SCOTTISH SCHOOLS SCIENCE EQUIPMENT RESEARCH CENTRE

Bulletin No. 141 **June 1984**

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Typeset by SSSERC in Juki Courier 10 pitch and Triumph Adler Mini-cubic 15 pitch on BBC model B & Beebug Wordwise.

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INTRODUCTION

Normal Service - ASAP

We like to avoid making excuses in these pages. However for those customers who may have noticed some delay in our response to enquiries and the somewhat tardy appearance of this Bulletin issue, we would like to state reasons.

The business of SSSERC is information. Like everyone else in the information game, we have had to deal with new technology in our office practice and publishing activities. This lead to a need to refurbish and rewire our office. Unfortunately in kicking sleeping dogs there is always the danger of being bitten! The rewiring work resulted in the discovery of our nth outbreak of dry-rot.

Add to that our being without our only secretary for a month, family illnesses, bereavement leave and a full exhibition/workshop programme and you will see that these days working at SSSERC is almost as bad as teaching in a school ! Hopefully the dust,literally, should have settled by the start of next session. We can then resume what we hope is seen as our normal high standard of service.

Research Fellow

Scottish readers may recall invitations for applications for this fellowship in a Bulletin insert a couple of issues back. Such matters always seem to take an inordinate time to bring to a conclusion. However, we can now announce the appointment, on secondment, of Mr Ian Downie as a SSSERC Research Fellow. Mr Downie is presently Principal Teacher of Physics at Auchmuty High School in Fife and has acted as a part-time consultant to SSSERC since the beginning of April, 1984. He will join the staff of this Centre in August to begin a full-time two year secondment.

He will be researching and writing a series of technical monographs for schools, on general techniques in microelectronics and in interfacing devices to microcomputers and microprocessors.

The project is industry/education grant-aided through the Industry Department Scotland, British Petroleum PLC and Britoil. In-kind support has been committed by a number of commercial and industrial concerns. The project publications will be distributed through SCDS Dundee Centre.

Scottish Young Scientists of the Year

This competition, sponsored jointly by Marconi in Scotland, the Scottish Region ASE and the British Association for the Advancement of Science (Tayside and Fife Section), is open to all pupils in the secondary sector in Scotland. It will run for the first time in session 1984-85. Details of the competition were sent to every Secondary Head Teacher sometime in April. Have you seen your school's copy? If for some reason it went astray, further copies are available from the ASE Region Secretary (see Address List, inside front cover).

MEDC Courses

We have recently received details of the latest Microelectronics Educational Development Centre course programme, September to December 1984. A number of the short courses offered therein may be of interest to teachers and technicians. For the latter the courses on microprocessor servicing may be of particular interest.

MEDC courses have a reputation as good value. Realistic course fees are charged and these can be anything from £60 for a one day seminar to £210 for a four day course. Compared with fees for machine specific courses as charged by some commercial firms these charges look very reasonable. On any one course a number of free places are reserved for academic staff from the post secondary sector. For further details of this course programme and other aspects of MEDC activity, contact the MEDC Information Officer (see Address List).

Saturday opening

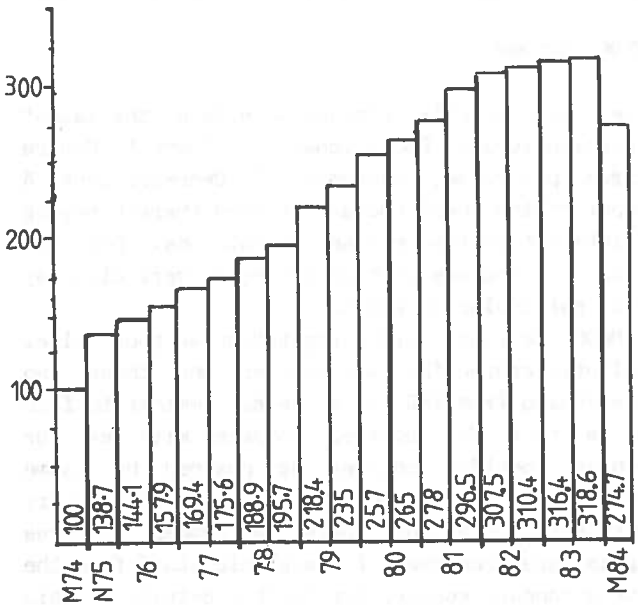
As usual we will be suspending Saturday morning opening during the school summer break. The last Saturday openings in the 1983-84 session were on 2nd and 9th of June. Saturday opening will restart on the 1st September,1984 and then on each of the

first two Saturdays of each month until further notice. Normal weekday hours, 9am-5pm, Monday to Friday will still operate over the summer.

Because staff hope to take leave on rota, you are advised to telephone in advance if you wish to see a specific person for specialist advice.

Cost index

Our cost index marks its tenth anniversary somewhat remarkably. For the first time, it went down! Between November,1983 and May,1984 the index actually fell by 13.8%, from 318.6 to 274.7. The annual figure from May 1983 becomes -13%. Obviously, all of the downward movement has been in the last six months since November '83.



We did not have to look far for an explanation. In costing the shopping basket of consumables, we obtain prices for equivalent items from more than one supplier. The prices included in calculating the index are the lowest quoted. As announced in Bulletin 139, competition for consumables business has become very fierce of late. One major supply house recently introduced major price cuts. Consequently many of their items leapt into our basket dragging the index downward.

Administrators and others would be ill-advised to take up this -13% cudgel against science departments. This first or one-off, decrease should be viewed against the ten year trend shown in the histogram. The decrease is a help certainly, but the index has a lot further to go down to restore lost purchasing power in many science departments. In addition we repeat our recent warning that the index only directly applies to consumables, our shopping basket contains no capital items.

Errata Bulletin 140

We apologise for the errors in Bulletin 140 whereby pieces of text from "In the Workshop" appeared in the midst of "Fibre Optics" in "Physics Notes". We were just testing you. More seriously, this was a printer error at the paste up stage and outwith our control. Sorry! We are now doing our own typesetting. In future any such errors will be all our own work.

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CLEAPSE Guides

We have recently received the following new or revised guides from our sister organisation, CLEAPSE School Science Service. Copies of these publications can be borrowed for up to one month by application to the Director of SSSERC.

L94 "Conductivity Meters." Hints on the use and maintenance of meters and probes with a summary of those available commercially.

L135 "Eye Protection." Part A discusses the problems and gives advice on the types to choose; it also includes sections on maintenance and storage.Part B gives information on current models.

L153B "Interfacing: Commercial Products." The second part of L153 "Interfacing Laboratory Experiments to Computers".

L158 "Laboratory Timing Devices" - mainly stopclocks and stopwatches with some information on wallclocks together with brief mention of the use of computer timer modules as well as GiPSI and VELA.

MEA "Measuring Cylinder repair."

MET "Meters"- zero adjusters,hairsprings,shunts etc., with a note on diode protection.

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SAFETY NOTES

Seeing the light -a shattering experience

We recently received a copy of a Fife circular to Senior Technicians reporting an accident involving a 12V auto bulb. The bulb shattered at switch on. Luckily the flying glass did not cause any damge but this was a potentially serious incident.The bulb was part of a batch purchased from an ASDA supermarket. Marked as made in Romania they were distributed by Ring Automotive, Leeds and rated 12V, 5W.

"Tests on the apparatus used point to the autobulb as being faulty and unsafe for use." Fife has instructed any of their schools holding stocks of these bulbs to withdraw them from use. 'Verb sap'!

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INTERFACING NOTES

"Networking" - an MCC Project Report

Most Scottish schools will have by now received a copy of this report on an investigation into the simultaneous use of a number of computer systems in the science classroom. The work reported on was carried out by Eric Pirie of Kyle Academy, Ayr. SSSERC's involvement was in the broad supervision of the project, with Eric theoretically seconded to this Centre for three days a week. In fact he did the work in his own school and in the end was providing technical assistance to us, rather than the other way around as originally envisaged.

The parent MCC project as a whole is now formally at an end. Since Eric's report went to press he has developed materials which will allow inexpensive networking of ZX81 satellites with machines other than the Apple in the control role. We have to hand sets of notes detailing hardware and software requirements for:

-Sinclair Spectrum with microdrive in the control role with ZX81 satellites. Networking is carried out through the Griffin 'I-Pack' ports.

-BBC Model B with disc drive in the control role, ZX81 satellites. Hardware connection is via the Beeb user port. *

Unfortunately lack of space, and the necessary context of the basic background in the original report, preclude direct publication in the Bulletin.

However we will make these notes available as an unofficial annexe to the MCC report. Terms will be a postal order or cheque for 50p to cover photocopying, payable to "SSSERC" please, and a stamped addressed 23 x 10cm. envelope.

* In co-operation with Mr Munro, Kyle Academy.

Sassenach and overseas readers interested in obtaining copies of the main report and details of other MCC publications should contact the

Scottish Curriculum Development Service
Dundee Centre.

[See Address List, inside cover]

The "Networking" report costs £1-50 including postage and packing. Orders totalling less than £10 must be accompanied by a Sterling cheque or postal order, crossed and payable to Dundee College of Education.

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SCIENCE AND THE HANDICAPPED PUPIL

This is a subject in which SSSERC has long had an interest. Readers may recall Colin Weatherley's sterling work at the Royal Blind School. This was initially part-time while he was Assistant Director at SSSERC and then as a full-time Research Fellow. There always has been a need for technical assistance in these areas. There is now a renewed urgency and interest.

There are possibly two main reasons for this revival. Firstly there has been a developing policy of integrating pupils with special needs into ordinary neighbourhood schools. This is coupled with a very proper concern that such pupils share as fully as possible in all of the curricular elements on offer in the school. One such, major, element is Science. Even where integration is not yet the policy, there is an increased awareness of the need for pupils in 'special' schools to have some kind of science course.

Secondly, developments in technology offer renewed hope of solving problems which a few years ago lead only to admissions of defeat on grounds of complexity, costs or both. Some of these problems may require relatively 'high-tech', if fairly cheap, answers. Other difficulties are more prosaic, requiring for their solution some experience of the problems of handicap and perhaps a deal of lateral thinking.

For example, the talking balance exists. The talking thermometer is equally feasible at an acceptable price,and someone reading this may already have made one. At the other end of the scale (sorry!) - how does one solve some of the problems of the pupil in a wheelchair who cannot work at a science bench designed for the able bodied? Again, we know of some sources of ideas, but possibly someone out there has even better solutions.

Sadly, multiple handicap seems increasingly common. It is thus not simply a question of thinking of the needs of blind pupils or of those with motor difficulties or mental handicap. Some problems may be common to several groups. For example holding equipment steady in an experiment is a difficulty shared by both the visually handicapped and those with motor difficulties. However many groups of handicapped pupils have their own specialised needs.

Unfortunately a very full work programme at this Centre precludes any major primary development effort, from SSSERC staff, in the short term. However the Centre always has acted as a clearing house for ideas and information. We are keen to do all we can in this way for ideas and designs for aids to the learning of science by handicapped pupils. We would welcome correspondence on this subject and even short articles for circulation or publication.

Through our Planning Committee we already have some suggestions from Muriel Buchanan at Firrhill High, Edinburgh. Firrhill has a twinning arrangement with the Royal Blind School, teaching science on an integrated basis visually handicapped and sighted pupils being taught together. Muriel points out that even now very little equipment exists, at an acceptable cost, that allows blind pupils to do science independent of assistance from a sighted pupil.

Some of the problems seem ideal for solution by (micro-)electronic means. Microelectronics is often described as "solutions looking for problems". So, sixth year, and other, projecteers on the annual project trek, how about tackling one of the topics listed under "Project Suggestions" in this issue? The tasks are challenging and the possible end products socially relevant and very worthwhile.

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PROJECT SUGGESTIONS

At this time of year potential CSYS students begin looking for ideas for projects. Finding out about what has already been done is, theoretically, relatively easy. Good ideas for fresher ground to break seem harder to locate. We have lost count of the biology and chemistry pupils wishing to borrow our oxygen meters for stream surveys. The physics and engineering project highways must by now be strewn with the skeletons of dead traffic light systems!

Instrumentation problems and other practical issues may provide routes to successful projects. The SEB rules, quite properly, guard against development of instrumentation becoming an end in itself. If such design and development is accompanied by calibration, data collection and interpretation a great deal of science may be learned.

We are not aiming here to provide complete project briefs nor hard technical descriptions. Rather we give a series of one- or two-liners, a sort of scientific and technical "Why don't you?". We start with basic needs for science teaching aids for handicapped pupils (see page 4.).

1.Temperature measurement

a) A very large digital readout thermometer for the visually impaired, within a tight accuracy and cost specification.

b) A talking thermometer using a speech synthesis chip.

2.Measuring liquid volumes

a) For the visually handicapped, perhaps using opto-electronics, with or without raised external markings on the measuring vessel.

b) For the visually handicapped and/or those with motor difficulties, novel mechanical methods for safely dispensing and measuring liquids.

3.Electrical measurements

A talking multimeter or, less ambitious, a talking ammeter or voltmeter.

4.Colour discrimination

This would open up a great deal of chemistry to the visually handicapped. Translation of wavelength of light to audio frequency or,more ambitiously, speech output.

5.Science in a wheelchair

Mechanical aids -a fertile field involving the physics of movement, engineering design and applied human biology (ergonomics and anthropometry).

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EGG RACES

Continuing on the same arterial, we would draw your attention to a recent publication from the British Association for the Advancement of Science and the British Association Young Scientists (BAYS).

Entitled "Ideas for Egg Races and other problem-solving activities.", this is a very impressive source book. It contains no less than 71 fully specified practical problems suitable for use by organisers of problem solving activities or competitions. Problems are described for a wide range of pupil ages from early primary right through to college students.

Available from the British Association (see address list, front inside cover) price £2-50 plus 75p for postage & packing,it must be an essential weapon in the armoury of anyone interested in promoting open ended learning.

We were delighted to note that the message even seems to be getting through to what many see as some of our more conservative (note the little 'c') institutions. "Ideas for Egg Races" has been published with the support of Lloyds Bank.

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FOUNDATION SCIENCE NOTES

Solar power

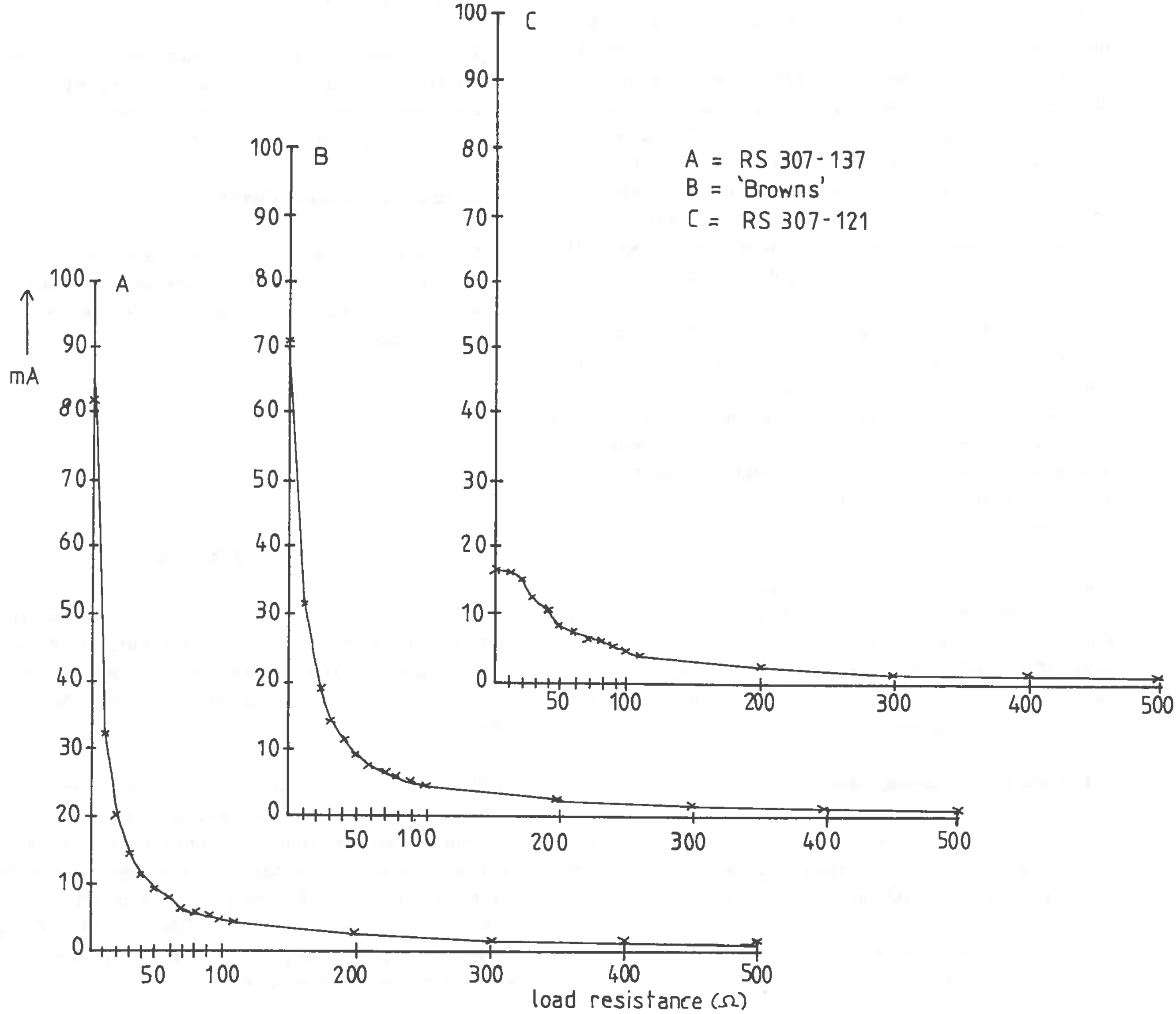

Fig.1.

Three solar cells -current output versus load resistance.

There is a requirement in both of the REFER "Energy" core topic examplars for simple demonstrations of motors driven by solar cells. In our exhibitions we had been using a d-i-y mounted cell from RS and a solar motor sold as a spare by Irwin-Desman.(Type No. RB0272 at £11-45). It is the relatively high price of suitable low current, low friction motors which has been the main reason for restricting these activities to demonstration. Following a suggestion from Liberton High (who else?) we have been looking at one or two other cells and motors.

Not too suprisingly we found that the cells we looked at didn't differ all that much in current output (see Fig.1). We were not too disappointed because, by sheer serendipity, we found that a motor we have stocked for a different application also makes a very good solar driven device.

Motor

This is the same model referred to under "Servo mechanisms" in the physics notes in Bulletin 139. It is a precision made motor obtained by us in numbers as obsolete stock from Portescap. We offered it at £6-30 in Bulletin 139 but that price included a reduction gearbox.

The gearbox isn't needed for simple applications at this level. We can offer the motor alone at £5-50 including postage and packing.

Solar cells

We have looked at three types, the RS encapsulated cell stock no. 307-137 at £3-64; the 'naked' RS cell 307-121 at £1.85 and a large cell from Browns Wireless at £3-75. Figure 1 shows the maximum current produced in full sunlight with the cell in series with a resistance box over a range of settings. The cells were also used under artificial tungsten light. Data for sunlight and a 40W bench lamp, under 'no load' conditions and with the Portescap motor in circuit, are summarised in Tables 1 & 2 below.

Cell	Short circuit current	Cell voltage
RS 307-137	82mA	540mV
RS 307-121	17mA	558mV
'Browns'	71mA	550mV

Table 1

Full sunlight performances.
Figures are for 'no load' conditions.
Portescap motor operates from all cell types under full sunlight.

Cell	Current	Voltage	Motor?
RS 307-137	1.2mA	350mV	YES
RS 307-121	0.5mA	31mV	NO
'Browns'	1.1mA	405mV	YES

Table 2

Figures are for cells at 25cm from a 40W opal bulb in a bench lamp mount, with the motor in circuit. The RS 307-121 did begin to drive the motor when this cell was placed 15cm from the lamp (when it delivered 0.6mA at 350mV).

The cells were also investigated in diffuse daylight, or blue light, indoors. It is difficult to make meaningful comparisons for such light levels. However the crude trials we were able to perform pointed to one advantage of the cell from Browns. At approximately 6 metres from a north facing window it was the only device capable of driving the motor, delivering 1.1mA at 235mV. The two RS cells gave markedly lower figures. The encapsulated cell (307-137) gave only 0.4mA at ca. 1mV, and the naked cell (307-121) only 50uA at about 0.4mV. The better performance of the Browns cell at low light levels was attributed to the presence of a lenticular cover over the active elements and, possibly, its larger area. This larger physical size may be a compensating drawback in other more advanced applications. Here it may be necessary to connect cells, in series or parallel, to charge batteries, drive very small vehicles etc. Several of either of the RS cells could be fitted into the space needed for just one the type from Browns. These cell dimensions are shown below in Table 3.

Cell type	Dimensions(mm)
RS307-137 (encapsulated)	28x22.7x5 (ex.pins)
RS 307-121	10x10x0.22
'Browns'	95x65x7

Table 3. Cell dimensions

D-i-y mounts

The smaller cells are best used on some kind of mount provided with standard 4mm terminals. Suitable mounts for both cell and motor are easily made from that SSSERC favourite - plastic rainwater pipe. Sketches of such mounts made from sections of such pipe are shown in figure 2.

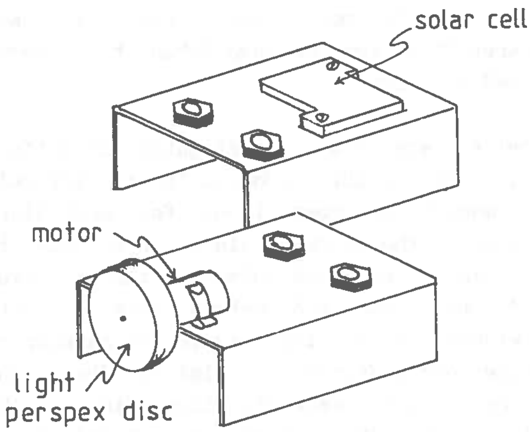

Fig.2

Hopefully, we have given some useful information, assisting application of these cells at this level. As with the other "Energy" sub-topics, there is ample scope for extending such work at this and other school levels. Such further use of solar cells is a topic to which we hope to return either in the Bulletin or possibly another, separate, SSSERC publication.

* * *

Toothpaste recipe hints

In the Tayside examplar "Healthy Bodies",Workcard 4 deals with pupil preparation of small samples of toothpaste. Unfortunately, as printed, the recipe produces a very stiff mix unless additional water or glycerine are added. The need for clarification of this and other small details, has lead to a request for us to publish additional information.

The "dental soap" referred to is purchased as sodium lauryl sulphate or sodium dodecyl sulphate (e.g. Harris S78960/9,£3-11 for 250g).

The "gum" is gum tragacanth (Harris S42645/8, £6-96 for 100g). Two alternative recipes to the somewhat skeletal version in the REFER examplar are given below:

	(i)	(ii)
precipited calcium carbonate	45%	57g
dental soap (sodium lauryl sulphate)	4%	1g
distilled water	28%	19.5g
glycerine	20%	21g
gum tragacanth	1%	1.5g
flavouring	1%	1 drop
saccharine	/	1 drop
preservative	/	1 microspatula full

The first of these recipes comes from "The Science Master's Book - Chemistry" (ASE) and is the same as that in Griffin's excellent little booklet on Cosmetic Science. Neither versions explain the nature of "%", but we think it reasonable to assume that this is by weight. This recipe produces a reasonable paste,but we find the second to be better (there we go again, sounding like an advertising agency!). This second recipe is from "Practical Cosmetic Science" by Ann young and published by Mills and Boon (no kidding!). This recipe was sent to us by Dreena Campbell of Craigie High School, Dundee together with other snippets which may be of interest, and which we summarise below.

Toothpaste contains several types of ingredients:

(a) Polishing agent

This is obviously one of the most important ingredients. It helps remove particles of food and discoloration. Materials chosen for this role include - precipitated chalk; tricalcium phosphate; aluminium sulphate and magnesium trisilicate.Approximately half of the weight of most toothpastes will be accounted for by the polishing agent(s).

(b) Moistener or humectant

This prevents drying out and hardening of the paste. Suitable agents are - glycerine; sorbitol and propylene glycol. Glycerine is one of the more suitable agents in this present exercise.

(c) Detergent and foaming agent (dental soap or cream)

A small quantity, 1.5 to 6%, aids the polishing action by acting as a wetting agent on the teeth. The most popular agents for this role are sodium or magnesium lauryl sulphates.

(d) Binding agent

Natural gums (oops!) such as gum tragacanth are often used or other natural agents such as starch or sodium alginate. This last is available from, for example, BDH, or their many agents, BDH Cat.No. 30105 at £2-70 for 100g. Also used is carageen or Irish moss extract, often to be obtained from health food outlets. Synthetics such as polypropylene glycols are also employed.

(e)Sweetners

Ingredients such as saccharine at 0.1 to 1.3% may be used. These are preferred to natural sugars which tend to crystallise and spoil the smooth paste.

(f)Flavouring

Oil of peppermint is one of the commonest used but the field is wide open for experimentation. It is probably only a matter of time before smoky bacon toothpaste appears on the market.

(g)Preservative

The most commonly used are sodium hydroxy-benzoate and sodium benzoate.

All preparations, despite minor differences in recipes, tend to follow the same sequence:

1. Dispersion of the binding agents in the humectant.

2. Slow addition of the detergent, so avoiding foaming difficulties.

3. Addition of water and preservative.*

4. Addition of sweetener and polishing agent with thorough stirring to ensure a smooth paste.

5. Finally the flavouring is added.

*For school work where the paste will not be stored for any time, there seems little point in adding preservative.

Evaluation of the finished product may seem fairly pointless to pupils if only consistency (finger test) and smell are noted. The activity is more fun if samples are used by pupils to clean their own teeth. This may cause problems unless certain common-sense precautions are taken.The use of laboratory glassware is most inadvisable because of the risk of contamination by other, hazardous, chemicals. It is also obvious that special stocks of ingredients are kept for this preparation and that they should be clearly labelled to this effect.

An alternative, though second best, trialling could be done by cleaning a set of model teeth (e.g. Griffin ZKH-750-Q, £36) or old sets of dentures (ugh!), pre-stained with water soluble dye.

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BIOLOGY NOTES

Thermistor Applications

Abstract

The case is argued for greater interest in and understanding of electronics by biology teachers. Thermistor applications are presented as one possible easy way into the construction and use of simple circuitry. The advantages of thermistors in detecting small temperature differences of physiological significance are outlined, together with some of the associated snags. The article then describes in more detail some simple circuitry and its application in the study of human physiology. Suggestions for further developments are made.

Introduction

One of the aims of this article, and of others to follow, is to encourage more biology teachers to develop an interest in modern instrumentation. Electronics is inescapable these days, even for the biologist. Outwith schools the professional physiologist, microscopist and ecologist all may routinely use electronic instrumentation. Even the nature study merchants aren't above fitting a radio collar to the odd fox! Hopefully there will always remain a primary place for simple observation and direct measurement. As we have said before in these pages, even in these days of satellite weather forecasts it still pays to look out of the window. Nonetheless the day is approaching when the first, and last, time a student may see a mechanical auxonometer or kymograph will either be in a museum or a school.

Whether,as biologists, we welcome or regret this trend is largely irrelevant to our need for better knowledge and understanding both of the advantages and the limitations of available transducers and circuitry. In turn this will lead to better informed decisions on the proper educational use of indirect measurements and on when other methods are preferable. For example, here we describe aspects of electronic temperature measurement. There are situations where such measurements are fully justified. There are others where a tube of glass containing a liquid is the better instrument to use.

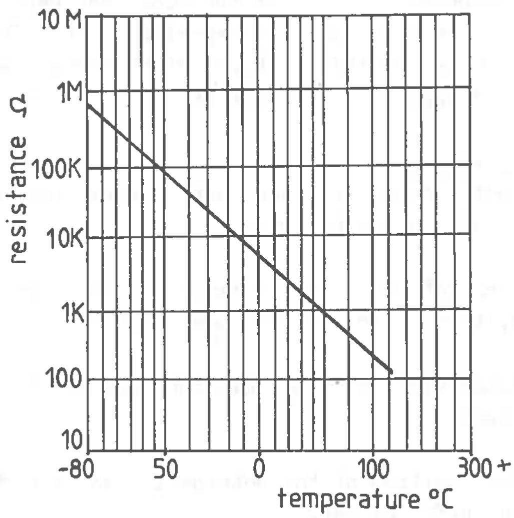
Some teachers condemn all electronic thermometry regardless of its context. Yet others we have seen using it outwith a proper context and hung on to a £1,000 computer system at that!

The current position - a mixture of reticence, downright technophobia and either ill-informed over-exuberance or destructive criticism - assists no one.

We start with thermistor circuits because the components are cheap, difficult to damage and, although thermistors themselves may exhibit some complex behaviour, the basic ideas behind the transducer circuitry are easy to understand.

Thermistor characteristics

Thermistors are pieces of semi-conductor material (e.g. oxides or other compounds of titanium, manganese, cobalt or nickel) whose resistance alters dramatically as their temperature changes. With the commoner types their resistance falls as their temperature is increased (see Fig.1.). In electronic jargonese they are thermally sensitive resistors with high, usually negative, temperature coefficients of resistance.



GL23 thermistor
Redrawn from extracted RS. data

Fig.1.

Thermistors are available in a wide range of physical forms or packaging, from naked beads through discs to robust mounts in metallic probes.

They have typical sensitivities an order of magnitude better than metal resistance thermometers, giving resistance changes of three to four percent per °K rather than the few parts per thousand per degree exhibited by a platinum resistance thermometer.

Bead form thermistors because of their small size, respond relatively rapidly to temperature changes. A further advantage is that, unlike metal resistors, when small they still have high initial resistance. This is advantageous because even for a small current flow through the thermistor the actual voltage change across the device, with a small change in temperature, is appreciable. The need for a small and limited current for temperature measurement arises because of the accompanying heating effect, the current heating up the thermometer itself. If the current heats up the thermistor significantly, then a number of complications may arise. Fortunately some of these may be put to good use in applications other than temperature measurement.

If the thermistor is gradually heating up because it is passing more current, therefore drawing more power, than it can dissipate as heat to its surroundings its resistance will gradually drift downward. It will then go on passing an increasing current until the total available power in the circuit is reached when an equilibrium will be established. Any environmental variable which changes the rate of heat loss from the thermistor may then affect the input to the measuring circuitry. The thermal conductivity or rate of flow of the medium surrounding the thermistor, as well as its actual temperature, may become important.

For example, the thermal conductivity of carbon dioxide is only about half that of air with that of water on the other hand being much greater than that of air. With a thermistor circuit which was not sufficiently current-limited, a temperature calibration made for one such medium would not hold for either of the others. So, for thermometry we would aim to keep heating effects to a minimum. Manufacturers of thermistors quote maximum dissipation figures in milliwatts (mW) and dissipation constants in $mW°C^{-1}$. For temperature measurement applications these design parameters must be taken into account (see below for a specific example).

For other applications we may aim to deliberately introduce the heating effect in order that we may detect environmetal changes affecting the thermistor's rate of cooling. Two good examples of such applications are in detectors for gas-liquid chromatography and in anemometry.

In the first type of application the separated components are detected because of differing thermal conductivities both between components and that of the mixture/carrier gas stream.

In anemometry, the measurement of gaseous flow rates, a heated thermistor is cooled and its resistance rises more rapidly the faster the gas flows across it. Here the problem is the opposite of that met in straightforward temperature measurement. Some fairly complex circuitry may be needed if flow rates are to be accurately measured over a range of ambient temperatures. This is because the temperature of the gas as well as its rate of flow has an effect on the cooling rate of the thermistor. Where the flow rate is that of air - for example in wind speed measurements -this additional variable clearly may be very important.

Happily, because of their large temperature coefficients of resistance, thermistors can often be used with simple circuitry. The more sophisticated circuits, compensating for non-linearity by using more expensive resistance/temperature curve matched thermistors, are only required for accurate measurements over a wide range of temperatures or for the more specialised applications touched upon above.

Of course the corollary is also true. Beware the cheap thermistor based device claimed to accurately measure the more demanding parameters such as air speed. Beware also the cheap thermistor thermometer claimed to measure accurately over a wide range in a variety of media such as air, salt- and freshwater.

Simple circuits

Probably the least complicated circuit in which to use a thermistor is to connect it directly to a digital multimeter on the Ohms range and measure directly its varying resistance.

A calibration graph of temperature versus resistance can readily be drawn up. A more usual circuit is the classic Wheatstone bridge, the general layout of which is illustrated schematically in Fig.2.

In biology we are often more interested in discovering small, relative temperature differences of physiological, or microclimatic, significance than we are in accurate absolute measurements. Thermistor bridge circuits lend themselves well to detecting such differences.

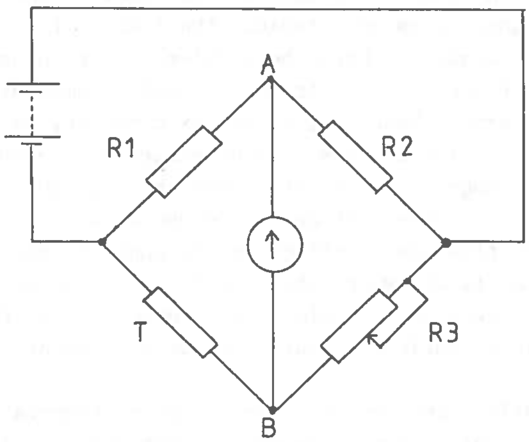


Fig.2.

R1 and R2 are chosen with the same values, each say roughly half of the nominal resistance of the thermistor at room temperature. The variable resistor, R3, has a value similiar to that of the thermistor so that the bridge may be balanced. Balancing means equalising the total resistance in each half of the bridge so that there is no potential difference (no voltage) and therefore no current flow between the points marked A and B on Fig.2. Should the temperature of the thermistor then change, so will its resistance. The bridge will no longer be in balance. An out of balance current will flow which can be detected on a meter connected between A and B.

Alternatively the potential difference now developed across A and B may be detected on a voltage sensing device. This can be a meter, potentiometric chart recorder or an analogue to digital converter (ADC) and a microprocessor /microcomputer.

Instead of balancing the thermistor solely against a variable resistor (R3,Fig.2.), a differential method or compensated bridge may be used (Fig.3.). With very sensitive naked bead thermistors this is the basis of the gas liquid chromatography katharometer detector referred to earlier. Here a matched pair of thermistors is used, one in the carrier gas just before the sample injection port and one at the column exit in the separated components.

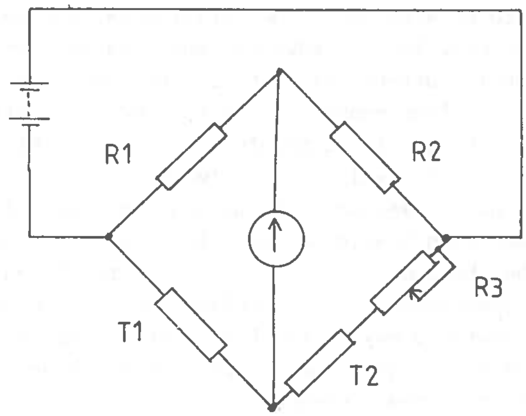


Fig.3

Such a circuit also has uses in biology as a sensitive differential thermometer. One thermistor may be placed in a control vessel or position, the other in the experimental. Any generalised environmental temperature changes should be common to both thermistors and thus cancelled out by T2. This can be useful when very small temperature differences are to be detected against a background of general thermal noise.

Practical examples of applications.

Both of the examples detailed below use the same, uncompensated, bridge circuit (Fig.4).A stripboard layout for a working circuit is given in Fig.5.

It will be noted that this practical circuit is a little more complex than that shown schematically in Fig.2. Two variable resistors are used, rather than the one "R3". In practice it proves difficult to accurately balance the bridge using only one variable resistor. Here we have set up instead a simple potential divider circuit. The 2K5 (2.5 kilohm) potentiometer gives a coarse, and the 1K a fine, control. Additional fixed resistors are also used to bring the bridge nearer the point of balance.

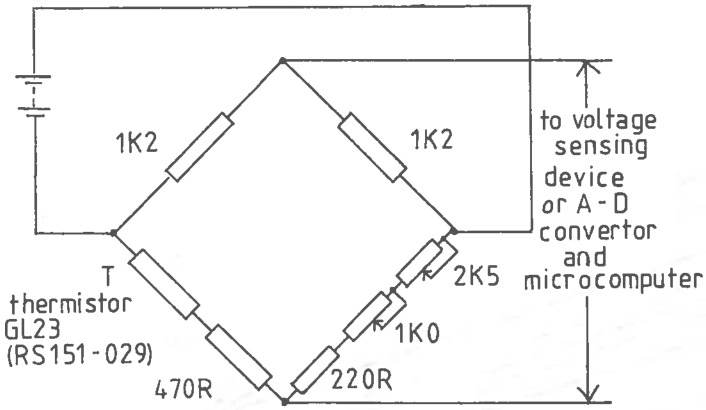


Fig.4.

The finer details of this circuit were arrived at by trial and error. This is freely admitted. Indeed this can be one of the more refreshing aspects of electronics. After due theoretical consideration, a detailed solution to a problem may only be gained via a final suck it and see stage.

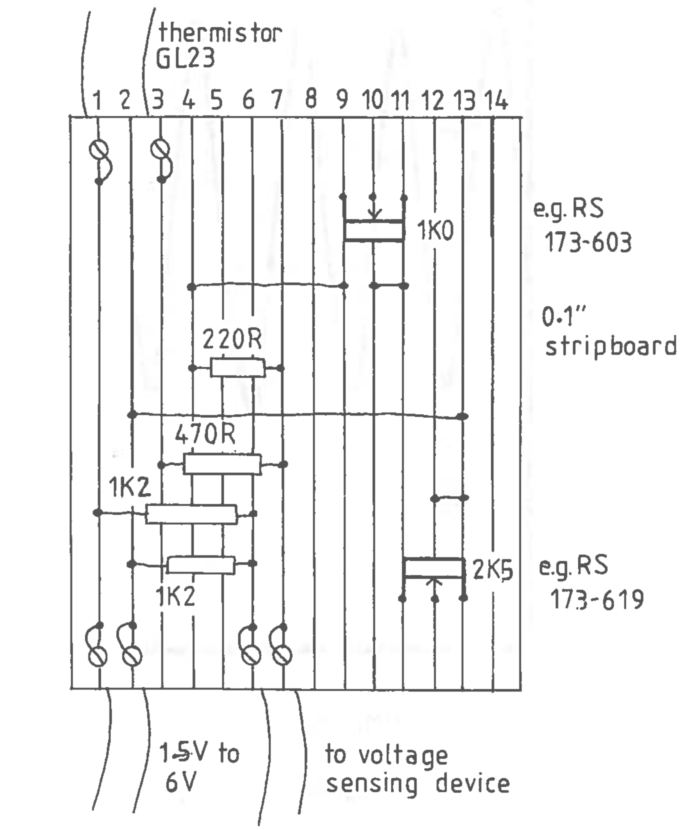


Fig.5.

The nominal resistance of the GL23 thermistor at approximately room temperature (20 C), is 2K . The bridge power supply must be floating. That is to say the negative side of the supply must not be connected to earth or some other point nominally at zero volts (i.e. it must not be grounded). A dry cell or battery proves a very convenient power supply. In our tests we used 1.5V; 4.5V and 6V batteries. The circuits performed satisfactorily with each of these but we suggest that in applications where temperature differences, rather than other variables, are the main concern it is better to stick to the lower voltage, 1.5V, wherever possible.

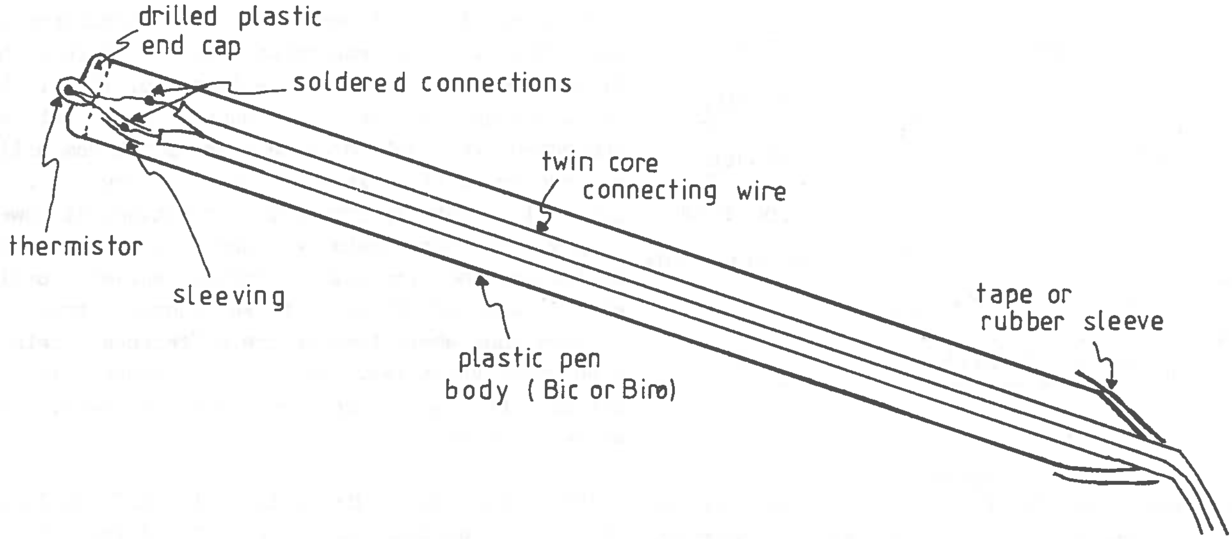
The maximum power dissipation of a GL23 is 130mW and the dissipation constant 1.2mW $^{\circ}C^{-1}$. Calculation, and measurements on the circuit itself, suggest that at the higher voltages quoted the thermistor may heat up significantly. As explained previously, this will mean that factors other than temperature begin to also have significant effects.

The thermistor will usually have to be mounted in some way. We chose to construct a poor man's probe using an old plastic pen body (Fig.6.) but other mounts and formats to suit particular applications are possible [See Ref.1, and suggestions below].

Use as a breathing monitor.

Inhaled air is cooler than exhaled air. There are other differences, such as moisture and carbon dioxide content. To keep things simple a 1.5V bridge supply should keep the effects of these other variables minimal.

The simplest arrangement is to hold the pen probe (Fig.6.) close to the lips and breathe in and out over the thermistor in its tip. A chart record obtained using this method, with the bridge output fed directly to a JJ CR500 recorder, is shown in Figure 7. This shows resting rate and depth of breathing. It is a simple matter to extend this to obtain such recordings before and after exercise.



Approx. ×1

Fig.6.

If desired, a more robust breathing monitor may be made by mounting the bridge circuit and battery in a box with the thermistor mounted so as to protrude into an internal tube. A length of breathing hose with removable mouthpiece (for disinfection) can be coupled up externally.

Probably more schools possess microcomputers than ever held chart recorders. We have also carried out these experiments using a range of interfaces and software. D-i-y arrangements are possible with the BBC model B, using as a basis the information given for the Beeb analogue port in Bulletin 140. We have also used the circuit successfully with Beeb and:

- the Harris 4 channel A-D interface and software (Cat.No.P87005/0 at £89)

-the Unilab interface (Cat.No. 532.001,£163) with the new "Grapher" software. This software with its facilities for some data analysis, would open up further possibilities with the breathing monitor. Grapher allows slope and area under a curve to be calculated and displayed. This would allow you to get numbers proportional to peak flow rates, tidal volumes and vital capacity out of your Beeb.

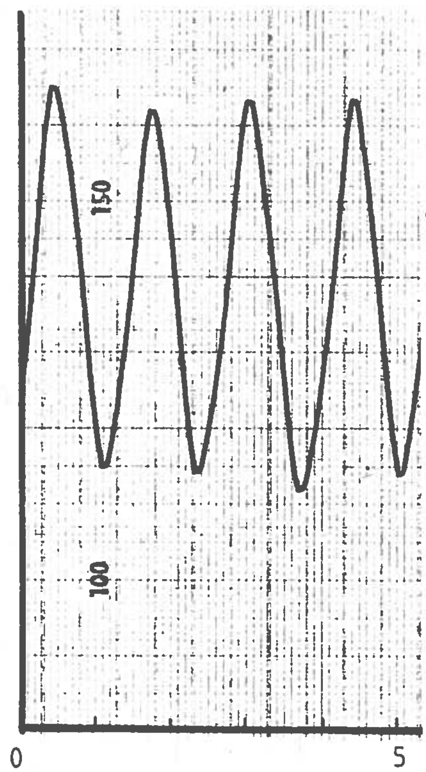


Fig.7.

-the DCP 'Interbeeb' from Griffin (Cat.No. CRA-950-010N,£52-13). The prototype Griffin software did not include a suitable real time data capture and plot routine. We therefore wrote our own by extending Program 2 on page 8 of Bulletin 140, changing some lines to cater for the different way of setting and reading the analogue inputs on the Interbeeb. We found that the bridge output needed to be amplified by hardware means with a 1.5V bridge voltage. With higher bridge voltages, 4.5V and 6V, it was just possible to use offset zero and amplification by software. This meant instructing the Beeb to plot not the straight value sitting on the A-D input but to plot that value minus a fixed number multiplied by an 'amplification' factor. Care was needed with this. Too great a factor means that the inherent inaccuracy of the A-D converter (±5%) becomes more significant and too many spurious points get plotted! (This subject will be dealt with more fully in a future Bulletin).

We have also used the circuit with the Sinclair Spectrum and the Griffin I-Pack interface (Cat.No. CRA-776-F at ca.£35 plus £12-50 for the Experimental Manual and Cassettes). Again we wrote our own data capture and graph plotting program which included some offsetting and amplification by software of the type indicated in Bulletin 140. A copy printout of typical results is shown in figure 8. We can supply copies of this program and further detail is given at the end of this article.

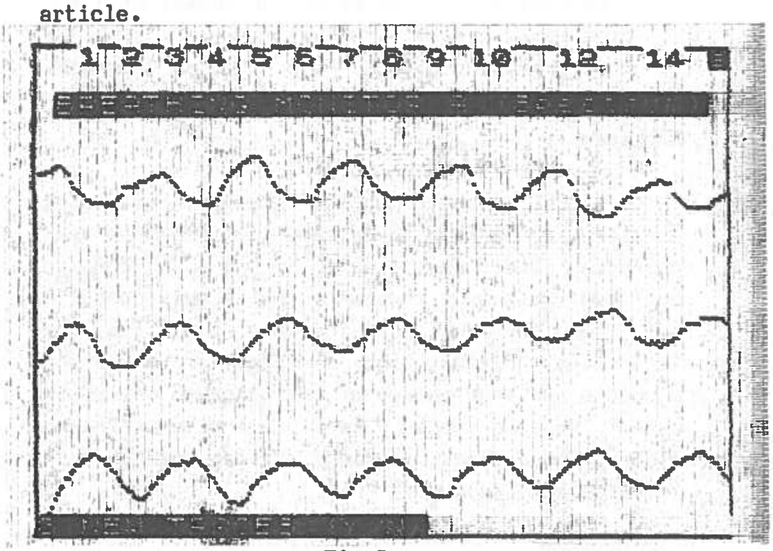


Fig.8.

Whichever interface/computer combination is used a digital multimeter should be connected across the bridge output. This allows you to balance the bridge. It can also be used to investigate signal levels for particular applications so facilitating hardware settings on interfaces or insertion of scaling factors in software. If the analogue to digital converter in use only accepts monopolar inputs then you must operate the bridge to one side only of balance.

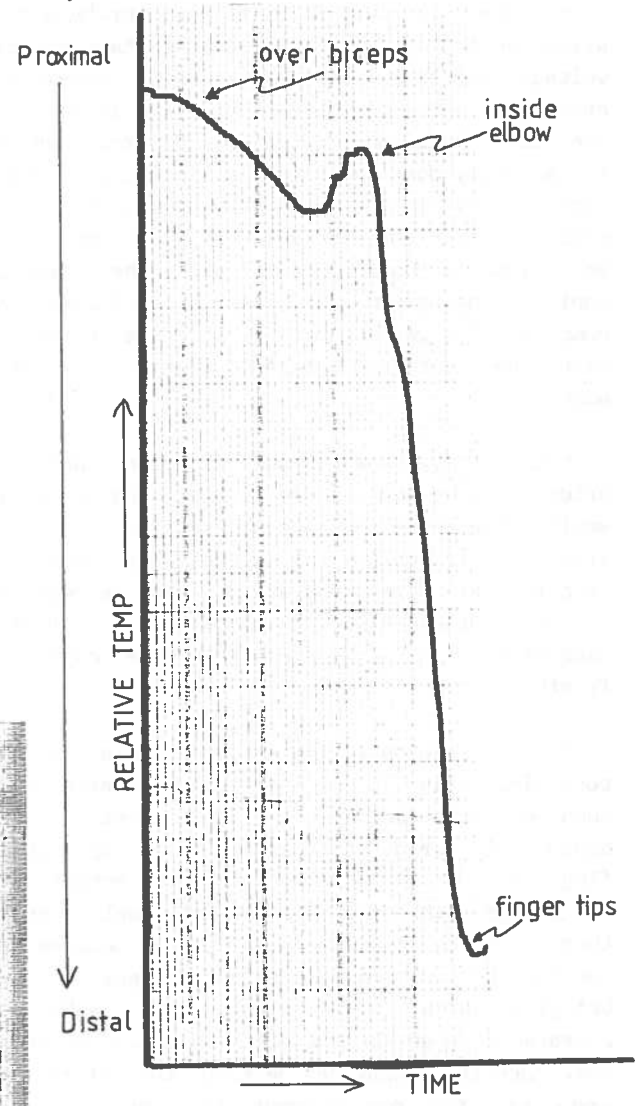


Fig.9.
Temperature gradient
Human arm

The multimeter will then allow you to check on the polarity of the bridge output terminals, in order that you may connect up correctly.

Temperature gradients

The record in figure 9 was obtained by placing the tip of the thermistor probe high on a human upper arm. It was left to equilibrate and the bridge controls used to set some arbitary positive voltage suitable for an input sensitivity available on the chart recorder used (in this case the 100mV range on a JJ CR500).The probe was then run smoothly down the arm to a fingertip. The blip part way down is a hot-spot at the inside of the elbow joint. Here a number of blood vessels run very close to the surface.As with the breathing monitor the graph can also be obtained on a computer VDU. We have carried out this experiment with the Beeb and interface combinations listed above.

These results show how sensitive the thermistor bridge can be and its usefulness in demonstrating small differences in temperature. The experiment itself paves the way for discussion on human body temperature - core temperature versus temperatures at extremities etc. This may raise further discussion on exposure and the causes of frostbite.

A simple demonstration on homeostasis is also possible. This is of particular interest since such demonstrations are as hens' teeth in the biological world. A thermistor is taped to the finger of one hand and left until the output from the bridge climbs and then begins to settle as the thermistor equilibrates. It may be necessary to use the bridge control potentiometers to keep bringing back the output signal within an acceptable range for the voltage sensing device in use. Once the output has settled the other hand and arm, the one without the thermistor, is plunged into a bucket or small aquarium of ice and water.
The output from the bridge will change even though it is the opposite limb which is being cooled. This shows how skin capillary contraction and the cutting of blood flow in the skin surface is a general phenomenon, occurring across the whole skin, even when the cooling stimulus is localised.

Further suggestions

A number of other experiments suggest themselves as ideal thermistor applications. Some of these have been described in past issues of the Bulletin. Then the measuring circuitry was the d-i-y SSSERC electronic thermometer and the now obsolete 'Medicon' disposable thermistor probe. With the advent of inexpensive digital meters and/or computer interfacing these experiments should be less fiddly to perform:

- -metabolic heat in yeast,germinating seeds etc., thermistors in glass or plastic containers in polystyrene insulating outers. Substituting for liquid in glass thermometers in thermos flasks and providing results in minutes rather than days. (Also avoiding the need to cheat by pouring warm water into flasks just before the class comes in!).
- -as a substitute for a differential air thermometer in metabolic heat detection with animals. Existing designs for differential thermometers using a manometer are so insensitive a mouse is often used in one of the chambers. Anyone who has thought about it, must see what a nonsense this is. Pupils can feel that a mouse is usually warmer than its surroundings merely by handling it. They don't need a load of insulated glassware and a manometer to tell or, more likely, confuse them. The use of a pair of thermistors, one in a control and the other in the vessel with the organism should allow much smaller, invertebrate subjects to be used for such experiments.

Endpiece

The SSSERC software for the Spectrum breathing monitor is available to Scottish schools and colleges, either as a listing or on a microdrive catridge. We regret that we cannot supply cassette tape copies. We just haven't the time nor facilities. Please send a stamped addressed envelope and your cheque of postal order for £1 to cover copying costs. For microdrive versions please send a blank cartridge. Please ensure this is adequately packed.

References

[1]. **Keeling,R.P.(1980)** A low-cost thermistor device for measurement of metabolic heat in yeast cells in suspension.Journal of Biological Education.**14**(1) 36-40.

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S.S.S.E.R.C.
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JUNE,1984

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