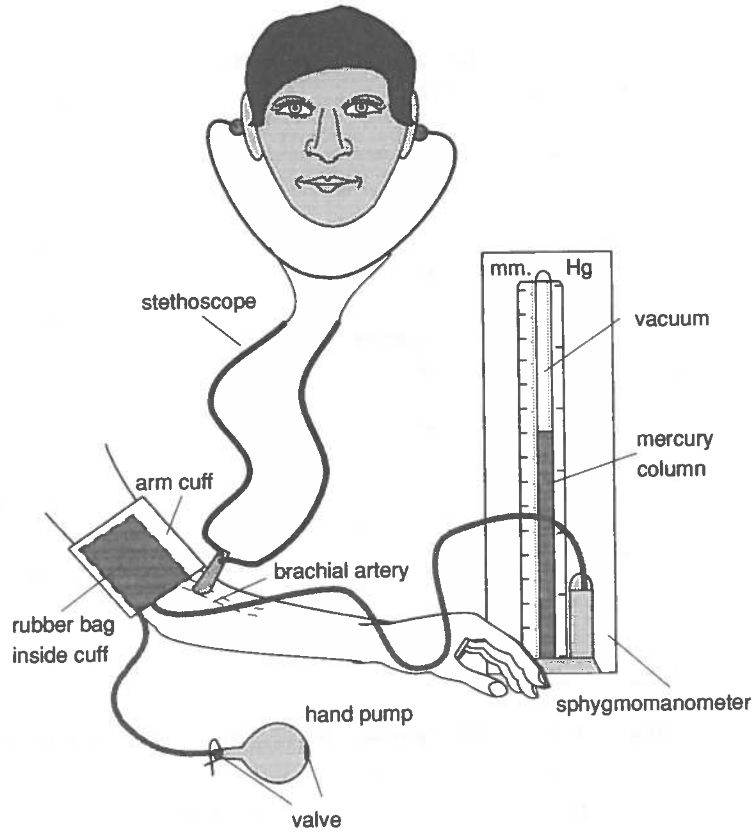

Fig.2 - Indirect measurement of blood pressure

At first these tended to be anaeroid dial gauges of the Bourdon type working on the same basic principle as the paper party toys. More recently these have been superseded by electronic sensors and transducer circuitry which allow pressures to be read directly from a digital display.

The operation of such electronic pressure transducers may use any one of a number of techniques, a basic understanding of which will provide the biologist with insight over a much wider range of applications.

Pressure transducers

Three broad techniques are outlined here based on :

- strain gauges
- capacitance
- piezoelectricity

Not dealt with are the less common variable inductance and linear differential transformer types (see Ref.[5]).

Strain gauge applications

Strain gauges are resistive sensors the basic operational principles of which were outlined in the "Technical Articles" section of Bulletin 171 [6].

For their use in sphygmomanometry the manometer or anaeroid gauge is replaced by a diaphragm (Fig.3). This may be of rubber or thin metal or other material of suitable flexibility. Pressure changes in the inflatable cuff will cause the diaphragm to flex.

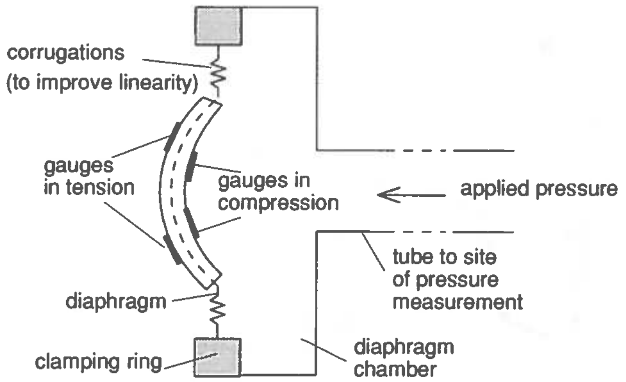

Fig.3 - Pressure transducer : strain gauges on a diaphragm

Two pairs of gauges, one in tension the other in compression on either side of the diaphragm will detect these small movements. If the gauges are made part of a suitable Wheatstone bridge circuit (Fig.4), then the output voltage can be calibrated in units of pressure. The whole assembly is thus a *transducer* - a device which converts the units of one physical parameter into those of another - in this case pressure to volume changes and in turn to a voltage proportional to pressure.

Capacitative sensors

The variables which determine the capacitance of parallel plate capacitors include the distance between the plates, their cross sectional area and the permittivity of the medium (the dielectric) between them. If either of the plates is moved in the dielectric (or vice versa - see below) the capacitance will vary proportionally to the displacement.

The diaphragm (Fig.3) is coupled to a plate, or to the dielectric between plates (Figs. 5 & 6). Alternatively the diaphragm is of metal and itself forms one plate of a capacitor [5]. Any changes in pressure result in varying capacitance.

Circuitry to convert that change in turn into a varying voltage is somewhat trickier than a strain gauge bridge. It usually involves use either of an a.c. bridge or a tuned circuit. In the a.c. bridge method the capacitor forms one arm of that bridge. The out of balance voltage of the bridge then gives a measure of changes in capacitance and hence of pressure. As with strain gauges, capacitors may be used as bridge pairs so compensating for other variables and external factors such as temperature etc.

If a tuned circuit is used, then changes in capacitance produce frequency changes which are in turn output from a frequency to voltage converter as a signal proportional to pressure. Simplest of all is a resistor and capacitor (R-C) series circuit in which the voltage (V_c) across a variable capacitor provides a measure of capacitance and, in turn, of pressure.

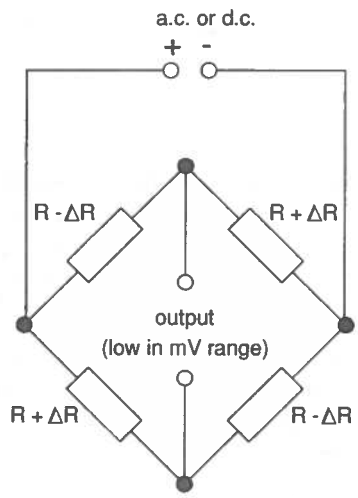

Fig.4 - Strain gauge bridge circuit

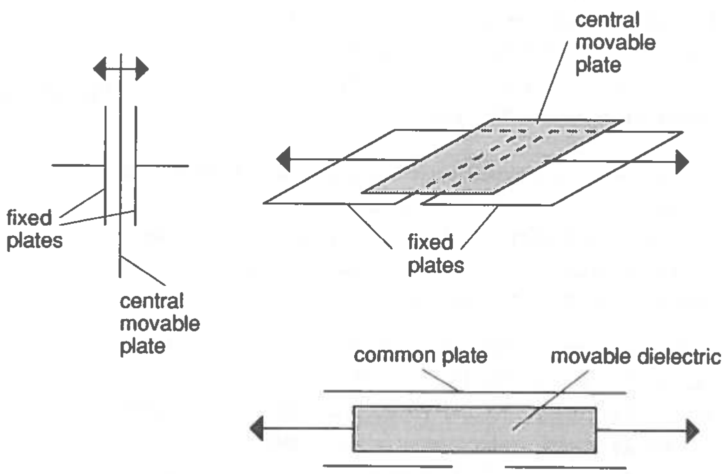

Fig.5 - Transducers based on differential capacitance (after Pope [5])

Harris electronic manometer

Commercial pressure (and volume or movement/displacement) transducers which rely on capacitative sensing have been on the schools market for some years now. For example the Philip Harris Electronic Barometer T12291/9 ca.£88) uses a capsule coupled to a moveable plate between a fixed pair.

An alternative for physiological applications is the Harris Electronic Manometer (T12330/5 ca.£53 plus manometer tubes available in a range of sizes for different applications). It relies on a sort of *hybrid* technology in that it looks like an ordinary glass, fluid filled, manometer but is in fact a variable capacitor. Liquid (water or ethanol) in the tube provides a moveable dielectric and strips of aluminium, on the outer sides of the glass manometer tube, fixed capacitor plates (Fig.6).

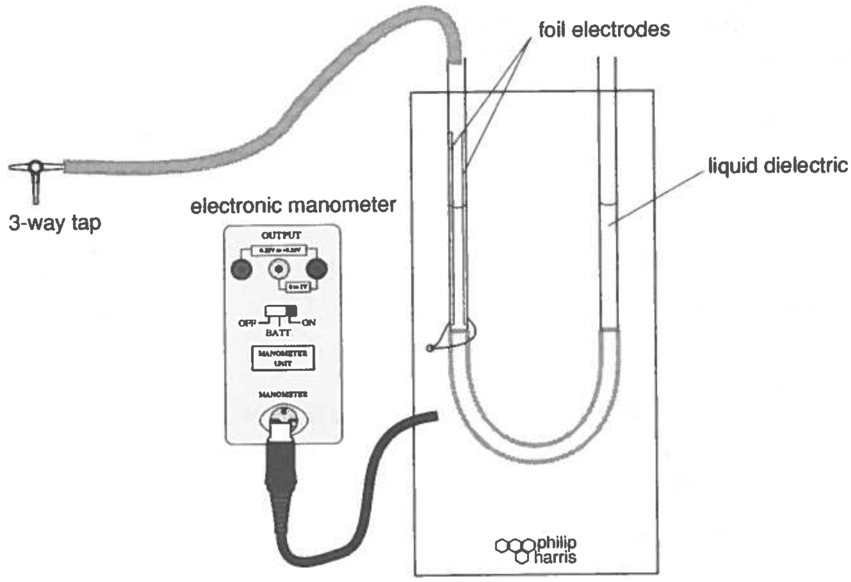

Fig.6

Piezoelectric pressure transducers

Certain materials develop potential differences (voltages) at or across their surfaces as they are being either compressed or extended in particular directions. This effect is known as the *piezoelectric* effect. It is perhaps most familiar in devices used for ignition such as gas lighters where the transitory voltages developed are large enough for a spark to be generated across an air gap. The effect may however also be used to measure strain, displacement, volume changes (and hence pressure) and impulse.

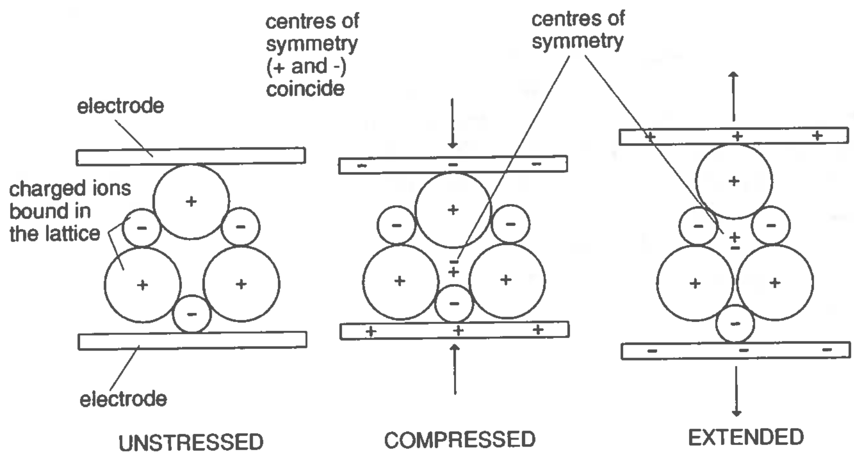

Fig. 7 - The piezoelectric effect

The use of a piezoelectric sensor in the measurement of impulse and the production of force v. time graphs was described in Bulletin 155 [7]. The piezoelectric material described therein was a sheet material, a man-made polymer known as *Kynar film*.

Some natural crystalline materials and several man-made ceramics also exhibit this piezoelectric property. As for Kynar film the basic underlying mechanism is asymmetry of charge in the molecules or crystal lattice of the piezoelectric material. This asymmetry is balanced and cancels out when the material is at *rest*. Should the material be distorted in some way, either being compressed or extended, then the asymmetry is apparent and a voltage develops across the material (Fig. 7). Piezoelectric devices may thus be used as *active* transducers since they produce a signal directly without any external power supply[2].

Some piezoelectric ceramics may be moulded and polarised so as to be pressure sensitive in a given direction. These can then give relatively large outputs (typically an increase in relative pressure of 1 bar applied to a 1 mm thick specimen gives a voltage of ca. 10 mV) [5].

In addition to their use in sphygmomanometry such sensors may be applied in the study of depth and rate of breathing (Fig.8) and in the study of rates of reaction where gases are released [8].

[2]The Griffin pressure sensor (XCR-500-K ca.£84), Unilab's Electronic Barometer (425.024, £67-50) and the Harris Pressure Sensor MkII all utilise such a sensor.

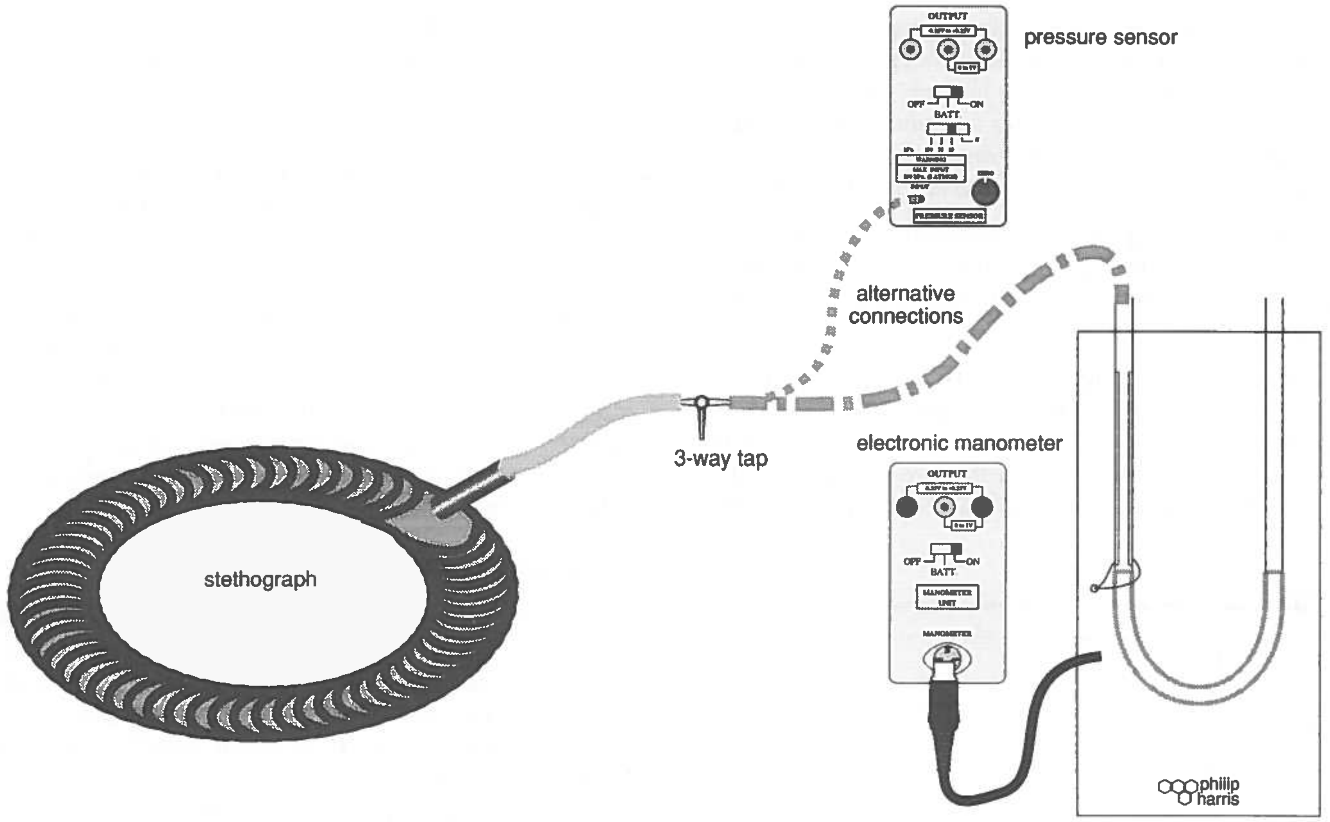

Fig.8 - Monitoring rate and depth of breathing by stethograph and pressure tranducer

Inhibition of an enzyme

We recently received a note, from Newbattle High School, of a novel application of such a sensor in the study of non-competitive inhibition of catalase by the salts of heavy metals.

Direct observational methods are also available for such studies. Such methods are described in supporting materials for revised Biology at the Higher Grade. One of these relies on estimating the heights of columns of detergent maintained foam in measuring cylinders as a measure of the volume of oxygen produced by the action of catalase on hydrogen peroxide solutions in the presence or absence of, for example, lead ions.

We have had some success in trialling this approach but results have, at times, been puzzling. Like the reaction of powdered marble and acid, the catalase mediated breakdown of hydrogen peroxide may be very rapid. One sixth year student's application of a pressure sensor has allowed the study of initial rates of reaction over the first few seconds or so.

The apparatus (Fig.9) is an independently designed variant of our *internal dispenser* idea (for the powdered marble reaction as described in Bulletin 172 [8]). The Newbattle method substitutes the side chamber of a Warburg flask for the flexible tube used in the SSERC dispenser.

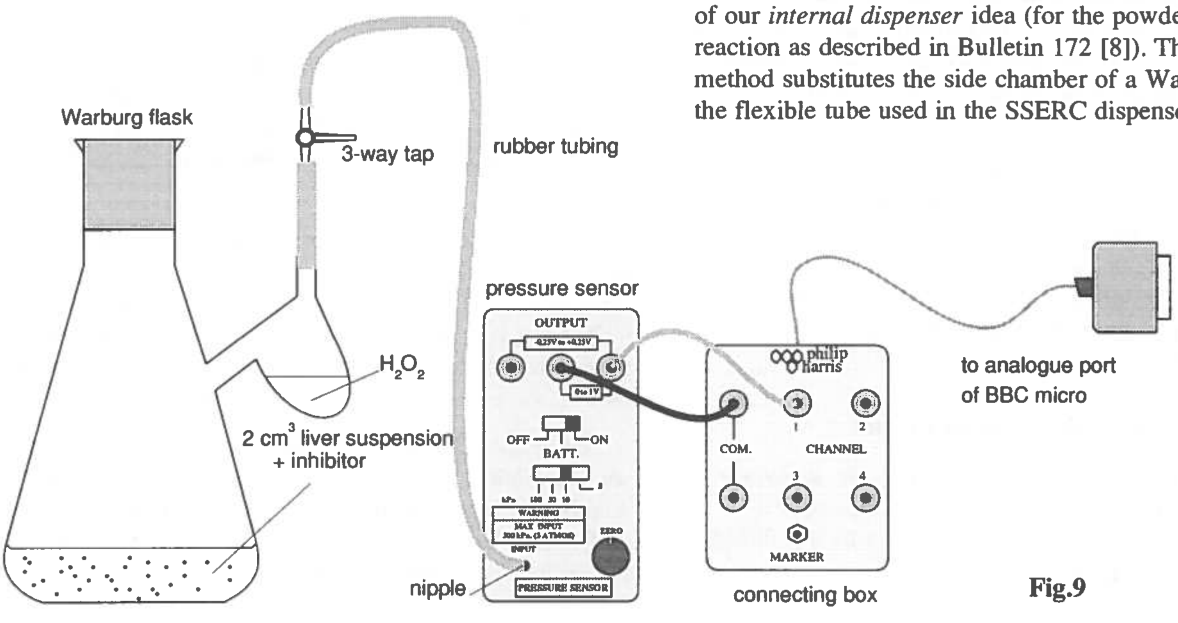

Fig.9

Reaction rates are monitored by logging the increase in pressure as oxygen is evolved. Since oxygen is only sparingly soluble in the reaction mixture, objections to the use of rate of pressure change as a parameter proportional to reaction rate are much less serious than for the chemistry application where the gas evolved is the more soluble CO_2.

The pressure gauge was a commercial device using a sensor of the piezoelectric type. It was initially calibrated against a car tyre foot pump with its own gauge (graduated in bar) as a secondary standard.

Sample results are shown (Fig. 10) for the reaction (mediated by catalase from liver) in the absence and presence of lead ions. It is obvious from these graphs that the reaction is indeed rapid - much more so than we had expected - and that the effect of lead on that initial rate is very marked.

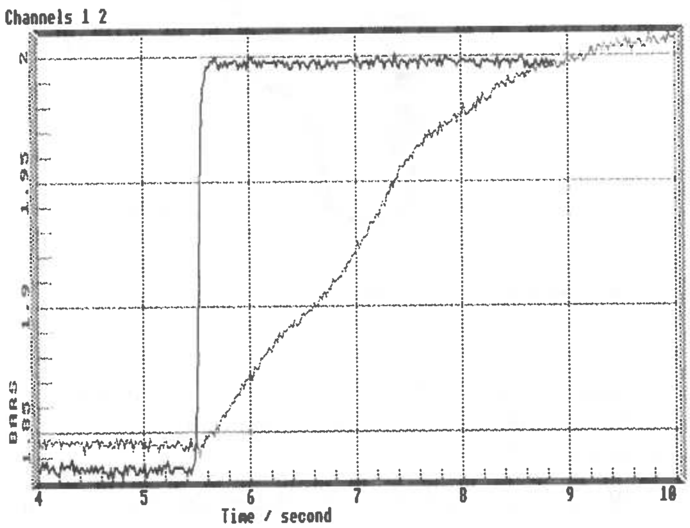

Fig.10 - Logging for 10 s, H_2O_2 added at T = 5 seconds

The almost vertical line shows the initial increase in pressure in the absence of lead ions. The somewhat lighter line shows the effect of adding 1 cm^3 of 0.1M lead nitrate solution. So rapid is the uninhibited reaction that it is necessary to use Datadisc's facility to adjust axes and *zoom in* to actually measure the slope - which is approximately 150 mb s^{-1}. In the presence of lead ions this drops to ca. 43 mb s^{-1}.

Contrary to our own initial assessment this activity is an excellent example of the proper use of an electronic transducer and of datalogging. There is a transient here. The maximum pressure change takes less than a second for the unihibited reaction. Measurements of rates are feasible only if data can be captured rapidly. It therefore meets our criteria as set out earlier in Table 1.

Piezoelectricity - other applications

The application described above exploits the *generator* action of piezoelectric materials. That is, when such a material is stressed, a voltage is generated which is directly proportional to thc applied stress.

The opposite is also true. If a voltage is applied to a piezoelectric material then it will momentarily expand or contract depending on the polarity of that voltage. This is the *motor* action of a piezoelectric material.

It follows that if a voltage of rapidly alternating polarity is applied across such a material it can be made to vibrate at a frequency dependent on the frequency of that applied voltage.

Piezoelectric ceramics and crystals can be made to so vibrate at high frequency. They then produce sound pulses at frequencies well beyond the limits of human audio acuity. They generate ultrasound. Such ultrasonic signals form the basis of ultrasonic measurements in survey work and in ultrasonic scanning for pre-natal foetal examination, brain scans etc.

Ultrasonic scanners

A schematic representation of a medical scanning system is shown in figure 11. It will be seen that if a *picture*, of a foetus say, is to be built up it is necessary that an array of several ultrasonic transducers be used. The triggering of pulses from this array has to be synchronised both for each transducer and with the pulse driving the timebase of a cathode ray oscilloscope (CRO) or visual display unit (VDU) on which scans are usually displayed [9].

Ultrasonic echoes from different tissues and depths within the patient and from across the transducer array have first to be *conditioned* to a common voltage range before being applied to the Y plates of the CRO. These signals have similarly to be synchronised to a common timebase.

Clearly such a complex set-up is too expensive for demonstrations at school level. It is however possible to demonstrate an analogue of such a system. Not yet available is any analogue of the transducers able to detect frequency shifts from moving objects (the *Doppler* effect). This is the basis of those scanning techniques able to detect differences in blood flow and thus pick up thromboses in the brain or other parts of the human body.

Ultrasonic echolocation

Electronic range finders also known as electronic or ultrasonic tape measures are now widely available on the market. These devices compute range or distance from the period between sending a signal and the reception of its echo.

A device using the same technology but developed specifically for educational applications is marketed by Educational Electronics. This is their *Motion Sensor*[3] (ref. 9200 £72). It is intended mainly for use in physics and as a general tool for scientific problem solving. It may also be used however to model ultrasonic scanning in medicine.

The general principle is illustrated in figure 12. A doll is used to model a foetus and a large box the human body or womb. It is important that the box or chamber is sufficiently large because the Motion Sensor will not properly detect objects within a certain minimum range.

[3] Also available Ref. 9210 - Activities Disc and Notes £20

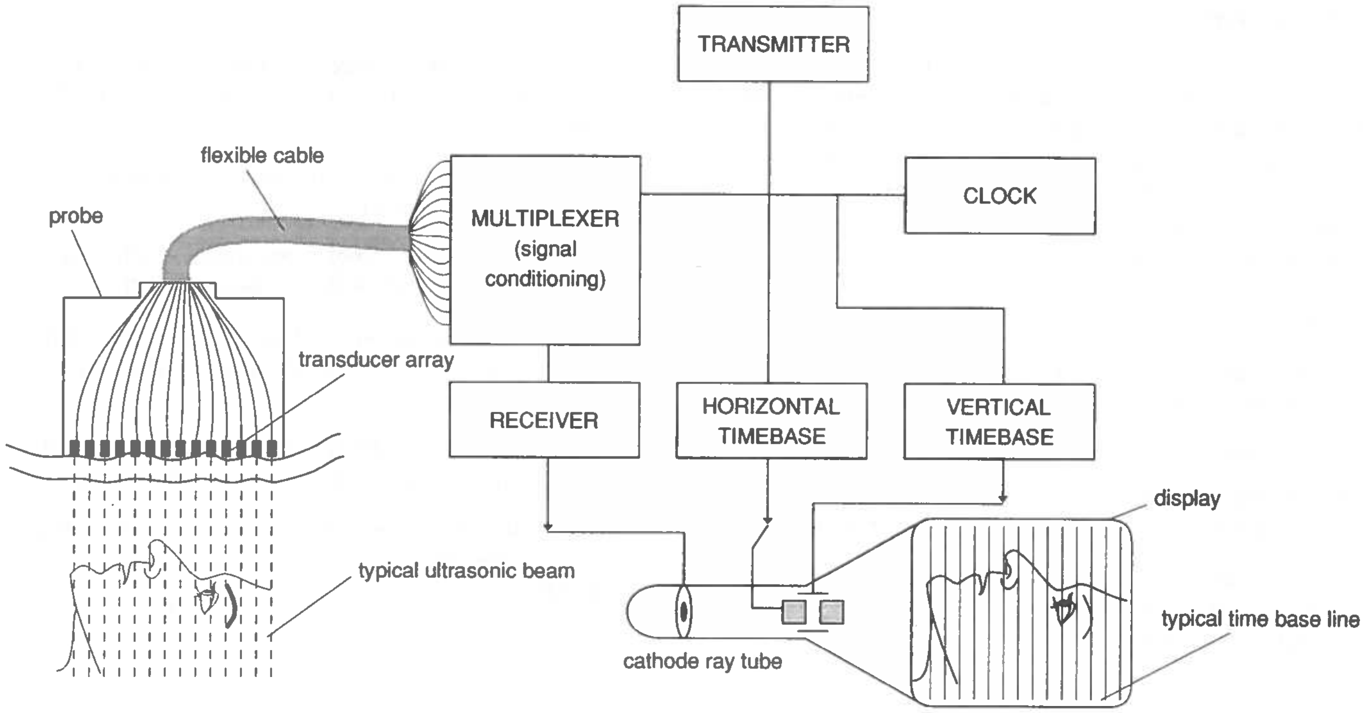

Fig.11 - Block diagram of a medical ultrasonic scanning system

The method illustrated in figure 12 relies on distance versus time plots obtained with software for the BBC microcomputer (Model B or Master[4]). The position of a doll which simulates a foetus is marked "X" on the diagram.

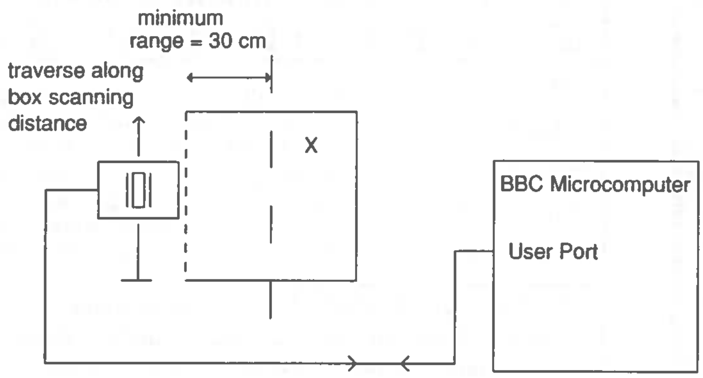

Fig.12 - Modelling ultrasonic scans with a *Motion Sensor*

A typical example of such a Motion Sensor graph is shown in figure 13.

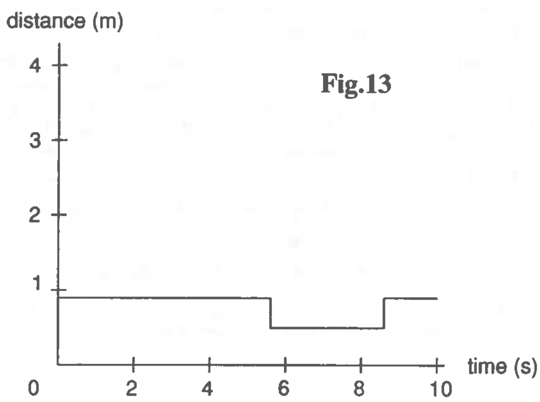

Fig.13

It is also possible to obtain results with manual plotting using an Ultrasonic tape measure. In this procedure (Fig. 14) readings are taken singly at equal intervals as the *tape* is traversed slowly across the front of the box. Results are then plotted manually.

For fuller technical details readers are strongly recommended to consult Volume 2 of the SSERC Technical Guides to Standard Grade Physics [10]. This is because Unit 3 of Standard Grade Physics is entitled "Health Physics". Several of the suggested activities within this Unit are therefore also of interest to teachers of biology and human biology with some also being applicable in SEB Short Courses in Health Studies.

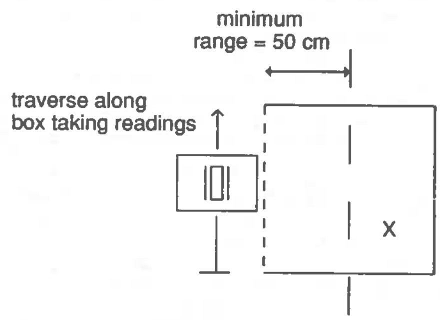

Fig.14

Endpiece

It is hoped that the material presented above will be of some assistance to teachers considering presentations in Human Biology at the Higher Grade. Future articles in this series will take a similar approach to practical work on the physiology of the heart and nervous system.

(See over for references etc.)

[4] Archimedes version available soon.

Acknowledgement

We are most grateful to Graham Moffat, Principal Teacher of Biology, Newbattle High School, and his sixth year student Ryan Evans, for the details of their pressure sensor based technique for studying catalase mediated reactions. We understand that Ryan went on to obtain results for other, lower, concentrations of lead as well as for other potential inhibitors.

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Stepper motor drive - Part 1

This is the first of a series of articles on means of driving stepper motors. It discusses some general properties of sequential circuits and shows how the signals to drive a 4-phase stepper are generated by *J-K* flip-flops.

Introduction

One of the attractions of driving a motor is that it provides a purpose with visible outcome in the otherwise secretive world of electronics. It may either run, or twitch, or stall, or not show any sign of life. It may go clockwise or anticlockwise, fast or slow. It might hunt. It will have a settling time. What load can it drive? Can it be accelerated to a higher maximum speed than can be reached from a cold start?

Motor control is an absorbing theme on which to build course work, whether in Technological Studies, Electronics Short Courses, or CSYS Physics options. This series of articles should provide you with some of the technical background to this subject.

Before considering how the stepper motor is driven, we look first at the *J-K* flip-flop, which is used in the controller circuit.

Sequential logic and the *J-K* flip-flop

It is not usually necessary to understand the internal workings of the device and it is described here as a black box (Fig.1). You do however need to understand how the outputs respond to the inputs.

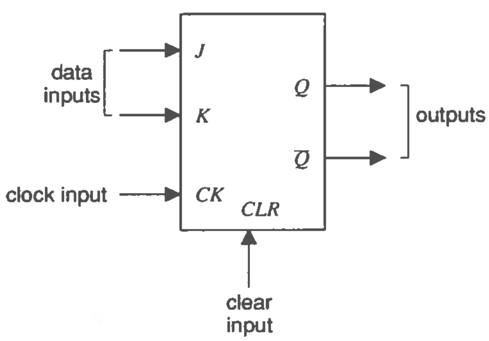


Fig.1 *J-K* flip-flop

The *J-K* flip-flop has two *data inputs* known as *J* and *K*. The version we are looking at also has a *clear input*, which can cause the output to ignore its data inputs and past history. If the clear input is 0 the output *Q* will be 0 irrespective of anything else.

The output *Q* has two stable states, a set state when its output is a 1 and a clear state when its output is a 0. It is therefore called a *bistable* logical device. A bistable output can be made to change state when a pulse is applied to one of its inputs known as the *clock input*. It is often therefore called a *flip-flop*. On command it either *flips* to one stable state, or *flops* back to the other.

In addition to having a standard output *Q* the *J-K* flip-flop has another output $\overline{Q}$, which is the complement of *Q*. Thus if *Q* is set, $\overline{Q}$ is clear, and *vice-versa*.

Unlike combinational logic devices, the output is influenced by its past history as well as by its present state. If the present state of the output *Q* on receipt of *n* clock pulses is described as Q_n, then the next state of *Q* is called Q_{n+1} after getting the next clock pulse. There may not necessarily have been a change of state. It all depends on the state of the inputs at the instant of clocking.

The dependence of outputs on inputs is shown by the *characteristic table* of the sequential logic device. This is not quite the same as a *truth table*. The outputs of combinational logic devices are completely predictable knowing the present states of the inputs. However in sequential logic the previous history also has a bearing. The characteristic table of a 74LS73 *J-K* flip-flop is shown here.

Data inputs J K	State of output register after clock pulse Q_{n+1}	Meaning
0 0	Q_n	Output *Q* does not change
0 1	0	Output *Q* always cleared, whatever its former state
1 0	1	Output *Q* always set, whatever its former state
1 1	$(\overline{Q_n})$	Output *Q* always changes state, whatever its previous state had been

Table 1 Characteristic table of 74LS73 *J-K* flip-flop

Clocking takes place on the *negative edge* of a clock pulse, which is a transition from a 1 to a 0.

Divide by two circuit

It can be seen from the characteristic table that if both data inputs are tied high, the output changes state with every clock pulse, a condition known as *toggling*. This is division by two. The output generates a pulse train whose frequency is one half that of the clock pulses (Fig.2 over). You can encode the signals that drive a 4-phase stepper motor by applying this technique.

Driving the motor

The usual type of stepper motor bought by schools is the *4-phase* motor, so called because it has four windings and operates off a 4-phase supply. Our circuit generates the four phases to drive this type of motor.

The four windings are called *1*, *2*, *3* and *4*. The signals which control them are labelled in the figures *φ1*, *φ2*, *φ3* and *φ4*. At any instant two windings are on and two are off such that *1* and *2* alternate in anti-phase with *3* and *4*. The sequence is

1 and *4*	*1* and *3*	*2* and *3*	*2* and *4*	- forward
2 and *4*	*2* and *3*	*1* and *3*	*1* and *4*	- reverse

By successively dividing a clock pulse by two, twice, using three *J-K* flip-flops, the requisite 4-phase signals can be generated (Fig.3).

The states of phases *1* and *2* can be inverted by the pair of EXCLUSIVE-OR gates to control the motor's direction. This action is controlled by a switch.

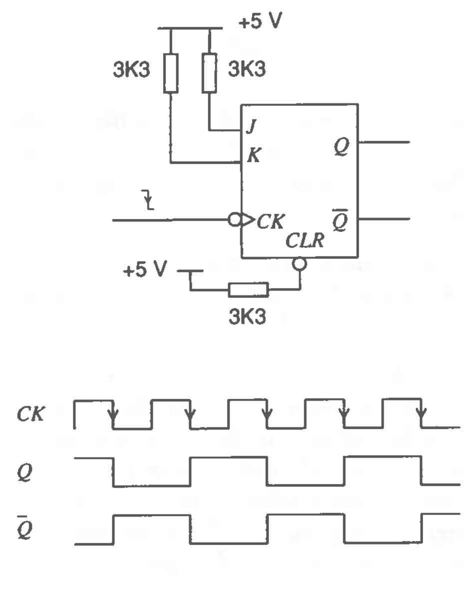


Fig.2 - Division by 2 with *J-K* flip-flop

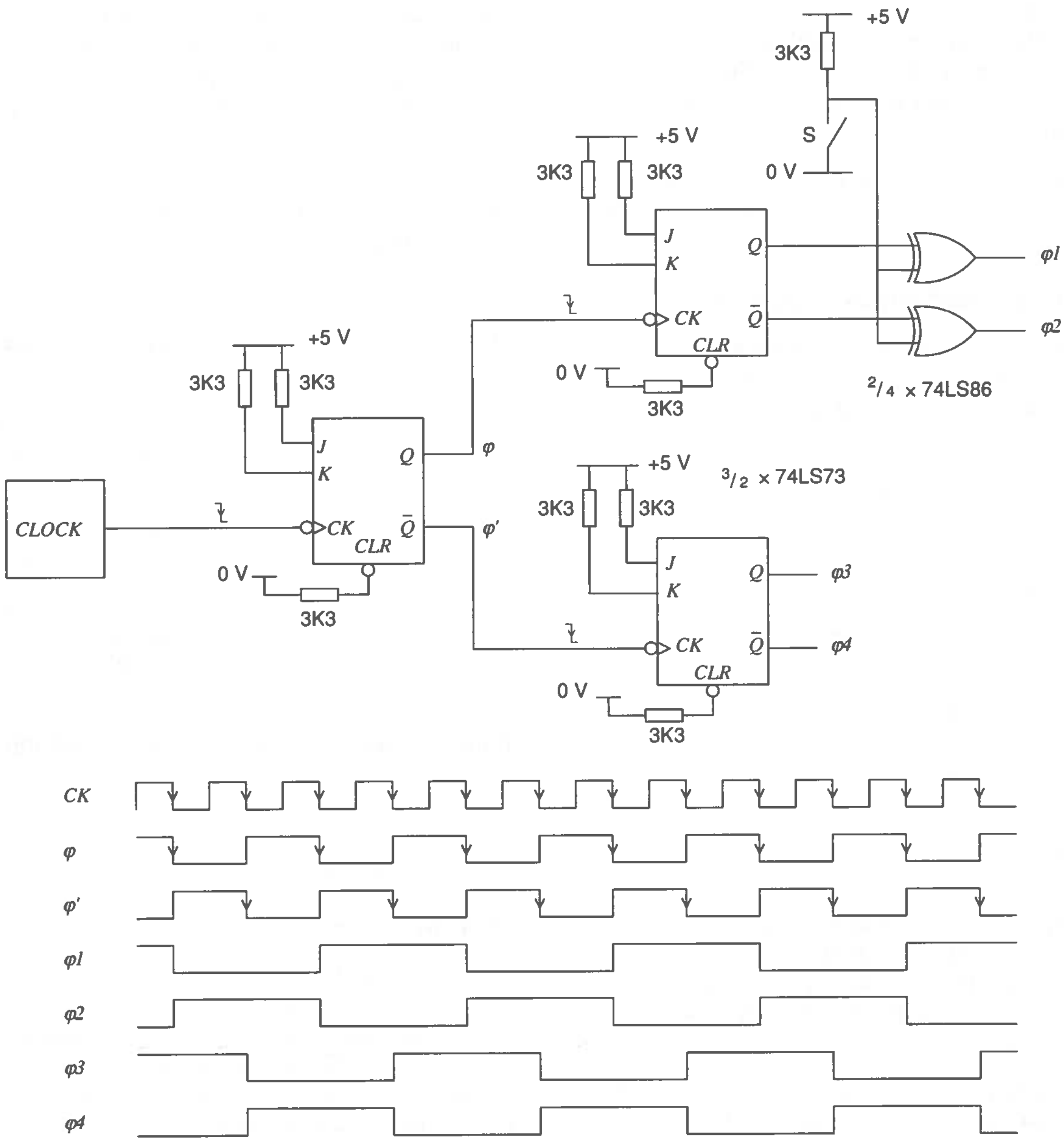
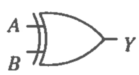
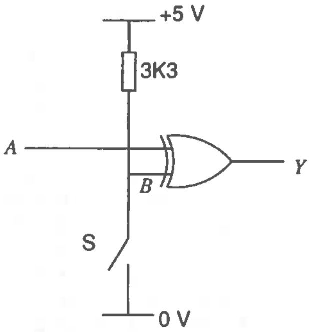


Fig.3 - Generation of 4-phase supply

It can be seen from the truth table of the EXCLUSIVE-OR (Fig.4) that if switch S is closed, input *B* is 0 and the output state equals input state *A*, whatever that may be.

However if S is open, the output state is the complement of *A*.





inputs		output
A	*B*	*Y*
0	0	0
0	1	1
1	0	1
1	1	0

Fig.4 - Inversion with EXCLUSIVE-OR

Three TTL-LS chips are used: two 74LS73's and one 74LS86. Don't forget to add a decoupling capacitor between the 5 V supply rail and ground rail in the vicinity of the logic devices. A 10 nF or 100 nF ceramic will suffice.

For several reasons, some form of buffering between the control circuit and motor windings is required. LS devices are incapable of, and indeed are not designed to, drive loads; LS devices operate off 5 V whereas stepper motors operate off 12 V usually; the noise generated by motor windings switching off might upset the sequential logic. Perhaps the simplest form of buffering (Fig.5) is provided by the ULN2003A 7-stage Darlington driver integrated circuit which contains seven medium current (500 mA) transistors with open collector outputs. It also includes input resistors and *flywheel* diodes.

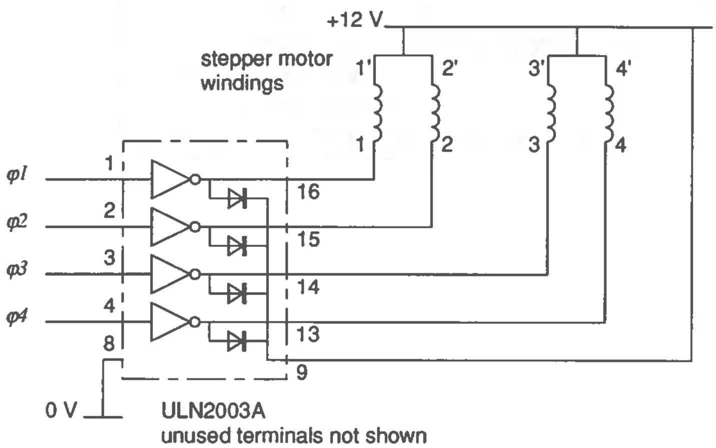


Fig.5 - Buffer circuit with 7-stage driver ULN2003A

Discrete transistors may also be used (Fig.6). Remember though to add the flywheel diodes across the windings. These short circuit the back EMF which is generated every time a winding is switched off. By fitting these, the risk of high voltage damage to the transistors and logic devices is avoided.

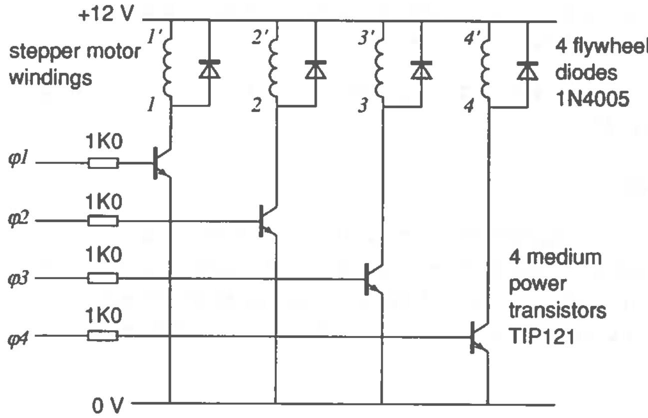
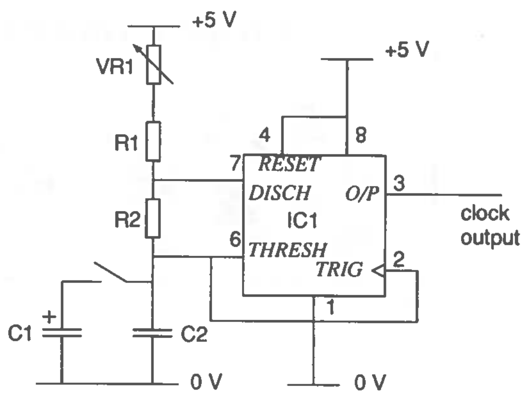


Fig.6 - Buffer circuit with transistors

Note from the circuit diagrams (Fig's 5 and 6) the standard manufacturers' practice of commoning pairs of windings. For instance terminals *1'* and *2'* are commoned, as are *3'* and *4'*.

Clock circuits

Unless the circuit is being controlled by microcomputer, you will need a hardwired oscillator, either a function generator with a TTL output, or signal generator, or self-built oscillator. The latter can be easily built from a 555 timer. It's worthwhile being able to adjust the frequency because much of the experimentation on stepping motors depends on the adjustment of the stepping rate. With the circuit given here (Fig.7) the frequency range is 10 Hz to 500 Hz.



R1	1K0	0.25 W, 5% Resistor
R2	10K	0.25 W, 5% Resistor
VR1	100K	Potentiometer, linear, single turn
C1	1 μF	Capacitor, tantalum bead or electrolytic
C2	220 nF	Capacitor, tantalum bead or polyester
IC1	NE555N Timer	

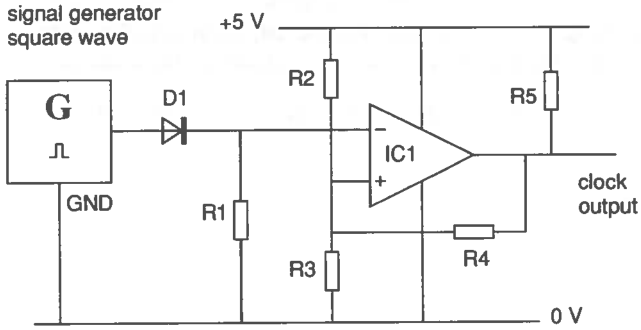
Fig.7 - TTL pulse generator with 555 timer

If the square wave output from a signal generator were to be used, the signal should be conditioned to match TTL logic levels. By using a comparator that works off a single supply rail such as an LM393 or an LM339, you have no need to use a dual rail supply. As the inputs to these comparators should not be taken negative, a diode should be added for protection.

Other ways of driving motors will be described in future articles.

Parts

The components required in the circuits are all commonplace and are available from many stockists such as Farnell Electronic Components, Rapid Electronics and RS Components. Pinouts can be obtained from catalogues or datasheets.



R1	10K	0.25 W, 5% Resistor
R2	22K	0.25 W, 5% Resistor
R3	10K	0.25 W, 5% Resistor
R4	100K	0.25 W, 5% Resistor
R5	3K3	0.25 W, 5% Resistor
D1	1N4148 Signal diode	
IC1	LM339 Quad voltage comparator i.c. or LM393 Dual voltage comparator i.c.	

Fig.8 TTL pulse output from signal generator

SSERC Publications

Technical Articles

CSYS Chemistry

Experiment using a computer - more student material

The procedure shown here is a continuation of that given in Bulletin 172 [1]. This material is presented as an interim measure to assist teachers to meet a new requirement in the Sixth Year Studies syllabus [2]. This states that at least one of the prescribed practical exercises is to be carried out using datalogging and computer interfacing techniques.

HAZCONS

COSHH risk asssessment results and suggested control measures : ethanol, 2-bromo-2-methylpropane (haloalkane) both highly flammable - ensure absence of sources of ignition; avoid inhalation of either vapour but for short exposure times at room temperature handling can be on the open bench; the alkyl halide (haloalkane) is an experimental animal carcinogen - when dispensing wear eye protection and suitable gloves (e.g. Silver Shield or nitrile for a short time); the product 2-methylpropan-2-ol is irritating to the skin but will be in dilute solution. Dispose of carefully to waste with further dilution.

EXPERIMENT G2 - Integration Method (single run for extended time)

The kinetics of the hydrolysis of (2-bromo-2-methylpropane)

This reaction results in the production of H^+ and Br^- ions. The experimental method which uses a single run for an extended time relies on the fact that for dilute solutions conductivity is proportional to the concentration of H^+ and Br^- ions. The voltage output from a conductivity meter is in turn proportional to that level of conductance and such a voltage may be logged by a microcomputer with a suitable interface. The use of a meter output saves the complication of having to calibrate to obtain a reading at time *infinity*.

Software can be applied in order to derive various mathematical functions of such voltages (proportionate to H^+ and Br^- concentrations). These functions correspond to different rate laws. They may be plotted as graphs to determine which yields a linear relationship. Fuller theoretical and mathematical treatment was provided in Bulletins 167 [3] and 172 [1].

Procedures

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 the chemicals

1. Prepare 60 cm^3 of aqueous ethanol in a dry 100 cm^3 conical flask by mixing 48 cm^3 of ethanol with 12 cm^3 of distilled water. If a water bath is used place this mixture in the bath to equilibrate its temperature with that of the bath (20°C or thereabouts is suitable).

2. Set up the apparatus as in Fig.3 on page 12 of *SSERC Bulletin 172*. Adjust the conductivity meter to the 1 x 10^{-3} Siemens scale.

3. Fill a 50 cm^3 burette with the ethanol/water mixture.

4. Using a graduated pipette add 1 cm^3 of 2-bromo-2-methylpropane into a clean, dry 100 cm^3 beaker or conical flask (see apparatus set up in *SSERC Bulletin 167* for the latter).

Setting up the software

5. Load the *Datadisc Plus* program disc into drive 0 of the disc drive and AUTOBOOT - Press <Shift & Break>, lift <Break> then <Shift> to obtain the *Main Menu.* If you want to store data on a disc other than the *Datadisc Plus* program disc press <D> to *Change drive for data*. Collect a blank formatted disc and place it in the second drive. If you have twin $5^1/_4''$ drives then the top side of the bottom drive is drive 1 and the underside of the bottom drive is drive 3.

6. From the *Main Menu* press <Return> to indicate that you are ready to record *Analogue data.* (There is no need for calibration - you will log in the *default* units of voltage which is proportional to conductivity).

7. Press <Return> from the *Recording Options* menu for recording on one channel against time.

8. Press <Return> to record on channel 1. This channel is used because the connections are to channel 1 on the connecting box.

9. Enter <1hour> and press <Return> to set up the computer to log data for 1 hour.

Logging the experimental data

10. Connect a multimeter (adjusted to measure up to 2 Volts d.c.) across *COM* and *channel 1* on the connecting box. The readings on this should parallel those shown on the conductivity meter.

11. From the burette run in 49 cm^3 of ethanol/water mixture prepared earlier. Insert the conductivity probe, shake the mixture and at the same time press the <SPACEBAR> on the computer to begin logging data.

You will see a line moving from left to right on a bare graph with only a rough scaling on the axes. This real-time display of voltage vs. time may show a very small apparent variation in plotted voltage. Do not panic. Software of the Datadisc Plus type looks for the maximum and minimum voltages and will automatically rescale. It will display a more pleasing graph once the data has been processed. As you have set up the logging to last 1 hour, data will be plotted on screen at a relatively slow rate so don't expect to see much within 5 minutes!

12. After the hour has elapsed, note the reading on the multimeter in volts. This is a reasonable approximation of V_∞ if time is pressing. Alternatively you may disconnect the multimeter and computer, leave the reaction mixture overnight, then read off the V_∞ figure next morning by reconnecting the multimeter.

Analysing the data using mathematical utilities

13. When the data has been displayed on screen press <U> for the *Display Utilities Menu.*

14. It would be a good idea to save your valuable data at this stage so type <S>. Enter a <filename> and then some details about the experiment when prompted. This should include a brief description of the amounts of each chemical used, the V_∞ voltage, date, user etc. Press <Shift and Return> together to finish saving. The instructions here assume a V_∞ of 0.841 V to illustrate the calculations.

15. The software will return you to the *Display Utilities Menu.* From there *Select <T> to Calculate related data.* The following display appears on the *Mathematical Utilities* menu:

```
Channel 1 : VOLTS             (x)

Ready to create a new channel of data
mathematically related to that above.

Enter a BASIC expression that will
calculate the new values, referring to
the existing data channels by the
symbols "x", "y", "z" and to the time
corresponding to a point by
"t" (seconds).

New value =
```

Type in <0.841 - *x*> as the right hand side of the equation to display:

```
New value = 0.841 - x
```

The computer assigns the symbol *x* to the original data on channel 1 [in VOLTS (*V*) but representing conductivity (ρ)] and calculates a new channel of data on channel 4.

$(V_\infty - V_t)$ is directly proportional to $(\rho_\infty - \rho_t)$ which in turn is directly proportional to $[RBr]_t$ - the concentration of alkyl halide at time $_t$.

16. Choose *One channel against time* from the *Display Utilities Menu* and display the data in channel 4. Is it a straight line? Or is it a curve with constant half-life? If time permits do a printout and measure the graph manually. If not try the next plot of LOG(V_∞ - V_t) vs. time.

17. A straight line relationship between LOG(V_∞ - V_t) i.e. LOG_{10}[RBr] versus time would indicate that this is a first order reaction with respect to 2-bromo-2-methylpropane. Now repeat the procedure in step 15 but enter <LOG(0.841 - *x*)> to give the display: `New value = LOG(0.841 - x)`

Note which channel number represents the new data.

The gradient of the LOG(V_∞ - V_t) vs. time graph is directly related to the rate constant k by:

gradient = -k/2.303 .... *(EQUATION 1)*

Follow the next step to use the computer to calculate the gradient of the LOG(V_∞ - V_t) vs. time graph.

18. From the *Display Utilities Menu* type <Y> to select *Least squares fit*. The following display appears on the *Mathematical Utilities* menu:

```
Least squares fit of y = Ax + B
Enter either the channel number
for x or T for time as x ->
```

Type <T> and press <Return> as the x-axis of the rate graph represents time.

19. You are asked to *Enter the channel number for y ->*. Enter e.g. <3> and press <Return>. The number you enter here should be the one you noted at step 17. The program then shows percentage completeness values up to 100 as it processes the results. The display then appears as:

```
y = (gradient)x + (intercept on y-axis)
y represents channel 1 data (best fit
straight line goes on a free channel)
x represents time (s)
Correlation coefficient =
```

The important number to record on paper is the gradient. The *Correlation coefficient* should be 1 for a good straight line fit with positive gradient or -1 for one with negative gradient.

You can see how well your *best straight line* corresponds to the original LOG(V_∞ - V_t) data by plotting the two together on the same graph.

20. Subsitute the value obtained for the gradient in *EQUATION 1* and obtain a value for the specific rate constant k.

Scale

Note that in the interests of economy and conservation it is feasible to carry out the reaction on a even smaller scale. Most conductivity cell probes will fit inside a boiling tube. A total volume of 15 cm^3 of reaction mixture will then easily cover the cell. The tube will not however be self supporting and will need to be held in a clamp.

References

1. "CSYS Chemisty", Technical Articles, Bulletin 172, SSERC, January 1992.
2. "Memorandum Number 16", SCDS (now SCCC), 1982 under revision.
3. "Applications of information technology", Feature Article, Bulletin 167, SSERC, September 1990.

Equipment Notes

Digital coulombmeters

Five models of digital coulombmeter are compared and their performances contrasted with that of an older model of electrometer. The article concludes with a brief description of the use of digital coulombmeters in teaching electrostatics.

Introduction

There can scarcely be two more obscure instruments in physics education than the gold leaf electroscope and the electrometer. Does the electroscope measure the quantity or polarity of charge, or potential difference? Does the electrometer measure voltage, or current, or charge, or even capacitance or resistance? Or is it an amplifier? These are the sorts of questions that beset the more perspective of our students and teachers. Goodness knows what the rest make of them.

Happily this mumbo jumbo can all be forgotten. With the advent of the digital coulombmeter, electrostatics can be studied with a perspicacity hitherto unknown. A pity it's been pushed to the edges of the syllabus!

How the meter works

A coulombmeter has two input terminals, one for the signal input, and the other at the 0 V reference mark of the meter's electrical system. A capacitor of capacitance C is fitted internally across these two terminals. When charge Q is placed on the signal live terminal, this capacitor charges up. A very high input impedance amplifier connects to the signal input to measure the voltage V across the capacitor. Charge is derived from $Q = CV$.

The method depends on charge sharing and assumes that virtually the entire charge is taken in by the meter. The accuracy depends on the capacitance of the external charged system being very much less than the meter's internal capacitance. For instance if the internal capacitance is 1 μF and the capacitance of the external charged system is 1 nF, the meter reads low by one part in 1001, or 0.1%. If however the external capacitance is the same as the meter's, the erroneous reading is 50% lower than the actual charge.

Description of tests

Accuracy

The accuracy of the meter was assessed by charge sharing with an external charged capacitor whose capacitance was much lower than that of the instrument. Batches of five capacitors all of 1% tolerance were used. Several such batches were used on each instrument.

Linearity

The linearity was tested by charge sharing using an external capacitor which had successively larger amounts of charge placed on it. Both negative and positive polarities were tested.

Random error

This was determined from the random scatter of readings about the linearity test plot and from successively placing equal amounts of charge on the instrument.

By analysing data from the accuracy, linearity and random error tests, it was possible to look for a systematic error, and where it occurred, to quantify it.

Leakage current

Charge was placed on an instrument and the readings logged over a period of four hours. In every instance, except for the first five minutes, the drift was exponential and very slow changing. In the five minutes after charging, the reading often shifted by several digits over and above the settled long term drift.

Features

Range and resolution

The usual size of charge picked up by an electrophorus from a polythene block is around 40 nC. The range must therefore be large enough to accept several spoonfuls of this quantity of charge. The minimum acceptable range is therefore ±200 nC. Exceptionally however, when relative humidity is abnormally low, as happens after vigorous cold fronts, or in föhn winds[1], a single spoonful may exceed 1000 nC. A range of ±2000 nC is therefore preferable.

If we also consider the resolution, the minimum should be 1 nC, which avoids being pernickety with decimals. For instance, in a spooning charge experiment, the succession 52 nC, 104 nC, 154 nC and 199 nC is easier to reckon with than is 52.2 nC, 103.9 nC, 153.6 nC and 198.5 nC, which would have been given on a meter with a 0.1 nC resolution.

Reset switch

The inclusion of such a switch improves the ease of use. If a reset switch is not provided, the meter is discharged by shorting the terminals with a wire link.

[1] If an air stream loses most of its moisture by precipitation over hills, it is called a föhn wind on descending to the lee of the hills as a warm, exceptionally dry wind.

Position of input terminals

The input terminals to a coulombmeter should be sited on the top of the enclosure so that a collecting plate can be used for the standard experiments of charge sharing, charging by induction, spooning charge and Faraday's ice-pail (Fig.1). Unlike other types of electrical meter which only operate by wiring up, the coulombmeter is often used unconnected. Amazingly, some models of coulombmeter have input terminals fitted to the enclosure front. Were they designed by persons who had never done an electrostatics experiment in their lives?

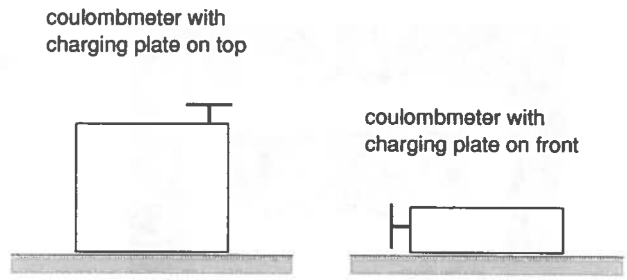


Fig.1 Right and wrong positions of input terminals

Test result summary

Descriptions and test performances are summarized in Table 1. Specific comments on each model of coulombmeter are given below. Each is shown to relative size in Figure 2.

Manufacturer	Griffin	Harris	Irwin	Unilab	Unilab	WPA
Model name	Digital Coulombmeter	Coulombmeter	Coulombmeter/ Nanoammeter	Mini-Electro-meter & DC Amplifier	Digital Coulombmeter	DC Meter
Stock number	XJC-201-J	P81165/3	EA3389	003.814	003.815	KED81
Price	£52.89	£62.13	£132.80	£57.20	£32.63	£218
Description:						
Range (nC)	±1999	±199.9	±1999	-2.0 to +10.0	±1999	±1999
Resolution (nC)	1	0.1	1	0.1	1	1
Capacitance (μF)	4.7	1	1	0.01	1	1
Reset switch	no	yes	yes	yes	yes	yes
Zero adjustment	no	no	no	yes	no	yes
Input terminals	side	side	top	top	top	top
Collecting plate	yes	no	no	no	yes	no
Display	LCD	LCD	LCD	ext. meter	LCD	LCD
Enclosure	polycarbonate	polycarbonate	polycarbonate	ABS plastic	metal	metal
Dimensions (mm)	90x108x74	112x90x45	203x130x37	152x97x62	95x67x74	258x144x175
Weight (g)	210	210	500	420	260	1800
Power source	PP3 battery	PP3 battery	PP3 battery	9 V battery	PP3 battery	240 V a.c.
Signal output	no	no	no	yes	no	yes
Performance:						
Accuracy	±5%	±2%	±1%	±5%	±1%	±2%
Random error	±0.3%	±1%	±0.3%	±5%	±0.3%	±0.3%
Linearity	satisfactory	satisfactory	satisfactory	satisfactory	satisfactory	satisfactory
Leakage current (pA)	3	1	0.5	0.0	9	5
Drift (% h-1)	1.2	3.5	0.2	0.3	3.1	1.9
Markings	clear	clear	clear	obscure	clear	clear
Other features:						
Current	-	-	1 range	2 ranges	-	4 ranges
Voltage	-	-	-	-	-	4 ranges
Assessment	B	B	B	C	A	B

Table 1 Digital coulombmeters: summary of findings

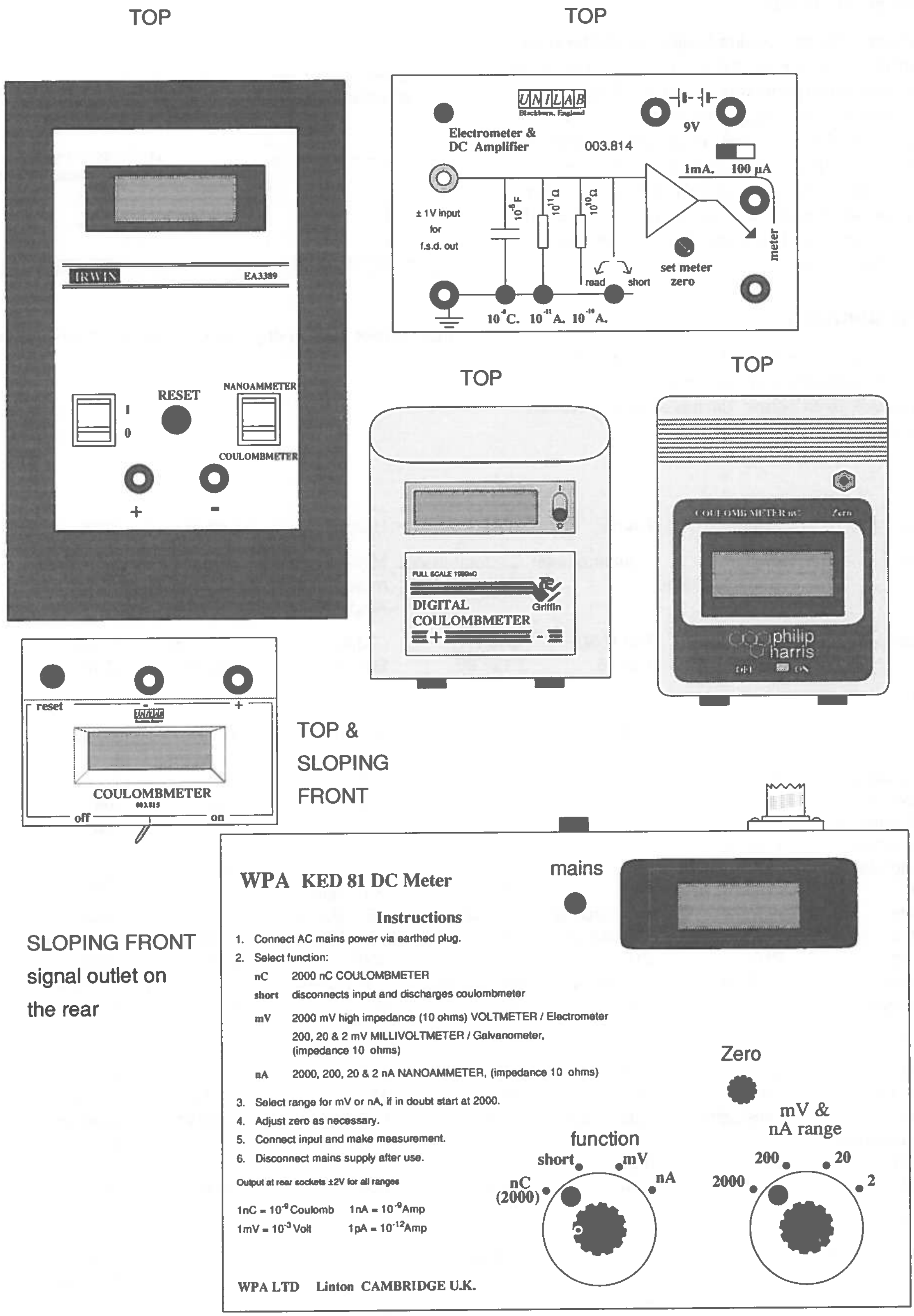


Fig.2 - Coulombmeters, drawn to scale

Griffin Digital Coulombmeter XJC-201-J

This is one of the Theta range of meters. It is very robust, is easy to use and operates reliably. However the sample we tested had a sizeable systematic error. The placement of the input terminals on the front of the enclosure is unfortunate.

Manufacturer's comments: Regarding the systematic error, we have identified a slight error in our calibration method which will be rectified in future production. Regarding the position of terminals, they regrettably had to be placed on the front because the coulombmeter fits into the same enclosure as is used to house the other instruments in the Theta range.

Harris Coulombmeter P81165/3

This meter also is robust, easy to use and reliable. And like the Griffin meter, it suffers from the misplacement of the terminals on the front rather than on the top of the enclosure. The range of ±199.9 nC is a little on the low side and the 0.1 nC resolution possibly too fine.

Irwin Coulombmeter/Nanoammeter EA3389

This meter has the best performance of all those sampled. With respect to accuracy, random error, linearity, leakage current and drift, the meter performed as well as any other in each category, and no other meter performed as well in this combination of categories.

The only snag is the price. £132 is an awful lot to spend on excellence, even with a nanoammeter facility thrown in.

Manufacturer's comment: The price is being reviewed and may be considerably reduced.

Unilab Mini-Electrometer & DC Amplifier 003.814

This dated apparatus can measure voltage, current and charge, and can be used as a high input impedance d.c. voltage amplifier. This report looks only at its facility to measure charge.

By comparison with digital coulombmeters, the electrometer is exceedingly obscure to work with. It is very much a physicists' instrument where you have to be a competent physicist to have confidence in what it does and how it should be used. It is not therefore a satisfactory instrument for benchwork by pupils - particularly not in electrostatics, which is an abstruse part of school physics.

The electrometer we tested had a systematic error, reading about 4% high. Superposed on this was a random error assessed at ±5%. The size of this random error renders any form of quantitative work unreliable and difficult.

The range of the electrometer is too low for some standard electrostatics experiments.

There is a related product which we have not formally tested, the Electrometer & DC Amplifier 003.813, which has many of the features of the Mini-Electrometer. This other instrument has three charge ranges, reading to 1 nC, 10 nC and 100 nC full scale.

Unilab Digital Coulombmeter 003.815

This meter was simple to work with and operated reliably. The sample we tested was accurate, the linearity was good and its random error, small. Relative to the others tested, its leakage current was largish and led to an appreciable drift in reading. However the size of drift at 3% an hour is unlikely to be significant in the usual range of experiments.

Manufacturer's comments: We were surprised at the relatively large leakage current on the Digital Coulombmeter and would have expected that the leakage and drift on the Mini-Electrometer would have been the greater of the two. We suspect that there may have been a fault with the digital unit. The range of the electrometer was set originally by the Nuffield team to cover a charge range of 0 to 10^{-8} C.

WPA DC Meter KED81

Like the Unilab Electrometer, this is a multi-function meter. In addition to measuring charge, it has four voltage ranges (±2.000 mV, ±20.00 mV, ±200.0 mV and ±2000 mV full scale) and four current ranges (±2.000 nA, ±20.00 nA, ±200.0 nA and ±2000 nA full scale). The £218 price tag reflects these many functions.

The scope of our tests covered only the coulombmeter function. Performance was generally sound. No significant adverse points were found.

A welcome facility, not found on any other digital coulombmeter, is an electrical output, allowing for data logging by microcomputer.

Verdict

Assessment codes in the Summary Table are:

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

B - satisfactory for use in above

C - unsatisfactory

Best buy?

Clearly the Unilab Digital Coulombmeter 003.815, at £32.63, having no significant adverse points, and having by far the lowest price, is the best buy.

The technical excellence of the Irwin Coulombmeter EA3389 at £132.80 is worth considering if its nanoammeter facility is also wanted. Also worth considering is the WPA DC Meter KED81 at £218. Not only does it provide comprehensive coverage of millivoltmeter and nanoammeter ranges, it gives you a signal output for electronic data processing.

(See over for notes on experimental uses of coulombmeters).

Experimental uses of coulombmeters

The following standard electrostatics experiments can all be effectively shown:

- charge sharing

- charging by induction

- spooning charge

- Faraday's ice-pail

- use of proof plane to sample surface density of charge on a large charged object

- showing that charge on a capacitor is proportional to voltage

It is recommended that an electrophorus is used in the demonstrations of charge sharing, charging by induction and spooning charge. The electrophorus should be charged by induction by placing it on a rubbed polythene or plastic slab. Excepting the Q versus V experiment, a charging plate should be fitted to the signal input of the coulombmeter. The capacitance of the capacitor in Q versus V should be at least one hundred times less than the meter's internal capacitance.

Unfortunately the capacitance of digital coulombmeters is too great to be used in showing photoelectric emission from metals. The gold leaf electroscope is the only simple means of showing this effect.

New course material

Computer control packages

We had a visit recently from Moshe Barak of Technion, the Israeli Institute of Technology, who is spending a year's sabbatical with MEDC in Paisley. Moshe has devised courses in computer control for use in upper secondary and middle higher[1] education and has translated these into English for use in this country.

Computerized light control

The first package Moshe has prepared is called *Computerized Light Control*. It comprises, in one form, a perspex box modelling a room with eight MES lamps on the ceiling and a phototransistor on the floor. There are also student notes, which run to 80 pages, an I/O card with 8 bits in and 8 bits out for the PC, a driver card for running the eight lamps and an A-D with signal conditioning to process the phototransistor signal, and sets of programs for the PC. The versions we saw were written in Turbo-Pascal. However software for UK establishments will probably be issued in BASIC, with PASCAL versions listed in the Student Manual.

The final hardware may be scaled down to matchbox size with LEDs replacing the lamps. A BBC Computer version may become available.

The course is in two parts. The first part describes the theoretical background. The second consists of laboratory experiments underpinning the theory.

Theoretical background

1. *Computers in control systems*: open loop control, feed-forward control, feedback control and computerized closed loop control.

2. *Activating external devices by the computer*: on-off control, computer programming, continuous control by D-A, pulse width modulation.

3. *Measuring the controlled variable*: analogue measurement and signal conditioning, A-D conversion, reading data through the input port, data sampling.

4. *Computerized closed loop control*: stepwize control, closed loop control by pulse width modulation, proportional control, proportional-integral control, proportional-integral-derivative control.

Laboratory experiments

There are five graded practical exercises, which should give the student the tacit knowledge necessary to support the theoretical parts of the coursework. Supporting software is provided.

Computer vision

Moshe's other course describes the mathematical processes for deriving information obtained from an optical scanner. The hardware consists of an array of 64 phototransistors in an 8 × 8 matrix. Factors worked out by the processing include the central coordinates of an object, its size and its orientation.

The context is robotics. A robotic arm should have the capacity automatically to adjust its gripper to suit the position, alignment and size of the object it is required to pick up.

Availability

FE colleges can obtain the materials required to run these courses by applying to MEDC. Means of working out ways whereby schools can obtain the materials have, at the time of writing these notes, still to be settled. However MEDC have provisionally offered to supply a limited number of schools, on a first come first served basis, with a set of student notes, bare p.c.b. boards, parts list, circuit diagrams and software. The projected cost is £25 a course. Any school buying the materials would then have to assemble their own circuits and associated hardware.

[1] This is nearly as silly as George Orwell's lower upper middle class.

Technical Tips

Alpha repairs: Solenoid unit

Wallace High School has offered a useful and simple method to overcome a problem often encountered with the solenoid unit supplied with Unilab Alpha boards. The problem is one of vandalism rather than component failure. Pupils remove the plastic end cap from the solenoid armature resulting in the spring or armature being then lost or mislaid. The solution is a spot of super glue on the cap shaft. The school reports no further occurrences of dismantled solenoid units.

Photodiode pin identification

Brevis esse laboro
Obscurus fio

(I strive to be brief, and I become obscure : HORACE)

In the article on photodiodes in our last issue, seven different photodiodes were mentioned, but the pin-out diagram of only one of these was given. I had a gut feeling at the time of writing the article that this would not be sufficiently helpful and apologize for the omission.

The root cause of the problem is the cryptic description in the supplier's catalogue. For instance, for our recommended diode choice BPW34, Farnell tell you that "Ident = Cathode".

For readers brought up in the art of disencryptology, the message, though terse, is perfectly clear. For the rest of us - at least for this bear of little brain - I feel confused like Piglet, who, you remember, thought he had an ancestor *TRESSPASSERS W*, or like Eccles, Major Bloodnock and Neddy Seagoon, confronted by an awful terror[1] behind a locked door in a London underground train - the door bore the legend *MIN THE D OR*.

Getting back to the point - or as it used to be said "And this is where the story really begins ...." - *Ident = Cathode* tells you that the cathode carries an identification mark. For the BPW34, the mark is a tiny dot of blue ink on the side of the lead fixed to the diode's cathode.

Rapid vice

Our article on capturing impulse with strain gauges[2] carried at least one piece of unsound advice. We were in fact aware of the risk we ran in recommending a small vice from Rapid Electronics costing little more than a Marks and Spencers' prawn sandwich. In making the recommendation, we unfortunately broke our rule of never writing about something before trying it out. (The vice had in fact been placed on a list of items to purchase months before the Bulletin was published. Due to mis-management on our part, we only got delivery of it some days after the Bulletin had gone to the printer.)

The vice (Rapid, 85-0380) is unsound for two reasons. For one, it fails to grip the bench securely. For the other, its jaws do not meet squarely.

A substitute small vice which, yes, we have tried, is the *Economy G-Clamp Vice* of RS Components (stock number 511-162), costing £9.15.

We are sorry for giving you bad advice.

The ring circuit

Pat MacEwan of Our Lady's High School, Broxburn, has given us a tip on how to monitor current in a ring circuit with one ammeter only.

In the Technical Guide to Standard Grade Physics[3] we recommended using two ammeters in order to balance the resistances of the conductors between the power supply and both sides of the ring circuit. Pat tells us he substitutes a length of resistance wire for one of the ammeters. Obviously the specification depends on the meter resistance. For instance if using a multimeter on its 2 A range whose resistance is 100 mΩ, a suitable balance might be obtained with either 87 mm of German silver, or 47 mm of manganin, or 34 mm of nichrome, all specified for 0.50 mm diameter wire.

Note that these values only hold for ideal conditions. Because of contact resistances and heating effects, some experimenting will be needed to get a tolerably good effect.

Calibrating a xenon strobe

Brian Redman of Selkirk High School has sent us a snippet which may prove useful for anyone faced with the need to calibrate a xenon strobe. Brian places an opto-sensor, which may be either a solar cell or photodiode, in front of the strobe and connects the sensor directly across the *y*-input of an oscilloscope. The trace is a series of narrow spikes, amplitude 200 mV, on the ground level signal. These are made more apparent by connecting a 100 μF capacitor across the sensor to add width.

Any small solar cell or photodiode sensitive to visible light should suffice. The photodiode can be reverse biased as shown in the last Bulletin issue[4].

[1] This goes back to the Quatermass terror.

[2] "Capturing impulse with strain gauges", Bulletin 171, October 1991, page 13.

[3] Activity 28 - The Ring Circuit, Technical Guide, Standard Grade Physics, Volume 1, pages 72-3.

[4] "Higher Grade Physics: Photodiodes: Part Three: Fast response", Bulletin 172, January 1992, pages 20-1.

Trade news

Welcome PASCO Scientific

PASCO Scientific is a Californian company with one sole business - they design, manufacture and service products for educational physics laboratories. Founded 28 years ago, using, then, as they all seemed to do, a garage as a workshop, the company now supply an extensive range of apparatus. Whilst many of their products are usable in junior secondary, many are specialist items for upper secondary, or junior university, level.

The company recently decided to market their products in the UK. They sell direct, and do not use agents. If a Scottish school wishes to buy from PASCO, they should order directly from their Californian address. Taking advantage of modern telecommunications and airfreight, this procedure, assert PASCO, should be no more onerous than ordering from a local UK company.

If you are interested in finding out about their product range, write to PASCO and ask for a catalogue and UK price list. This is in sterling, prices holding for one calendar year unless the exchange rate goes completely out the box.

If then you are interested in ordering, ask for a quotation. We understand from PASCO that they will sort out currency exchange, import duty, carriage charges and VAT (if applicable). Their quotation will specify what these charges are. If then you decide to buy, send a shipping[1] address, billing address and order number. Local authority order forms may be used. Reassure, if necessary, your regional purchasing officer that bills are paid for in sterling.

Delivery times should be between three to four weeks normally.

For prompt attention, communication by fax is quick and inexpensive. The PASCO office opens at 7 a.m. local time, which is 15 00 hours GMT, in time for you to receive a reply before you leave from work that day.

Evaluation of PASCO products and delivery service

Because PASCO products are now on sale to Scottish schools, the Centre will be including items from their range in our evaluation programme. We are already looking at items of mechanics apparatus and hope to be able to review these in our next Bulletin issue.

To test their delivery service, we posted an order for apparatus on 28th February last year, receiving the goods on 16th May. This was followed by a bill requesting payment in dollars. After writing to say we wished to pay in sterling, PASCO's UK bank contacted us to let us pay that way by debiting our own bank account.

Thus we found that importing from PASCO does not cause too much hassle, and they have apologized for the little trouble we had.

We shall try the service again, and report back on how it went.

[1] OK you guys and gals, but this is how they put it!

Labfacility

Labfacility specialise in supplying sensors and test instruments. Their interests include temperature measurement with thermocouples and temperature resistance thermometers, and electrochemical measurements with pH and oxygen electrodes, and conductivity cells.

They have a policy of promoting their company through schools and colleges. Should any educational establishment wish to receive a practical handbook and wall chart on thermometry free of charge, they should write to Labfacility requesting these items. The handbook is worth getting. As well as including tables of data on thermocouples and resistance thermometers, it provides some of the technical know-how on making proper use of these devices.

Solar water pumping system

Hiltec Solar Limited have sent us a leaflet describing their solar pumping system. According to their notes, it comprises a special pump with electronic drive which can pump at up to 500 litres an hour to a height of 1.6 metres. The system is powered by a protected energy conserving solar panel, which operates even in overcast conditions. The company assert that their system is very safe however wet conditions may be since it does not require either mains power or batteries, and as it only requires light it should run cost-free for years producing no emissions or waste products. The price is £181.90 inclusive of VAT.

If any school is looking for a theme around which to base project work on energy studies, or renewable energy, this system could be worth investigating.

Schools' Laboratory Equipment Company

It is very pleasing to meet up with a full-time teacher who spends his evenings and weekends making his own laboratory apparatus. Doubly so when the person has the skills to make a good job of what he builds. Wilson Fraser has taken his hobby one stage further than most and set up the Schools' Laboratory Equipment Company.

His products include apparatus storage boxes for multimeters and Unilab Alpha boards, simple apparatus for practical investigations in physics, and circuit boards. The samples we looked at were well designed, soundly made and attractively finished. A catalogue is available. The company address can be found on the inside rear cover.

New software from djb

The *Relational Investigations* package gives users the means of establishing mathematical relationships between variables obtained from data gathered from experimental measurement. Data can either be keyed in manually, or imported from the Unilab *Simple Logger*, or djb's *Mechanics Applications* packages, or from the user's own files. There is the facility to transform data by squaring, inverting, or by using logarithmic, exponential or trigonometric functions. There are facilities to fit the best straight line through data, or to present data in spreadsheet format.

The *Tacho Motion* package is software for use with SSERC tachogenerators to monitor, in continuous fashion, the velocity of a moving vehicle. Many different experiments are possible (some were described in Bulletins 160 and 163). It includes the facility to calibrate the sensor in $m\ s^{-1}$. Displacement-time and acceleration-time graphs can be displayed in addition to the direct velocity-versus-time output.

The Centre hopes to review both packages in the next, or next again, issue.

Batteries

We have received a price list from Starta Electronics Limited, a specialist distributor supplying a wide range of cells and batteries.

Singling out one product, D-type zinc-chloride cells from Varta cost 37p each at the 10+ price bracket, or 35p each at quantities equal to, or exceeding, 100. There is no minimum order charge and carriage charges are waived for quantities of 100 or over. For larger quantities, please contact Starta for a specific quotation.

New Fluke multimeters

The series 10 range of autoranging, pocket sized, digital multimeters has a novel feature which, for some teachers, may be ideal, but for most, unsuitable, probably. This clever, but contentious, new feature works out automatically the physical quantity being measured. When inserted into a circuit, the meter selects either voltage, resistance or continuity as appropriate, and selects the range.

Fluke assert that this is an ideal first multimeter for inexperienced operators. Our own fear is that pupils using this gadget may be left even more in the dark about what they are doing and measuring.

Like it or hate it, it's there and can't be ignored. The model with this self-selecting feature, which Fluke call *VCHEK*, is the Type 12. It's available from Fluke distributors such as Farnell Electronic Components, order code 226-970, price £63.95.

Telling the time

Edinburgh Centre for Accelerated Learning, making use of their experience in helping children with learning difficulties, have produced an innovative clock dial to help children who have difficulty in understanding the concept of time telling; this probably encompasses all children.

Brian Hill, the designer of the dial, suggests that a period of 15 minutes, with the clock and the instruction sheet is sufficient for the child to 'master the art of telling the time'.

For those versed in the art, part of the success of the programme draws on kinaesthetic intelligence as an aid to understanding.

We asked a teacher of primary aged children to trial the clock with both average and less able pupils. The findings were positive, success in all cases, although the time taken in practice was found to be slightly longer than the suggested 15 minutes.

Further details on the clock and the techniques used by the Centre can be obtained from Brian Hill at the address shown in the inside rear cover.

Well done, Philip Harris

We are pleased to report that *First Sense*, the computer interface, which we reviewed in Bulletin 171, has received a British Design Council Award, one of only eleven issued this year. The event is sponsored by National Power plc, who awarded *First Sense* with an additional trophy for the most Innovative Product of 1992.

Stereomicroscope offer

SSERC currently has a stock of used, long-arm, stereo-microscopes by Vickers. These are quality instruments which have been checked over and tested by us.

A bargain at £100 each
discounts on purchases of 5 or more

For a full specification see Item number 754 in our list of equipment offers on page 39.

Surplus Equipment Offers

Please note that items are not arranged according to the item number sequence. They have been grouped by similarity of application, or for other reasons. Often the item number serves only for stock identification by us in making up orders.

Please also note that you will be charged for postage. Unless the sum is very small (< £10) payment is best made against an official order and SSERC invoice. However, if sending cash with your order, please include money to cover postal charges. If you fail to make reasonable provision, items of equivalent value may be deducted from your order to pay for postage.

Orders for Strathclyde Regional customers are subject to a surcharge of 25% (currently under review).

Changes in stock

Since most of our stock is bought on the surplus market it is subject to an uncertainty of supply. Some items regrettably become unobtainable. Items recently dropped from our stock list include the precision motor at £5.00 (655), the miniature motor with speed governor (592) and 25 W potentiometer (327). We are sorry for any disappointment this may cause.

Our biggest regret is that the precision motor manufacturer, Portescap, are no longer able to supply us with dead stock. They say we've cleared them out. Our latest purchase was of stock that is not quite dead - hence the colossal hike up in price for tachogenerator motors from £5.00 to £14.00. High though that price is, it still offers you a bargain by being roughly 50% cheaper than comparable new motors from other sources.

Please note that our precision motor specifications now include the back EMF constant, of use in tachogenerator applications in mechanics, or in technology.

New stock items include the Shandon chromatography kit, low voltage submersible pumps, a pulley wheel kit, propellors, braided glass sleeving and safety signs. We also carry a stock of high quality stereo microscopes, which we have reconditioned.

Acknowledgements

The Centre is grateful to the companies Griffin and George, Racal-Guardall and Unilab, who have donated goods for distribution to schools through our surplus sales.

Motors

590 Stepper motor, single phase, 5 V manufactured for clock or other timing device. Delicate gearing with 40 tooth plastic wheel as output. Suitable for demonstration, or as a method of digital input for control or timing. Uni-directional. Dimens. 30 x 25 x 10 mm. £1.20

591 Stepper motor, 4 phase, 12-14 V d.c., 400 mA, 27.5 Ω coil, step angle 7.5°, powerful motor with 15 mm x 6 mm dia. output shaft. Dimensions 40 mm x 70 mm dia. on 70 mm square mounting plate with fixing holes at 56 mm centres. Circuit diagram supplied. £4.50

749 Precision motor, 0.15 - 15 V d.c., no load current and speed 10 mA and 5250 r.p.m., stall torque 24 mNm, 9 segments, dimensions 47.5 mm x 23 mm dia., output shaft 11 mm x 3 mm dia., back EMF constant 2.8 V/1000 r.p.m. Suggested application: tachogenerator. £14.00

750 Precision motor, 0.08 - 24 V d.c., no load current and speed 3 mA and 5300 r.p.m., stall torque 7 mNm, 5 segments, dimensions 32 mm x 22 mm dia., shaft with pinion 4 mm long x 4.5 mm dia. Suggested application: lemon cell motor. £10.00

755 Pulley wheel kit comprising:

plastic pulley wheel, 30 mm dia., with deep V-notch, to fit 4 mm dia. shaft,

two M4 grub screws to secure pulley wheel,

Allen key for grub screws, and

3 mm to 4 mm axle adaptor.

The whole making up a kit devised for SSERC tachogenerators with 3 mm shafts. Specially supplied to SSERC by Unilab. 25p

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

614 Miniature motor, 3 - 6 V d.c., no load current 220 mA at 9600 r.p.m. and 3 V, stall torque 110 mNm, dimensions 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia. 40p

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

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

732 Motor with gear box, high torque, 1.5 - 12 V d.c., 125 r.p.m. at 12 V, dimensions 40 x 40 x 28 mm, shaft 10 mm x 3 mm dia. with key. Suitable for driving buggies, conveyor belt, etc. £5.00 (Some 6 V versions also available.)

748 Powerful small motor, 0-12 V d.c., no load current 300 mA at 12 V, dimensions 50 mm x 36 mm dia., shaft 15 mm x 3 mm dia. £2.00

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

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

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

Miscellaneous items

629 Dual-tone buzzer with flashing light, mounted on small p.c.b. The unit has a PP3 battery clip and two flying leads for switch applications. 40p

710 Sonic switch and motor assembly. 1st sound starts the motor, a 2nd reverses the direction of rotation, a 3rd sound stops the motor. Driven by 4 AA cells (not supplied). 45p

715 Pressure gauge, ca. 40 mm o.d. case, 25 mm deep and 33 mm dia. dial reading 0 - 4 bar (i.e. above atmospheric). With rear fitting for $^{1}/_{8}$" BSP. Suitable for use as indicator for pneumatics circuits in Technological Studies. 75p

746 4 mm push-in fitting, with adaptor for pressure gauge on previous page (Item 715) £1.60

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

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

385 Pressure switch, operable by water or air pressure. Rated 15 A, 250 V (low voltage operation therefore possible).
Dimensions 2" x 3" dia. 65p

419 Humidity switch, operates by contraction or expansion of membrane. Suitable for greenhouse or similar control project. Rated 3.75 A, 240 V. 75p

349 Dual action water valve, 24 V a.c. coil. This is a normally closed, direct controlled, two-way solenoid valve for water. £7.90

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

371 Ferrite rod aerial, two coils MW and LW, dimensions 140 mm x 10 mm dia. 85p

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

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

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

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

353 Reed switch, SPST, 80 mm long overall, fits RS reed operating coil type 1. 30p

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

645 Ceramic magnets, assorted shapes and sizes. 7p

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

742 Key switch, 8 pole changeover. 40p

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

688 Croc clip, miniature, insulated, red. 5p
759 ditto, black 5p

741 LES lamp, 6 V. 15p

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

691 MES battenholder. 20p

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

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

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

724 Dual in line (DIL) sockets - 8 way 5p
760 - 14 way 7p

693 Power supply, switched mode, input: LT d.c., output: 5 V regulated. £2.00

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

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

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

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

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

757 Twin bladed propeller, plastic, diameter 130 mm, fits 2 mm shaft. 10p

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

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

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

659 Assorted rubber bungs, 1or 2 hole, per pack. 50p

743 Aluminium evaporating basin, 100 ml. 60p

744 Aluminium evaporating basin, 100 ml, disposable. 30p

754 Stereo microscope, Vickers long arm type with knuckle joint, mechanically coupled eyepiece tube, x10 eyepiece, x1 and x2 objectives on tumble change, built-in illuminator, some with second illuminator with either top or basal illumination, weight 12 kg, very stable even with arm swung away from base. Suitable for biology, primary, electronics, geology, etc. Equivalent present day model would cost in excess of £250. Delivery can be arranged for multiple purchases, otherwise has to be uplifted. £100.00

Components - resistors

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

737 Ditto, 22 Ω, lin, 36 mm dia. 30p

329 Ditto, 33 Ω, lin, 36 mm dia. 30p

330 Ditto, 50 Ω, lin, 40 mm dia. 30p

331 Ditto, 100 Ω, lin, 36 mm dia. 30p

421 DIL resistor networks, following values available:

62R, 100R, 1K0, 1K2, 6K8, 10K, 20K, 150K, 125R/139R and 1M0/6K0. Price per 10: 30p

420	5% carbon film, $^1/_4$ W resistor values as follows: 1R5, 10R, 15R, 22R, 33R, 47R, 56R 68R, 82R, 100R, 120R, 150R, 180R, 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R, 1K0, 1K2, 1K5, 1K8, 2K2, 2K7, 3K3, 3K9, 4K7, 5K6, 6K8, 8K2, 10K, 12K, 15K, 18K, 22K, 27K, 33K, 39K, 47K, 56K, 68K, 82K, 100K, 150K, 220K, 330K, 390K, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M. Per 10:	6p
BP100	Precision Helipots, Beckman, mainly 10 turn,	10-50p

Components - capacitors

695	Capacitors, tantalum, 4.7 μF 35 V, 15 μF 10 V, 47 μF 6.3 V.	1p
696	Capacitors, polycarbonate, 10 nF, 47 nF, 680 nF, 1 μF, 2.2 μF.	2p
697	Capacitor, polyester, 15 nF 63 V.	1p
698	Capacitors, electrolytic, 1 μF 25 V, 2.2 μF 63 V, 10 μF 35 V, 33 μF 10 V.	1p
358	Capacitor, electrolytic, 28 μF, 400 V.	£1.00

Components - semiconductors

322	Germanium diodes	8p
701	Transistor, BC184, NPN Si, low power.	4p
702	Transistor, BC214, PNP Si, low power.	4p
717	Triac, Z0105DT, 0.8 A, low power.	5p
726	MC74HC02N quad 2-input NOR gates.	5p
725	MC74HC139N dual 2 to 4 line decoders/multiplexers.	5p
699	MC14015BCP dual 4-stage shift register.	5p
711	Voltage regulator, 6.2 V, 100 mA, pre-cut leads.	10p

Sensors

615	Thermocouple wire, type K, 0.5 mm dia., 1 m of each type supplied: Chromel (Ni Cr) and Alumel (Ni Al); makes d.i.y. thermocouple, described in Bulletins 158 and 165.	£2.20
640	Disk thermistor, resistance of 15 kΩ at 25°C, β = 4200 K. Means of accurate usage described in Bulletin 162.	30p
641	Precision R-T curve matched thermistor, resistance of 3000 Ω at 25°C, tolerance ±0.2°C, R-T characteristics supplied. Means of accurate usage described in Bulletin 162.	£2.90
718	Pyroelectric infrared sensor, single element, Philips RPY101, spectral response 6.5 μm to >14 μm, recommended blanking frequency range of 0.1 Hz to 20 Hz. The sensor is sealed in a low profile TO39 can with a window optically coated to filter out wave-lengths below 6.5 μm. Data sheet supplied.	50p
751	Hacksaw blade with pair of strain gauges, terminal pads and leads attached. Suitable for impulse measurement as described in Bulletin 171.	£12.00
502	Kynar film, screened, 28 μm thick, surface area 18 x 100 mm, with co-axial lead and either BNC or 4 mm connectors (please specify type).	£20.00
503	Kynar film, unscreened, 28 μm thick, surface area 12 x 30 mm, no connecting leads.	55p
504	Copper foil with conductive adhesive backing, makes pads for Kynar film to which connecting leads may be soldered. Priced per inch.	10p
506	Resistor, 1 gigohm, $^1/_4$ W.	£1.25

Opto-electronics devices

507	Optical fibre, plastic, single strand, 1 mm dia. Applications described in Bulletin 140 and SG Physics Technical Guide Vol.1. Price per metre	40p
508	LEDs, 3 mm, red. Price per 10	50p
761	ditto, yellow. Per 10	50p
762	ditto, green. Per 10	50p

Other components

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

Items not for posting

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

Glassware

656	Screw cap storage jar, plastic cap, 4 oz., narrow neck	10p
657	As above but with wide neck.	10p
663	Flat bottom round flask, 250 ml.	50p
664	Flat bottom round flask, 500 ml.	50p
665	Flat bottom round flask, 800 ml.	50p
747	Quickfit vented receiver, 10 ml.	20p

Chemicals

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

667	250 ml N.H carbamide (Urea).	25p
668	500 ml dodecan-1-ol.	50p
670	500 g Keiselguhr acid, washed.	25p
671	25 g L-Leucine.	25p
672	500 g Magnesite native lump.	25p
673	250 g manganese metal flake, 99.9%.	50p
674	250 g manganese(II) sulphate AR	25p
676	500 g quartz, native lump.	25p
677	100 g sodium butanoate.	25p
678	500 g strontium chloride AR	25p
680	500 g tin metal foil alloy, wrapping quality, 50% lead.	50p
681	zinc acetate AR	25p
682	2.25 litre ammonia solution.	50p
685	500 ml N-decanoic Acid.	25p
712	Smoke pellets by Brocks. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans, etc Large (each).	50p
	Ditto. Small (each).	40p

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

BEEA, 20 Beaufort Court, Admirals Way, London
E14 9XL Tel. 071 537 4997

Bemco Wilson, Bankhead Drive, Edinburgh EH11
Tel. 031 453 6363

British Standards Institution, Sales Office, BSI,
Linford Wood, Milton Keynes MK14 6LE

djb microtech Ltd., Delfie House, 1 Delfie Drive,
Greenock, Renfrewshire PA16 9EN

Edinburgh Centre for Accelerated Learning,
103 Pierrefords Avenue, Farnborough,
Hants., GU14 8NZ

Educational Electronics Ltd., Woburn Lodge,
Waterloo Road, Linslade, Leighton Buzzard,
Bedfordshire LU7 7NR; Tel. 0525 373666

Farnell Electronic Components Limited, Canal Road,
Leeds LS12 2TU; Tel. 0532 636311.

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.

Hiltec Solar Ltd., Unit 24D, North Tyne Industrial Estate,
Whitley Road, Longbenton, Newcastle upon Tyne
NE12 9SZ Tel. 091 266 3478; Fax 091 266 3478

Irwin-Desman Limited, 294 Purley Way, Croydon
CR9 4QL; Tel. 081 686 6441.

Labfacility Ltd., 99 Waldegrave Road, Teddington,
Middlesex TW11 8LR
Tel. 081 943 5331; Fax 081 943 4351

MEDC, 8-14 Storie Street, Paisley, Renfrewshire
PA1 2BX Tel. 041 887 2158

PASCO Scientific, 1010 Foothills Boulevard, PO Box
619011, Roseville, California USA 95661 - 9011
Tel. 0101 916 786 3800; Fax 0101 916 786 8905

Rapid Electronics Limited, Heckworth Close,
Severalls Industrial Estate, Colchester CO4 4TB;
Tel. 0206 751166.

RS Components Limited, PO Box 99, Corby,
Northamptonshire NN17 9RS; Tel. 0536 201201

Ross Electrical, 13 Macadam Place, Dryburgh
Industrial Estate, Dundee DD2 3XD
Tel. 0382 84151

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

Scottish Examination Board, Ironmills Road, Dalkeith
Midlothian EH22 1LE Tel. 031 663 6601

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

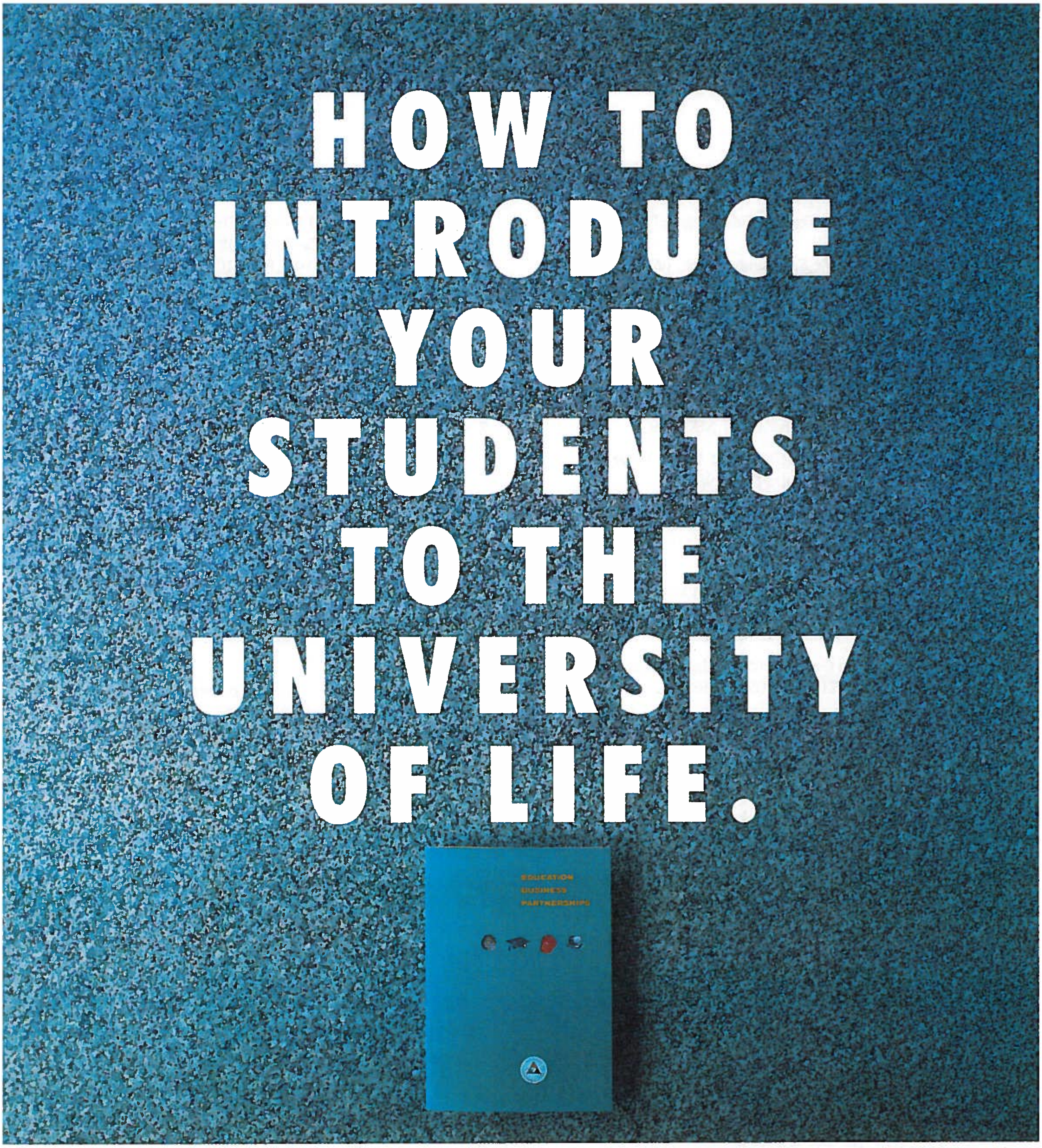
Schools' Laboratory Equipment Company,
1 Loch Place, South Queensferry,
Edinburgh EH30 9NG

Senate Electrical at:
Langstracht, Mastrick, Aberdeen AB2 6HY
Tel. 0224 690981 **or**
45 Loanbank Quadrant, Govan Industrial Estate,
Glasgow G51 3HZ Tel. 041 445 2411

Starta Electronics, 7A Enterprise Trading Estate,
Station Road, Rayne, Braintree, Essex CM7 8TY
Tel .0376 550334; Fax 0376 44559

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

WPA Limited, The Old Station, Cambridge Road,
Linton, Cambridgeshire CB1 6NW;
Tel. 0223 892688.



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