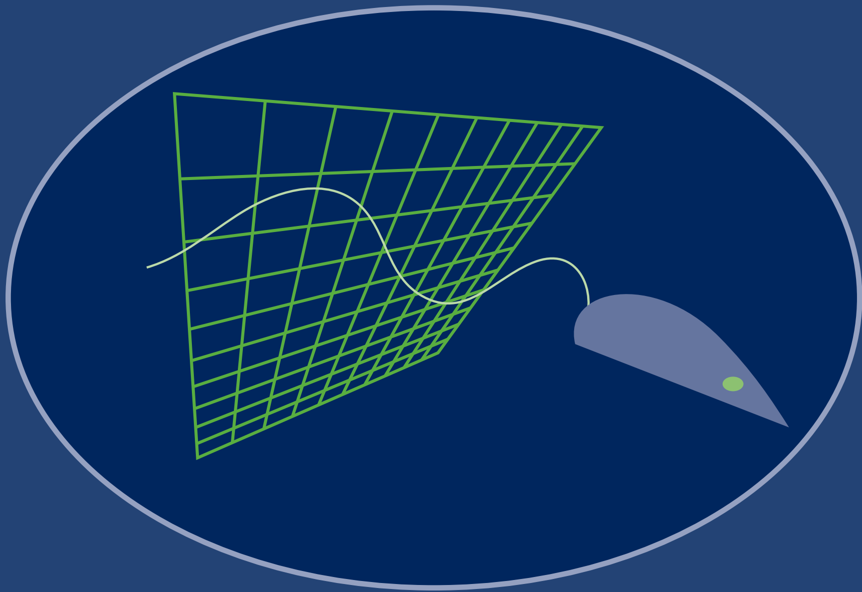
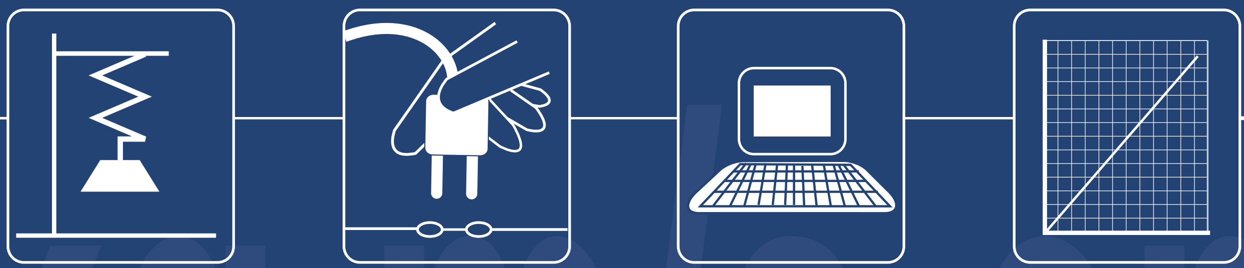


Datalogging in Practice



Roger Frost

Definitive guides

Activities index

Data logging in Practice

Roger Frost

IT in Science - Cambridge ISBN 0 9520257 4 4

A compendium of practical ideas for using sensors to teach science

Other titles in this series:

Data logging and control	ISBN 0-9520257-1-X
The IT in Secondary Science Book	ISBN 0-9520257-2-8
Roger Frost's organic chemistry - multimedia	www.organic.rogerfrost.com
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Credits

The ideas in this compendium come from many sources. Thanks are due to the publications, people and manufacturers listed below for ideas, inspiration and advice. Special credit is due to those who tried an idea in school, shared it and showed what they valued. The author's role has been to assemble the knowledge. If any sources have escaped my attention please get in touch.

With thanks to

Adrian Oldknow and Ron Taylor in 'Data-Capture and modelling in mathematics and science' published by Becta (www.becta.org.uk)

Barbara Higginbotham and Sensing Science - Primary Curriculum Pack, Data Harvest 1997 (www.data-harvest.co.uk)

Brett Laniosh, S Gilbert and 'Measurement & Data logging at Key Stage 3 & 4 - A practical guide', Dudley LEA, UK

CLEAPSS School Science Service - numerous equipment guides and reviews including Sensing and Data logging: an introduction

DCP Microdevelopments, Dave Palmer, Dave Hagan and Griffin and George. 'Data logging a basic guide for teachers' (www.dcpmicro.com) by Rod Taylor, The City Technology College, Kingshurst, UK

Dr Gary Skinner, Bedales School, Hampshire, UK for biology results.

Enhancing Science with IT Classroom Materials published by Becta (www.becta.org.uk) and the UK Virtual Teacher's Centre.

Fourier Systems and Meir Gerner (www.fourier-sys.com)

Insight software Teaching and Learning guide, Logotron (www.logo.com)

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Paul R Mills, Bob Tateson and Northern College Biology Newsletter No.61 (www.norcol.ac.uk)

Tom Howard, John Gipps, Peter Adams, Bruce Saunders and Tain Electronics Pty Ltd (www.tain.com.au)

Philip Harris Education, Rob Dickinson, John & David Crellin and Datadisc web site (www.datadisc.co.uk)

Roy Barton and others in Data Harvest's experiment manuals (www.data-harvest.co.uk)

Schools Online Science at Sheffield Hallam University (www.shu.ac.uk)

Scientific and Chemical Supplies, UK and Mike Hogg. (www.sci-chem.co.uk)

Scottish Schools Equipment Research Centre and Ian Birrell in SSERC Newsletters (Email: www.sserc.org.uk

Southern Biological Supplies Pty Ltd, Australia Peter Adams and Fred Ford for guidance (www.southernbiological.com)

Texas Instruments CBL System - Experiment manuals (www.ti.com)

The Shell Maths Centre at Nottingham University for 'Everyday Graphs' (www.nottingham.ac.uk)

Vernier Software and data logging systems, USA (www.vernier.com)

Wim van Bochoven and Ron Smit, 'Sensor' project, CPS Holland (www.cps.nl)

Note:

For addresses, see the Contacts section & rogerfrost.com

About the author

Roger Frost runs training days for science teachers, reviews software and writes features for education newspapers. Book publishers ask him to recommend IT ideas to go with their science schemes, while other organisations such as ASE, Becta, SCAA, DfEE commission him to write reports.
He was a clinical biochemist for ten years before becoming a teacher of science and computing. In 1988 he became an advisory teacher at ILECC, the London computer centre and later at North London Science Centre. Since 1993 he has worked as a freelance writer, trainer and IT consultant.

Published work includes:

Science Online (www.Becta.org.uk) co-author 2000 ISBN 1 85379437 6
Software for Science Teaching (IT in Science) 1998 ISBN 0 9520257 5 2
Learning Highways – exploring the potential of the Internet 1998 (NCET) With Roger Blamire
Enhancing Science with IT (NCET) 1994 Co-author ISBN 1 85379270 5
The IT in Secondary Science Book (IT in Science), 1994 ISBN 0-9520257-2-8
IT in Primary Science (IT in Science) ISBN 0-9520257-3-6
Data logging and Control 1993 ISBN 0-9520257-1-X
Information Technology (Nelson), 1993 With Roz Reyburn ISBN 0-17-438572-2
The IT in Science Blue book, 1992
The IT in Science Buff book, 1991

IT in Science on the Internet

For teaching materials, worksheets and information about ICT, visit Dataloggerama at www.rogerfrost.com

Small print

This book is a self-help manual for schools. Some things need to be said to cover my tracks: for example, the ideas here are judged on their merit for enhancing science teaching. The advice is offered in good faith – we rely on your experience with safety rules and equipment details as to the suitability of anything here. We have not scrutinised the experiments for explosive and lethal cocktails that may cause damage to persons and property. Psychological trauma resulting from trying to do this on say, the IT manager's network, carpet or typist chairs is also something we disclaim responsibility for. Help in maintaining the recommendations in this book is welcome. Professional trainers in the UK should obtain permission to copy any part of this work for staff training. We're quite nice about it so write to press@rogerfrost.com or phone us for bigger favours. Leaflets about titles in this series are available from the publisher. And if you would like advice, a speaker or a training day, please contact Roger Frost.

Using this book

This book offers advice, activities and practical ideas for using sensors and handling data.

Or visit www.rogerfrost.com to click on the links

Contents

Why use IT?

Much has been said about the value of IT (ICT) to science teaching. While parents, students, teachers and politicians agree that we should use it, all perceive its benefits differently. If you find a different rationale coming from the head and the school IT co-ordinator it's a simple sign that we need to be absolutely clear about what counts.

Here therefore is a quick exercise: below is a list of good things about IT, can we agree on which are the most important? Sort the 'good things about IT' into those that are properties of IT and those that are benefits.

About IT	**Is this a feature?**	**Or a benefit?**	**Top three ideas**
'Real time' graphs offer opportunities for discussion		✓	
Data logging allows us to experience variables such as pH and oxygen.			
Data logging graphs show how variables change			
IT allows students to see changes as graphs in 'real-time'			
IT better handles variables			
IT brings school science into the current age			
IT can be a strong motivator			
IT can lead to a better understanding of science			
IT encourages students to ask questions.			
IT helps us measure with improved precision			
IT improves students view of the status of science			
IT is used in the world of work			
IT measures very fast or very slow changes.			
IT offers a way to develop analysis skills			
IT offers an automatic way of collecting data			
IT presents more opportunities to investigate science			

When or when not to use IT

"IT for ITs sake can make the science fake"

To examine the reasons we use sensors in experiments, mark the data logging activities below that are most relevant to your work.

Burn a candle in a bell jar and measure the temperature and the oxygen, humidity and light levels.	Make acid-base titration curves by dripping acid from a burette and measure the pH.
Measure the oxygen and light levels in an aquarium for a whole week.	Do an acid-base titration by dripping acid from a burette and measure the heat of neutralisation.
Compare different insulating materials using temperature probes.	Record a cooling curve in a tube in a cool water bath.
Find the most heat producing ingredients for a sports injury pack.	See how temperatures high up and low down in the soil, change during a day.
See the effect of concentration on osmotic pressure by using a pressure sensor.	Study distance-time graphs of students walking towards a distance sensor
Measure reaction time using two light switches or light gates	Study force and acceleration using light gates or dynamics pulley.
Measure the cooling of test tubes to show the benefit of penguins huddling	Study simple harmonic motion by monitoring a pendulum with a position sensor
Monitor the noise from the class with a sound sensor.	Use a data logger as a stand alone meter in field work
Measure the rate of the acid plus thiosulfate reaction using a light sensor	Use a light sensor to see how two strip lamps interfere and produce beats.

When or when not to use IT

Tick the best reasons for doing your experiment using sensors

A fairly easy activity requiring little equipment for getting up to speed with data logging		Allows us to measure a change that normally takes too long or runs overnight	
Allows you to quantify a change or difference you don't normally quantify		Introduces the idea of graphs and measurement using the computer	
Provides a real time graph that offers an opportunity for a useful discussion about what is happening		Leads students onto an investigation of their own	
Data is plotted on a graph in real time to show its rate of change		Involves the simultaneous measurement of several variables that could otherwise be difficult	
This is an opportunity to show how IT can help science - or scientists		Easier to understand for less able students	
Provides an opportunity to investigate science using better tools		Graphic display of 'abstract' variables such as pH or oxygen level	
Provides an opportunity for work where students can use a range of investigative skills		Offers an opportunity to extend able students	
Introductory activity to get students used to the software in the lower school		Provides an opportunity to develop skills in data analysis	
Provides an opportunity to develop IT capability		Provides an appropriately modern way to do this experiment	
Doing the experiment like this saves time		Provides a more accurate or precise method of doing this	
A novel approach to an experiment		Students will enjoy doing this	
A very small, subtle change is made significant using sensors		Having two data sets appear at the same helps students to look at them critically	

Using software to handle data

More than just recording data from sensors, data logging software lets us handle the data in special ways. There are ways to display the data, to read graphs, do maths and format them. Here we look at the things that software can do.

Display tools

Display tools allow you to discuss a graph. Bar gauges, time graphs and other graphic displays provide feedback during an experiment. For example, a bar gauge rises as you make a sound. This is useful feedback, but the discussion and interaction that goes with it are the keys to making data logging into something to learn from. After an experiment the software may let you 'play back' the experiment as if it were happening again. A digital meter display is especially handy for demonstrations - for example, a whole class can see the pH numbers change as you add acid to alkali. You can split the screen, having half with a digital display and half with a bar gauge and all should still be able to see. A feature that lets you change the scale to zoom in on interesting parts of a graph is crucial. Finally, being able to see the correspondence between a graph and a table of results is helpful too.

Graph measuring tools

Graph measuring tools let you do special things very quickly. The essential graph measuring tool is a cursor or cross-hair that reads the points on the graph. Some programs let you use the cross-hairs like callipers to compare say, the period of one pendulum swing with another. You also can find the highest and lowest values when you have measured something cooling, or calculate the difference between two points to show how much the pH changed or how long the change took to happen. Statistical features let you work out the average temperature in an insulation experiment to see which graph line had the highest temperature overall. You could also see the standard deviation of a data set - though I am scratching for a reason why. A really versatile tool calculates the area under a graph to tell you which container stayed hottest the longest. And if it seems that there is some overlap in what is on offer, appreciate that you choose from this range of tools to suit different experiments and different age groups. In other words, you will not need to use them all in a single situation and in fact doing so risks confusion.

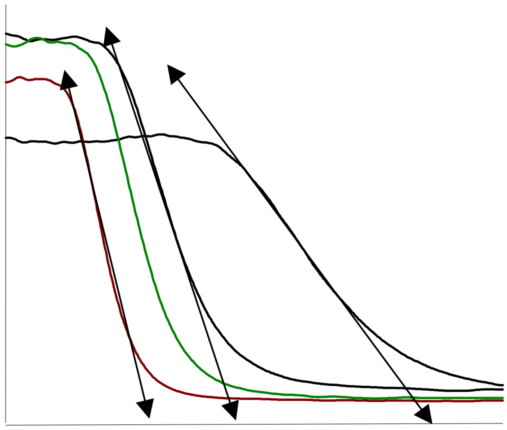
The most familiar graph-measuring tool will calculate a gradient at any point along a line. The software uses a few consecutive points to calculate a slope such that if three points in a row go up, you can read off a positive gradient. If you see a steady line you will want to measure its gradient. If you see the sine wave of a pendulum you can see how its gradient (or velocity) changes. However attractive we find the gradient concept, it’s a fact that the data we collect nearly always 'wobbles'. This confuses the calculation so that gradient is erratic. In most cases we need to use other approaches.

A first alternative, suitable for advanced groups, is to calculate the differential of the line and plot this against time. This will show the part of the graph that is changing fastest. A second idea is to find the 'best' part of the graph, and fit a function to it. The gradient of this line should be the same as before. (Remember: the software gives you a value for 'm' in a straight-line based on $y=mx+c$).

A third easier alternative is calculating the 'rate of change'. This takes two points and works out the average gradient between them. This works well nearly all of the time but we need another graph measuring method for younger groups.

We could, for example, measure the difference between two points on the graph. We could measure which graph changed the most in 10 minutes. Or we could see where the graph lines intercept the time axis as here:

Using software to handle data



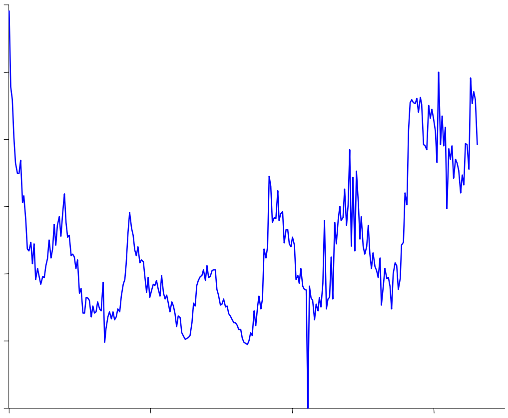
In short, if you do try to measure the gradient, do so on a 'wobble-free' line.
To see this in practice, see the experiment sheets later on rates of reactions and pendulums.

Formatting features

You may want to add a title, labels, a grid or comments to a graph. You can change what plots against what, switch to a log scale, change the size of lettering, graph scales, tick marks or graph points. There is more to formatting than cosmetic changes because these features help in various ways to highlight your findings.
It may be too much to expect this and still have a straightforward and uncluttered package, but if you need this much control, send the data to your spreadsheet. Incidentally, if you copy and paste the graph to a word processor such as Word, a double click opens a drawing package where you can gain further control over how it looks.

Calculating and graph editing tools

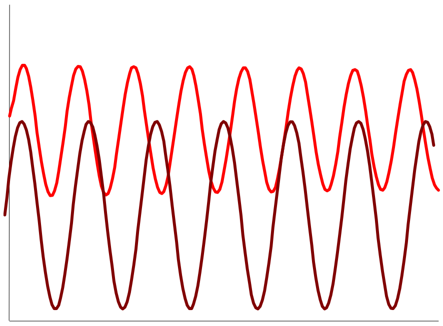
If you have a noisy graph, you can 'smooth' it. Smoothing makes the trace look better but loses its fine grain detail. A noisy record of an oxygen sensor improves greatly with smoothing, but do the same with a distance sensor and you can lose detail you need. One rule of thumb is that if you need to do some maths on the data, do this before smoothing.



Sensors may contain circuits that smooth the data before you ever get to see it. For any that remains, data logging software has various ways of removing noise. Borrowing from the world of electronics, it may offer different smoothing algorithms: the median smoothing algorithm simply averages readings that are close together while Fourier smoothing looks for high frequency changes. For example, you could remove a sudden spike in a graph with Fourier smoothing, when averaging would leave the graph with a bump. Incidentally, When you need to look at the data in a new way, you calculate a fresh graph line. The software gives you a set of equations to manipulate the data and draw (or 'define') the line. You can subtract room temperature from a graph or remove your control reading from your test reading. Look in the software for an 'x-y' equation and choose which line is x and which is y. When you want to see how fast things are changing, you can calculate the differential of the line. You can find the equivalence point in a pH titration by calculating the differential of the pH. You can find the velocity of a pendulum by calculating the differential of its angle. When you do a differential, the machine plots the gradient of the graph against time. Use this when you are teaching an advanced group - the graph reading section above offers alternatives for other groups.

Curve fitting

Curve fitting lets you guess at a mathematical model of your results and the model allows you to make predictions. In curve fitting you choose from a list of functions that draw straight lines or curves and see which best fits the data. You can punch numbers into an equation until it fits the original data or in some software, you nudge the graph until it fits:

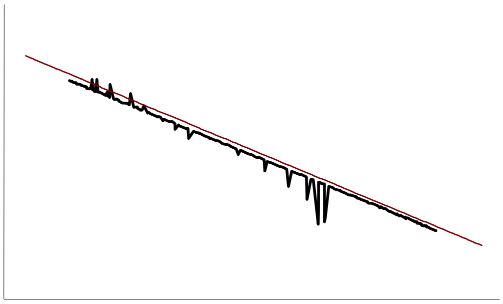


Either way, you end up with a model of your original data – and without the wobbles that calculating a curve from your data tends to produce. From this you can make a prediction, for example, if you fit a straight line to a pressure versus temperature graph you can predict absolute zero. Just read off the temperature intercept and hope that it goes through zero K.

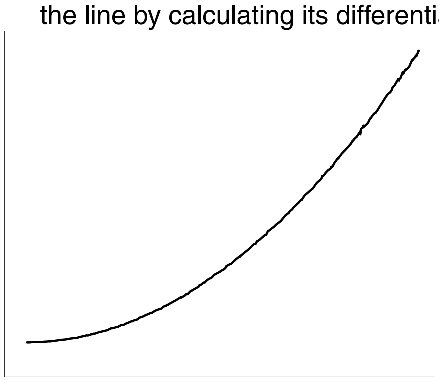
There will be many occasions when only part of a graph is interesting. For example, in a rate of reaction experiment you could fit a logistic function to the whole S-shaped graph but really, fitting a line to the middle part feels OK. To do this, you just select or zoom in on the part you want and then fit the line to that.

There are many types of function to fit and of course knowing what the relationship is in the first place tends to get the right answer! If you can't find the exact function that you need, try building one up in parts. If you want $ax^{1/b} + c$ but you can only find $ax^b + c$ in the software, first calculate 1/b then put the result in $ax^{1/b} + c$. Here are some of the fit functions you might find:

- Try $y = c + m x$ for when you expect a straight line such as the relationship of temperature to pressure. The slope (m) is constant and the graph intercepts the x axis at c



- Try the quadratic or parabolic $y = c + mx + a x^2$ for square law functions. If you had measured the distance as an object falls, you could use the function to find the acceleration due to gravity. The slope of the curve changes continuously. Show this with the gradient tool, then straighten the line by calculating its differential.



- Try $y = A \log(Bx)$ for a logarithmic relationship
- Try the exponential $y = A e^{Bx}$ for examples where the rate is not constant such as cooling, radioactive decay, or yeast growth curves.
- Try a logistics function on S shaped graphs from pH titrations and rates of change.
- Try a sine function $y= c + a \sin(bx)$ for waves and pendulum swings. Note that a is the amplitude, c the vertical shift and b the period.

Use a spreadsheet?

You can open your data in a spreadsheet program and do all you wish with it. The spreadsheet is a very useful general-purpose analysis tool, so any skills you have are put to good use. Furthermore spreadsheets, such as MS Excel, have a familiar look and feel that helps everyone get up to speed with it. Use your data logging program to save your data as a CSV file. MS Excel will then be able to use it.

I'm not particularly inclined to use a spreadsheet as there are many special things (like reading values from a graph) that data logging packages do more efficiently.

What can you say about a graph?

"Looking at a graph on a computer screen shows only part of the picture"

Graphs are very helpful pictures of change. Just as an art teacher directs attention to a painting and helps attach meaning to it, data logging activities need to do this with graphs. And just as the artist needs the language to describe paintings, so too must the science learner develop the language to describe graphs.

But more than describe a graph, IT tools allow students to work out areas, measure rates of change, calculate new graphs or model them with an equation. These are 'new' to the culture of science teaching. If the questions and discussion around a graph is crucial for achieving the benefits of ICT, this set of discussion prompts aims to feed those discussions.

Q. Predict the graph you expect to see.	Q. Sketch a graph to show what you think will happen
Q. At what temperature do you expect the graph to start? Will it go up or down?	
Q. There are two traces. Which line is which?	Q. Why are the peaks different?
Q. Which line is changing faster?	Q. What made the bump on the graph?
Q. Should the two traces start at the same point?	Q. Why did the trace go up rather than down?
Q. How does the graph show you that x is better?	Q. When does the temperature change fastest?
Q. Compare the graph with your prediction	Q. How do you know when it has finished changing?
Q. Label the graph to say what happened	Q. Is there a pattern in the way the two traces change? Describe the pattern.
Q. How would the graph be different if you had done it another way? Test your idea.	Q. Which trace had the highest reading overall?
Q. How much have the readings changed:	Q. How much did it change? Which changed the most? Is there much difference?
Q. Which trace shows the highest reading?	Q. How much do the graphs change in a minute? What does this tell us?
Q. How long did the change take?	Q. What is the gradient of the graph? What is the gradient of a best-fit line?
Q. Where did the graph change fastest? How fast does the graph change?	Q. What happens if you subtract the control reading from the trace? (e.g. subtract room temperature)
Q. Fit a curve or line to the graph. What does this tell us?	Q. Calculate the integral of the line. What does this tell us?

Teaching strategies

Teaching schemes are the result of choosing the most appropriate ways to deliver a curriculum. Sometimes students do things, sometimes we show them and sometimes we tell them. This exercise is about applying the same choices to data logging activities. Put the experiments below into the table opposite.

1. Monitor class noise	2. Study simple harmonic motion of a pendulum	3. Measure the effect of emulsifiers on the activity of lipase
4. Compare insulators	5. Find the optimal ingredients for a sports injury pack	6. Oxygen and light levels in an aquarium
7. Study force and acceleration	8. Cooling curves and latent heat	9. Look at huddling emperor penguins
10. Study distance-time graphs with a distance sensor	11. Measure rates of reaction of acid and sodium thiosulfate.	12. Monitor how the soil temperature changes during a day
13. Monitor AC ripple on a strip lamp and seeing how two lamps interfere	14. Acid-base titration	15. Measure the effect of concentration on osmotic pressure

Teaching strategies

Choose the most fitting strategy for the experiments opposite

Strategy	Experiment	Justify your choice
These experiments I would demonstrate and discuss		e.g. it's more valuable; affordable; reliable; manageable; efficient
In these experiments, I would give students my results to analyse		
These are experiments that the whole class should do		
Some students can do these experiments while the rest of the class do it the usual way		
These ideas are good for student projects		
These experiments are best done as we currently do them		
These ideas are best for science club		

Support and staff development

"Most of us need some support to move ourselves on; only some of us generate our own energy."

Science departments offer tips and advice on introducing IT in school.

"Start with activities and demos that are reliable and easy. I felt that a room with ten computers, ten data loggers and countless boiling beakers of ice was not a situation to thrust at a first time user – I'd not try it myself anyway. Instead we started with activities and demos that were reliable and easy."	"Choose the right group to work with. I'd be very anxious about doing this with some of my classes. With a large group it doesn't seem to be really viable. With a wild group forget it – I tried it with them as a special treat but it ended in tears. But my year 10's were great…"
"Write it into the work scheme. The school set out an action plan where one teacher would introduce an experiment this year and others would come on stream next. They used a highlighter pen to mark the work scheme with IT opportunities. They graded them with stars – one star meant it was a suggestion, two stars meant it was a 'must-do'. The head of science forced the issue: he removed ordinary experiments from the work scheme and replaced them with IT experiments."	"Start with grief-free success. The chemistry teacher really wanted to do an acid-base titration but how do you tell them it's best to start with something reliable and manageable. It's best to get up to speed with an easy idea than have do the value-added activity that is too clever or tricky. For example, it's easier to use temperature sensors, or use a spreadsheet to draw a graph or use science software to revise for an exam. Data logging is the hardest place to start using IT."
"Get students to help with demonstrations. I demonstrate a few experiments using the sensors. But the students are very astute and notice the tiniest hint of hesitation with the mouse. That's why I get a student to do the mouse stuff as I talk them through. You have to be very patient with them - even if they aren't with you!"	"Not every one is keen on IT or will ever be. This is a mixed ability profession – humans staff it and not every one is keen. We respect how they feel and trust that when the rest of us are up to speed they will fall in line. There's just no point in upsetting good teachers. If after our best support their heart isn't in it, there's no point in banging on at them."
"Don't snatch the mouse out of someone's hand. When you're stuck, someone will take your mouse, whiz around over the screen with it and do it all for you. We've rule here that no one may do this. Instead they have to talk the person through the snag. You'd think that people teaching IT would know better – I mean, if I snatched that pen from you and did the writing for you, you'd pretty soon feel deflated."	"Get a successful IT lesson in your armoury - a sort of party piece. Repeat your party piece with every class to learn the pitfalls faster. What staff needed was a successful IT lesson in their armoury. They needed to see a good lesson with IT and they need to get good at something, to have a sort of party piece. I used this party piece with every class that month. OK, it took some contriving to do that, but I learned to handle the pitfalls much faster."
"Document IT lessons. We need curriculum materials and exemplars as a priority."	"Use old computers. People get a bit anxious about brand new computers and environments that change frequently. They'll only use things when the equipment has stood still long enough and looks as old as the rest of the place."
"Use portable computers. We went for portables that the staff borrow in the evenings. It's hard to get them back I know, but you do notice that these teachers are very confident with them – using discs and printers and so on. Convenient and comfortable access to computers has moved them on. We started using the laptops for doing graphs with spreadsheets and writing experiment reports."	"Build a bit of a computer culture about the place with displays and students using machines in science club. We started to build a bit of an IT culture about the department. Students browse through the CD-ROMs at lunchtime and use them for science club. The club mounted a really good IT display in the science corridor and they're going to move it to the foyer for next week's open day."

Support and staff development

"Pray for serious support from school. The management was serious about IT, and the deputy head formed a group of 1-2 science staff who could take IT forward. He chose people who had time to draw breath and explicitly not the head of science! They worked with the IT co-ordinator, trying out things in class and often with support. The group became a sort-of working party and argued for timetabled support for the rest of the department."	"Staff need to use a computer for their work. They need to get good with computer for their own work before they feel able to teach others. Here everyone does their work on the word processor, and quite a few use spreadsheets. We're more comfortable handling a class with these applications than with data logging. Don't try to do too much Start with something easier than data logging Use clipart to make worksheets"
"Get the vision right. Over the years we've bought bits of gear but we still don't have what we need to make IT work with a whole class. The result is inaction and despondency because frankly we're being too ambitious. It makes more sense to look at what you can do. You could say we've refocused our vision to match our resources."	"Use reliable equipment: I used to make our own sensors here – it was miles cheaper but these days you can get them ready made. With the home made sensors wires were always coming off – but now the commercial ones don't cost much more and they even calibrate themselves. It gives others a lot more confidence."
"A good printer motivates teachers. We saw having a printer that worked brilliantly and printed in colour not as any sort of luxury, but as a key motivator. When staff see their work looking that good it really is worth using a computer. Compared to the cost of staff development, ink cartridges come at bargain prices."	"Time to go on courses and attend trade shows. Staff who need IT training are allowed to go on a course although we have bought someone in for a training day. We encourage staff to get to education trade shows and events to expose them to the culture of IT in education. Examples include the BETT show in London and science association events."
"Team-teach first lessons using IT New users appreciate a helper nearby. We're no strangers to visiting each other's lessons so this would work. Here, your first lesson using IT is nearly always team-taught with another – what's more it didn't always matter if the helper wasn't an expert either. They would learn too."	"Use palmtops on field work. The biology teacher was never keen on computers, but I joined her on a field trip and took laptop and palmtop computers. The students quickly learned how to record data and draw graphs on the palmtops. The teacher was impressed."
"Choose IT that enhances the science. IT ought to be about improving things. Some topics are just too dry so we're keen for ideas where IT makes the science easier to teach. These things convince the sceptical teacher. Still, I'd admit that not everything we do with computers is aimed at 'extending science' as you say. You've got to lead people into this so there's no point in going for a big whammy - like an experiment where you use sensors, do an investigation AND try to assess it at the same time. That's suicide. Some things we do just because they help get people familiar with the gear."	"Get familiar with the software. There's no rational reason why we should balk at using this equipment. Becoming familiar with the software was key. We put a graph on the screen and set about teaching ourselves the ins and outs of the software. We made a list of things like 'how to measure a rate of change', 'what to do if no trace appears' and so on. Some software is much better for getting started and it's getting started that we are about. The choice of software is very important. I take classes into the IT room just to use the software to analyse a pendulum graph."
"Analyse data in the computer suite. Having a whole class do much the same thing is easier than some other ways of handling IT. Do a demonstration and take a data file to the network room for analysis. Choose between trying this first with senior groups where a data rich file on rate of reactions, pendulums or dynamics offers much to do or doing a basic exercise with junior groups. Ask another teacher to co-teach the lesson."	"Use a department meeting to showcase IT activities. Our department meeting often has a slot where I show an experiment I've done. The technician has been great at debugging ideas, she gets things ready for the meeting and joins in. Sometimes we just go over skills like copying a graph into a word processor. When we've seen something working and we can then discuss its place in our work scheme."

Policy points

Here we present a selection of tips about using computers.

There's always something broken: From time to time something will go wrong and it is sad to have to tell one group to watch another group. As one teacher puts it "I have nine sets of equipment but I plan for only eight to be fully working. When I do a demonstration I have a spare of everything to hand. Insoluble problems are often due to two things being wrong at once! Ideally I'd like two of everything as swapping things is the easiest way to solve snags.

It takes ages to organise: Setting up, packing away and checking in a data logging system takes a lot of time. One idea is to have a 'monitor' for each group. Another is to leave the equipment permanently connected and ready to go. Another is to keep each set in a plastic tray or tool box. The items and cables can be labelled to say what they are and where they connect, and you may find that colour or number coding is helpful. By using a coding system, you soon notice that 'cable B in kit B is faulty' – whereas without a label the problem will recur randomly.

Students forget how to use it: If students use it once a year they will surely forget. Do data logging in time blocks: choose a science topic such as forces or energy where there are lots of opportunities to use data logging. You can demonstrate how to use it in the first lesson and use it in many subsequent lessons - that way the students are more likely to remember how to use the equipment. Teachers learn by repetition too, a teacher was so impressed with a linear air-track and his light gates he used it in every lesson that week.

Students aren't impressed: Using a computer can give a head start when you introduce something, though how long it lasts depends on how well you deliver. Most students have seen the awesome things that computers can do so maybe don't expect too much response. A force feedback joystick (which jolts them as they play arcade games) is tough competition for a data logger. Do not expect dropped jaws or even kudos for being adept at a computer. Under-promise and over deliver excitement is the policy.

Students are better than me at computers: If teachers are adept at showing respect for the science knowledge that students bring to the classroom, we can show the same respect for student's computer skills too. The science teacher brings the skills for handling data to the classroom. This is where the kudos comes from. If you feel in competition with students, shift your battle to this familiar ground (but don't fall off the computer).

Printing: Imagine at the end of a lesson, in full sight of the class, you take everyone's work and throw it in the bin. That's just what we do when we use IT and forego student's keeping or printing their work. A lesson deserves a payoff so we have good printers that make the effort worthwhile, and fast printers that help to remove queues and bottlenecks. Colour printers seem to be essential when two coloured graph traces overlap – alternatively students can run over the lines with a felt pen.

Policy points

There's not enough equipment: If there's not enough kit to go round, you have a choice: you can do projects, just demonstrate or do nothing. Demonstrations and discussion help get one up to speed - although a large screen is essential. Use only fast changing experiments for demonstrations as watching a cooling curve is like watching paint dry. Set up longer experiments during the lesson introduction; look at the results at the end. The class might analyse the data in a computer room using one of the many activities in this book.

It's too hard: Take a simple experiment to compare insulators, add a data logging system and you have a lot of equipment and not a good place to start. If your system has a digital meter display, start by using these without the computers. In short, get support.

Need a worksheet: In one science department, the lead staff member for IT trialled an IT activity and wrote a worksheet for it. It said how to set up the experiment and had work to deal with idle moments where results are slow coming. It offered practical tips as well as questions to ask as the graph appeared on screen. It was not perfect but here were activities involving reading, sketch graphs and thinking questions. Whatever, this worksheet was the lesson organiser, his 'ring of confidence' and if you like, a comfort blanket.

Data handling is too hard for the class: Data handling is hard if students are thrown into it, and hopefully that's not being suggested. A colleague reassures that data handling isn't just about numbers "We encourage students to annotate their graphs – we get them to add words on screen or in pencil. Their notes say what happened and capture the discussions they've had. We get them to write about 'how long it took' or 'how much it changed' and more importantly what it means. If there's no time in class we make homework out of this. It is too important to ignore." In time, handling data will become part of the culture and some of what seems hard now will filter down the school.

The computer does the experiment so quickly that students don't learn from it: We'd need to research this point but we can agree that the technology raises questions about what and how we teach. When you measure the acceleration due to gravity in under a minute, you start to wonder. Students quickly get the idea of a distance-time graph by using a distance sensor. Using IT certainly trivialises some experiments and there are three coping strategies: As you now have a way of doing something that previously wasted a lot of time, you can move on to the next thing you teach. Secondly, you can use the time to extend the work and see if the mass or height of the object affects the acceleration. Thirdly, you can of course do it the old way.

They need to learn how to draw graphs: Using IT trivialises the drawing of graphs. Students need to learn how to draw graphs but there are two things here: one is learning to plot graphs; the other is learning to understand the data. The students drawing graphs merely focus upon getting the dots in the right places rather than appreciating the patterns in their data. Data logging turns the idea around to produce something especially useful for younger and low ability kids - it helps them to understand graph patterns. That in turn helps them understand how to draw them.

Events and open days

Using IT is one thing, but spreading awareness of how it has helped is important too. That awareness encourages students and staff to exploit what it offers. Do this well and you not only help others, you can gain funding too.

If that sounds a bit frank, spreading awareness is a way to break out of a resources Catch 22: If you do not have kit you cannot use it, and if you do not use what you have, it is hard to persuade people to give you funds to buy more!

Put up corridor posters, make open day displays, run science fairs, have IT activities to entertain parents queuing at report evenings; do a school newsletter, do an Internet site, put up displays at science teacher meetings.

The message should be 'how we benefited from using IT'. This works much better than saying 'look we use computers'.

See if you can show that the pupils achieved a higher level in science. This works better than saying that they have developed computer skills.

Display ideas

- Title should say in just a few words what you were trying to do. Look for a title that will appeal to the greater part of the audience.
- Photographs can show students planning experiments as a team; show the experiment as a story board; add captions and mix close ups and people shots. You can print very good photographs using digital equipment and glossy papers.
- Graphs should be printed and annotated to say what is happening and why. Edit them in a drawing program (MS Word has one built in) and thicken traces or increase text sizes. Print them in colour.
- Activity write-ups should be kept as short as possible - on a display one sentence is enough.

Science fair ideas

- Measure your reaction time using light gates. Put the result in a database beside your year of birth. Is there a pattern between reaction time and your age?
- Does after-shave make your skin cold? Use temperature sensors and rub alcohol on a round flask of water. Decorate the flask as a face.
- Stress tester - measure the skin temperature or pulse as people do a puzzle.
- Multimedia CD-ROMs – titles about the human body and planets. Pictorial CD-ROM database on elements or animals. Lots of options for stations here - list two or three things to find out on a card nearby.
- Which falls faster, a piece of wood or a piece of metal? Compare how fast heavy and light things fall using light gates.
- Hand temperature – who can 'put' the most energy into a temperature probe. Use a toy with a probe inside.
- Can you walk a graph? Put a graph on screen and try to copy it as you walk towards a sonar distance sensor. Have a paper puzzle where you have to match graphs to events.
- How many times do you breathe in a minute? How many times does your heart beat in a minute? How does this change after some step-ups? Use breathing and pulse sensors.
- Survey software – survey attitudes or attributes of the attendees. Provide detail on studying the results.
- Does sherbet make you cold or does it just feel cold? Does peppermint make your skin cold or does it just feel cold? Use temperature sensors to investigate.
  **(Sherbet is citric acid + baking powder + sugar).*
- Control technology – garden greenhouse temperature controller; premature baby life support system; robots.
- Control technology – create a prank exhibit holding a rare 'spitting frog'. Use a light sensor, light beam and 12 volt water pump. When the victim leans over and breaks the light beam the pump squirts a jet of water.

Department policy

Here we look at some schools that are ripe for progress. We tell you about the resources they have or what they are doing. Highlight the aspects that could work for you. Discuss ways that you can make progress

1. This science department has assigned a multimedia desktop computer to each lab. The computers are on trolleys and as the entire department is on a single level, they can be wheeled into any science lesson. They have a basic sensor kit for each one, a few more esoteric sensors and quite a few CD-ROMs. One of these computers connects to a wall mounted television in one of the labs. The department also has two machines in the science office both connected to a laser printer. These are used by most of the department for word processing. All the staff use computers for doing their reports because the head insists on it. Two members of the seven in this department make use of the trolley machines.

2. A few years ago this science department had a windfall and bought ten data logging kits with temperature probes. They bought further individual sensors until the money ran out. Recently the head has been pushing for more IT in school – investing in a new Internet suite, though this is physically far from the science department who have four machines of their own. Recently someone went through the cupboards to see what they have and set about planning what to do next.

3. The science department has one computer in the science office that is used for admin. They have two data logging kits. There is one computer on a trolley shared between six labs – a seemingly unhappy situation but there is a very good networked computer suite just a few doors down the corridor. The key to this room is kept close-by in the prep room although few know this. The idea was that the science department would book this room of computers and take along their data logging kits to do less messy experiments. However, the room is heavily timetabled for IT lessons leaving very few slots. Few members of the department seem happy to make the trip to the room. In fact, when one keen member asked for some software to be put on the network he was told it could not be done. The person is working towards a UDI situation where 'science' has their own computer resources.

4. A department in a large school has a set of ten new laptop computers each with a small set of sensors. They made a joint bid with the geography department to get them, although geography only use them for field trips. They have highlighted three lessons per class per year in their work schemes when they will use them. A member of the department has the responsibility for implementing the use of IT in science and with a prior windfall bought a data logging kit with one of each type of sensor. The laptops are kept on a trolley, and the technical staff keep the batteries charged. The computers are booked with an equipment requisition slip. A timetable on a noticeboard shows advance bookings. They have a portable colour printer though printing causes a bottleneck at the end of a lesson. The equipment is well used – at present mostly for drawing graphs and writing experiment reports in a 'Works' package.

5. This department has one desktop computer, three laptop computers and eight handheld palmtops computers. They have sensor kits with two temperature probes, for each of the palmtops. The equipment is stored in labelled sets with each in a separate tray. The set-up allows the whole class to use a computer - although when the palmtops have collected the data, it has to be transferred to the laptops for printing. They also use the palmtops for recording results from manual experiments and around the school surveys. Students quickly learned to use them to draw graphs with the built-in spreadsheet. They aim to get a full class set of palmtops when funds become available.

6. As a result of a whole school IT plan, the science department, in common with much of the school, has a computer at the back of each room connected to a network point. One of machines has a good printer attached which serves the whole department. They have a basic but modern data logging kit and recently discovered a cupboard full of sensors bought some ten years ago with some special funding. The boxes of old-style floppy discs in the cupboard are labelled with the names of some heavy weight programs – a sure sign that a technical life-form once used this cupboard. A keen member of staff has agreed to take stock of what they have and what they can do. Nearby is a carpeted suite of computers that the department has access to.

7. The head of science at a split site school was offered a set of old but serviceable computers for a large lab in the lower school. She accepted them with the proviso of some extra funding to buy a set of data loggers. She has highlighted several opportunities to use computers for measuring temperature and lots of trolley-ramp type experiments in their work scheme.

Hardware strategies

"In the IT room no-one can hear you scream"

The aim here is to arrive at a plan for the department. Rework these (often cheeky) ideas to suit. Which can you work on now?

Idea	Idea to compare it with
Computers on trolleys or mobile furniture	Computers and monitors on mid-height shelves to clear working space
	Older 'handed down' computers to do just data logging
Personal computers for teacher admin and demonstrations	Laptop computers for teacher admin and demonstrations
A class set of 'pocket' computers for data logging	A class set of small portables or sub-notebooks
Cheapest possible machines built locally with service contracts	Reliable best brand machines and an in-house technician
	A class set of calculators (e.g. Texas Instruments) for data logging and analysis
A class set of less expensive computers (lower specification or older)	Current specification laptops with multimedia.
A class set of new, cheap, high spec machines	A set of low spec machines with service contracts and wireless network cards
A science room with stand-alone personal computers and printers	A networked science room with Internet access to ease printing and file sharing.

A computer connected to a wall mounted TV for demonstrations	A computer connected to a projection system for demonstrations
A PC projector with the highest affordable brightness	A less bright PC projector with a high brightness portable screen
The cheapest PC projector	The cheapest PC projector and a spare lamp
PC's with small flat panel displays	PC's with large CRT monitors

Affordable Colour laser printers	Affordable colour laser printers with money put aside for all consumables
Fast printers to avoid printing queues	
Printer shared through a switch box and printer lead.	Wire free printing from laptops
Networked but remote colour printers	Local colour printers

School owned and managed	Department owned and managed
Department owned and IT department crisis managed	Department owned and managed. IT department maintained
Computer suite ever available with a shared door key.	IT lessons fill the IT room timetable. Key is stored somewhere.
IT department manages	IT department facilitates

Labels for equipment

In schools people share computers and the glamorous name for this is 'hot-desking' though it's not as exciting as it sounds. Those who can happily adapt to different machines clearly have skill though the rest us need have things written down. Here then are some examples to make a simple point: when there's a lot to remember it needs to be written down.

We've seen more than one school that realised we have a hard time recalling the idiosyncrasies of technology. One had eight laptops and eight trays of data logging equipment - everything was labelled; instructions were copied from manuals and put on laminated card. Each item in the data logging trays was labelled to say what it was and which set it belonged to. There was a photograph on a laminated card showing the trays' contents.

The laptop

You should have a laptop, a cable with mains plug and a power transformer.
Plug in the power pack at the back. Connect to the mains and switch on.
Make sure the lights on the power transformer AND the computer are on. If not, give your connections a push.
Pull the two slide switches (on the side) towards you and lift the screen.
Push the power button at the back of the keyboard - once to turn it on.
The data logger plugs into the red socket. This is called COM2 in the software

Closing down

When you have finished, choose 'Start' and 'Shut down'. This computer turns off automatically.
If the computer completely 'locks up', press and hold the power button at the back of the keyboard to shut it down.

Using the 'mouse'

The laptop has a touchpad instead of a mouse.
Slide your finger to move the pointer.
To click, press the left button OR double tap the touchpad.
To find a program quickly, use the 'Windows' key and hit the cursor keys.
Use the cursor keys and 'Enter' to respond to screen prompts
To shut down, press ALT + F4 ; Enter a few times.

Connecting to the TV

Connect the phono lead to a socket at the front of the TV. (The socket is behind a tiny flap door).
Connect the lead to the yellow socket at the back of the computer
Switch on the TV and use the remote to set it to AV
When the computer is running, right click the desktop, choose Properties, Settings, Advanced. Click TV, Click PAL, Click OK.

Data logging software notes

Connect your sensors to the data logger and the computer before starting the software.
There are bar and meter displays to use in demonstrations
Press the 'readings' button to read values from the graph
Use the change button to see which graph has gone down the most.
Use the average button to compare two cooling slopes
Use the area button to see which graph stayed higher longest.
Don't use 'gradient'. Instead find out how much the graph rose overall in say, 10 minutes.

Displays on a bigger screen

Had a computer been designed for education, it would surely have been built with wall size screen. A big screen that all eyes can fix on is essential for demonstrations and essential for discussion. Short of handing out binoculars to the class, we look at the alternatives for showing an image everyone can see.

General points

Adjust your system settings so that menus and dialogue box lettering is extra large. On my system, the things I need to show are clear and bold unlike the way Microsoft set it up. This is easy to do and recommended even if you have the best display system. Software designed for primary schools displays things bigger than usual to give a much clearer display. I use junior data logging software when there is no better way of people seeing. I harass software developers to use the screen space well. Please do so too.

Use a TV as a monitor

At some point in history, computer monitors and television parted company and developed in different ways. The result is that a large TV is inexpensive, while computer screens cost more.
As a result of the games and DVD boom, desktop and laptop computers with a TV output are common. The output may be a yellow 'phono' socket which is easy to overlook. Use an audio cable to take this to a similar socket on a TV. You can also connect to the large, multi-pin SCART or Euro socket on a TV – some SCART plugs have red, white and yellow connectors. Connect to the yellow of course. Once you're wired up, get the PC to send its output to the TV. This may be setting in Display Properties. You need also to switch the TV to this socket – look on the channel changer for a button marked 'AV'.
Many computers have an S-video output and for this you either need a TV with an S-video input or an S-video to Composite adaptor.
You can add a TV output 'card' to an existing machine. This card could be a dedicated TV output card or a graphics adapter with a TV out socket. Don't confuse these with TV cards designed to show television on the PC - though some of these have the socket you need. Keene.co.uk do a nice and easy USB adaptor while Avermedia have a range of TV scan convertors. The cables you need can be found in video transfer kits available in accessory shops. Whatever the result it will work best when permanently connected to the PC.
TV screens look best on wall brackets. Picture sharpness is no match for a monitor but it will do nicely if the image is not too detailed.

Use a large monitor

The price of 19" and larger computer monitors make these an option to consider very seriously. Other things being equal, four students can share such a screen. You can demonstrate to about ten people sitting close. A class of thirty would need a 25-28" screen. If you use a splitter to feed the signal to several monitors you have a very useable system.

Use lots of monitors

There are switch boxes that feed all the monitors in the room with the image from one machine. There are also training networks that allow the teacher to broadcast an image to all screens. They also let you peep at each student's screen and see what they are doing. These are not as expensive as you would imagine as a lot of it is done with software.
You've seen video walls? You can fit extra display sockets to the PC and show one image split between different monitor screens. (Try this at home and you'll not want to use a single screen again.) This is much less expensive than buying a single large screen. My maths says that 3 x 15 inch flat panels is cheaper and more screen area than 1 x 19 inch flat panel.

Use a projector

While there are huge ceiling mounted three beam (RGB) devices which you can buy second-hand, the definitive system is a computer projector.
Most projectors look little different to a slide projector, except that the lamp inside is very costly. Projectors come in different flavours and the brightness can't be relied on (anymore than car petrol consumption). You need to consider the lens 'throw', resolution, brightness and running costs and match this to the room and your budget.
Appreciate that small portable projectors make some compromises – even though the specs may be identical. A built-in camera is a great asset and for very little extra expense. Wireless network projectors, which allow a laptop to display from a distance, are useful when pupils need to present from different machines.
If you can afford a projector most likely you can afford a good screen. The screen can seriously

maximise what the projector offers. Boxed portable screens are much nicer than the tripod ones which many people have yet to learn how to set up. Get advice because some screen surfaces are directional and will not suit a wide room.
Sometimes you can display the image on the projector and computer monitor simultaneously. When you connect a projector to a desktop computer you use a splitter cable to send the image to both screens. When you connect a projector to a laptop computer you need to tell the laptop to output to its monitor socket.
In theory you can display the projector image and laptop LCD simultaneously but in practice it only works well with one or the other. If you're in a hurry to get the lesson started always output to the projector because it's rare to find a laptop LCD screen, graphics card and projector that are happy with the same resolution and refresh rate.

On a laptop you can change a 'BIOS' setting so that the image will display on a projector if one is connected. Mine is set permanently like this and it saves hassle.
There are interesting ways to connect the projector remote control into the system to replace your mouse. If you want to do more that click through a PowerPoint, get a cordless radio mouse. Logitech do a combined radio mouse / presenter device which really is the business.

Other things to note

The best set-up I've seen back-projected the image onto a translucent panel. This arrangement can be a permanent and has the panel flushed with the wall. The projector is hidden behind in an access hatch. A large mirror directs the beam from the projector to the screen. You use the projector menu and ask it to reverse the image.

An overhead projector and LCD panel was once the standard way to put a computer image on a big screen. A darkened room was often essential. Also the LCD panel rarely refreshed the screen fast enough to cope with the video you found in multimedia software.

While these are no more, those using *Texas Instruments* calculators for data logging can buy an inexpensive liquid crystal panel that displays the image large. This works very well with a powerful overhead projector.

Data logging interfaces

There are two kinds of interface box that connect the sensors to the computer. The first and least expensive provides a simple route from the sensor to the computer and allows you to display results 'live'.

The second kind, a data logger, has additional recording and storage facilities. It can store readings from events taking days or weeks to unfold. Afterwards, the computer can read the data from it. These stand alone devices can often record data at high speed – for example they can record the flicker of a lamp and take 100's of readings in a second. The data logger has buttons to start and stop recording as well as an independent power supply. The buttons allow you to alter the recording speed or say when the recording should start. The data logger may have an LCD display to monitor what it is doing. When you leave a data logger to record it compresses the data. At each doubling of the recording time (e.g. 4s, 8s, 16s) it discards half the data. A computer is nearly always essential if you want to analyse the data. If specifications vary even the lowest spec is powerful enough for most uses.

	Data logger A	Data logger B	Data logger C	Interface D
Special feature	LCD meter	-	LCD meter	Plug and play - USB
How much it stores	104,000 readings	32,000 readings	4500 readings	50,000
How fast it records	14,000 / sec	10 / sec	500 / sec	1000 / sec
Battery	Alkaline - 180 hour life. Data protected by silver cell.	NiCd rechargeable and unpredictable. Data lost with charge.	NiMH rechargeable and unpredictable. Safe memory NVRAM	Alkaline or Computer powered Safe memory
Resolution	10 bit	10 bit	10 bit	10 bit

How the parts work together

In nearly every system you can find, data logging sensors plug into a box. The sensor sends its 'readings' to the box and informs it which type of sensor it is. The sensor identifies itself using pins on the sensor plug – some systems place a resistor across the pins and use its value to identify it. Other sensors have a PIC chip which 'tells' the data logger all it needs to know. If you ever find a sensor identified incorrectly, it may be because the batteries are running low.

Some sensors have their own power supply but the best derive all their power via the interface. The latter is many times easier to manage. Some devices get all their power through a USB connection or Parallel port and these tend to be the most reliable.

The interface box has a circuit that converts an analogue sensor signal to a digital signal. It also has a way of communicating with the computer and most systems use 'serial' communication. Serial connections are compatible with almost every type of computer. While this is not fast communication, they transfer data fast enough for most purposes. If you want to show sound waves with these data loggers, you would record the sound at high speed and transfer the data to the computer afterwards.

You will find systems can record so fast that you can use the computer as an oscilloscope. These breathtaking tools replace the serial connection with faster Parallel, USB and SCSI connections. These are no longer expensive.

Data logging interfaces

"Every push button on a machine gives you an opportunity to press it when you shouldn't!"

Here follows a list of data logging features with a commentary. As with all technology you have to keep the need for features in perspective as they significantly affect the ease of use.

Feature	Comment	Score
Interface has an LCD meter display	Display is very reassuring and good for taking ‘single’ readings in class and on field work	
Interface needs a computer to collect its data	Students can see graphs appear in ‘real-time’	
Interface has an LCD meter and graph display	Graph display is very reassuring for long experiments and field work	
System has a meter, display and analysis features.	Does not need additional computers. An all-in solution – you’re pretty much there.	
Data logger can collect readings independently of the computer.	Good for long experiments and field work. You may only need one of these.	
Data logger allows results collected in the lab to be downloaded in the IT room	Queuing and printing bottlenecks likely. Would it be useful to see this data live and ‘as it happens’?	
Data logger allows results collected in the lab to be downloaded to the lab computer	Queuing and printing bottlenecks likely. OK for occasional use	
Data logger has a rechargeable battery	An important cost consideration. Good feature for often used equipment	
Interface uses a Mains adapter	Clumsy in use, though this may be tolerable. Does the IT room has spare power sockets?	
Data logger uses Alkaline batteries	Running costs may be tolerable. Tend to discharge in storage	
Data logger records very fast	A nice but niche use. You may want just one of these	
Data logger can be set to start recording during the night	It may be easier to start recording now!	
Data logger can be set to start recording at a certain sensor reading	For capturing fast events. Software on the computer can do this for you	
Data logger can store the results of many experiments	Value depends on how secure the data is. Still a niche feature	
Allows the number of readings and interval between readings to be customised.	Used mainly for fast recording. Less essential for long term recording	
Interface is USB powered	Very reliable, plug and play system	
Data logger time and date stamps collected data	Great aide-memoir for field work	

Sensors

IN the following pages we list what sensors do together and offer some impressions of how useful they are. You can copy this list to make colleagues aware of what you have.

As shown in 'Data logging and Control', with a little ingenuity sensors can be made more versatile – for example a position sensor can be used to record breathing on a spirometer or the expansion of an iron bar.
Some sensors have a choice of ranges to make them more versatile. This can be good but the downside is that every button added gives us another thing to press by mistake. If you multiply the number of buttons by the number of students you have, you'll see my point.

Sensors often process data before you ever see it and this isn't always wanted. A breathing sensor processes breathing movement data into a breathing rate. A first impression is that this is good, but appreciate that it is good for students to see the breathing movements and to count the peaks.
Raw data can be as interesting. That's why we need to weigh up the benefits of seeing pulse rates versus pulse waves, radioactivity counts versus radioactivity count rate, mass versus mass loss. as rate of change data.

A final practical tip is to clamp your probes. This prevents wires pulling things over and allows you to fix a probe so that it dips into what you are measuring. Use clamp or clothes peg to fix a temperature probe at the centre of a cooling liquid.

Disclaimer: the advice that follows needs to be set beside the manufacturer's instructions. Their advice takes precedence over this. You can find further information by visiting manufacturer's web sites – find the links at www.rogerfrost.com.

Our sensor ratings: * and +

Stars measure the sensor's intrigue, interest, and learning potential from * to ****.
Plusses measure how often a science department might use the sensor from + to ++++

Sensors to measure motion

Accelerometer ****/++

These tiny chip devices are the sensors used as triggers for car air bags. You can take one into a lift, fix one to a dynamics trolley to look at collisions or swing them around to investigate circular motion. A very promising device to measure the previously unmeasurable.

Light gates and switches **** /+++

These are digital switches that record a time when triggered by say, a dynamics trolley or a card. When you enter parameters like distance or mass into the software, velocity, acceleration or momentum are instantly calculated. This and the accuracy and precision of the timing offer huge potential for physics. Measuring 'g' becomes a two-minute experiment from start to finish. Measuring reaction time and karate chops are neat ways of introducing pupils to them.
You can find various designs of 'gate' – there are U shapes with large or small gaps between their infra-red emitter and detector. Some have a gap of a metre or so and can time a person. Some are not gates as such, but a single sensor – probably a photo transistor which responds to a change in light intensity – you really need to clamp them still and illuminate them across a gap where the trolley might pass. These can be much cheaper than a gate, but more of a fiddle to set up and get working - in a permanent set up they would be fine. Look out for switches that find special uses. A push switch can be used to initiate timing manually; a peg switch is used to start timing when you drop a card. A pressure mat switch can be placed on the floor to time people cycling over it, or measure how long they can jump and stay in the air. Rest assured light gates and switches have their uses, but do compare them with sonar distance sensors or dynamics pulleys because these give a more analogue picture of motion.

Sensors

Force or dynamics / mechanics pulley **** /+++

A fascinating device for measuring the velocity and acceleration of a dynamics trolley, falling object or the puck on an air track. The pulley does the same as a 'ticker timer' but also generates the graphs for you. While its uses overlap with light gates and sonar distance sensors, these take 50 readings a second and offer better results. Some light gates have a pulley attachment to do the necessary. Ultimately, something like one of these it is a must for physics.

Rotation sensor * /+

Reported uses include finding how the applied current affected the rotation speed of an electric motor.

Shock sensor ** / +

Piezo electric device – used for testing the shock absorption of footwear or timing footsteps, and impact of a bouncing ball.

Sonar distance sensor or ranger **** / ++

These distance or motion sensors use sound reflected from an object to detect changes in its position. Most designs are based on the sensor developed as the range finder for Polaroid's cameras. You can walk towards the sensor and watch a graph of your displacement, velocity or acceleration appear on the screen. It is usual to put a graph on the screen and then get students to try to create one on top of it. You can point one at a swinging pendulum; or suspend them under a mass on a spring. You can also hold one above a bouncing ball and show the bounces, though they tend to look upside down because down is far away from the sensor. By most accounts, this is a very useful sensor to learn from - it is worth getting hold of some teaching materials to see its great scope. The range finder sensor component inside is fairly expensive so these will not be cheap. Do use them with a power transformer as they eat batteries. The range is typically from 50 to 500 cm – go too close and they get confused. There are limits on how fast they record so light gates are still useful for measuring fast changes. A force or dynamics pulley offers much better accuracy should you need it, but these are a rare find. See page 38 onwards for its uses.

Strain gauge ** / +

Used to measure deflections on beams and as a materials tester.

Sensors to measure heat and temperature

These sensors are available in all flavours to suit different applications. You should be able to decide on the type that suits whole class use and have any others for projects. Take care not to use different range sensors in the same experiment as different temperature scales on the screen are very confusing! For the same reason, avoid switchable range sensors as these inadvertently add a variable to class management. The mix of traces appearing on screens across the room has had us in tears!

Heat flow sensor *** / +

Used to measure the flow and direction of heat through clothing or building materials. It contains countless thermistors and unlike a temperature sensor, provides readings as Watts/m2. While its uses seem limited, this is an interesting sensor that provides a useful measurement. It might be compared with sensors that compare two temperatures and measure the difference but wins every time. See page 67 for its uses.

Full range temperature **** / ++++

Extremely versatile and often inexpensive probe. As with many devices, accuracy is less good at the extremes of their range – hence water appears to boil at the wrong temperature. Some probes like PTAT probes (proportional to absolute temperature) aim to get round this.

Low temperature sensor *** / +

Intended for sub-zero work on depression of freezing point for example.

Body temperature range sensor **** / +++

Working on the idea than a narrow range sensor is more sensitive, this is useful for measuring subtle changes in skin, room or water temperature. Use it for changes in skin temperature due to exercise or perspiration. Most teachers will make do with a full range temperature sensor but it is surprising how many experiments, like washing powders, could be adapted to work at a lower temperature.

Thermocouple and high temperature sensors ** / +

These devices will have a few niche uses measuring flame temperatures for example.

Sensors for light and sound

Light sensor *** / +++

Often elaborated on to produce a makeshift colorimeter, useful for many biology and chemistry experiments on rates of reactions. As monochromatic light is less important with turbid solutions the makeshift colorimeter seems adequate for measuring the speed of precipitation reactions. Some have a linear response that suits them better to quantitative work such as showing the inverse square 'law', some have a logarithmic response which is perfectly adequate for other, more general uses. For example, you could use almost any light sensor device as a marker sensor to show day and night. They vary in their response, for example an LDR type responds more slowly than a diode type. The faster type can pick up the AC ripple from a fluorescent tube – which can be a source of interference to the sensor in normal use. Makes also vary in their spectral response - something to consider when you compare the brightness of different coloured fabrics. Curiously, some respond well to infra-red and can pick up the signal from a remote control. Variously calibrated as %, Watt/m² or lux.

Colorimeter sensor *** / ++

Rare but very useful for quantitative work in biology and chemistry experiments where a rate of a reaction is measured. Bleaching food dye, the iodine-propanone reaction and the action of pepsin on milk are some examples. Monochromatic light is very important in colorimetry, so this ‘sensor’ will come with a few filters. Main advantage is one of convenience over making your own colorimeter with a light probe.

Infra-red sensor ** / +

Might be used for measuring radiant heat or the heat from different surfaces. There are still too few reports of curriculum applications where infra-red changes in relation to time or some other variable.

Sound sensor **** / ++

Sound sensors tend to find their use as stand alone noise meters but this misses some interesting uses where sound level changes over time. Just using it as a class noise meter is one option to try. It finds its main use as a marker sensor when recording over time. For example, it might provide a clue that people were causing a room to warm up. Other uses such as testing the loudness of sounds or comparing sound insulators will work if you can reduce the background noise. Note that the sound sensor usually measures over a range that starts above zero. In common with noise meters, they are 'A-weighted' - meaning that their response has been adjusted to match that of the human ear.

Microphone sensor *** / +

Some ranges feature a microphone as distinct from an 'A-weighted' sound sensor that measures noise levels in dB. The microphone may have a sufficiently fast response to allow you to measure the speed of sound and capture waveforms and this is impressive. On many systems, and there are a few exceptions, you may need to first capture the sound on a fast data logger and then transfer it to the computer. The sensor may even offer a way of switching between these functions. It is worth also seeing what you can do with an ordinary microphone connected to the sound card of the computer. Special software, such as ‘Multimedia Sound’ (AVP in the UK) is available to do some impressive waveform analysis.

Sound switch **** / +

Used to measure the speed of sound. Two hardware approaches to this: you set a pair of microphones a certain distance apart, make a sound and then read the interval between two peaks from a graph. In another you strike two pieces of metal together and the metal closes a switch and starts the timing. Software shows the time it takes for the sound to reach a microphone. Can also be used to show how temperature affects the speed of sound or even for timing how fast an object takes to fall and hit the floor.

Ultra-Violet sensor ** / +

Might be used for measuring the variation in UV light during the day or as meter to compare sun creams and sunglasses.

Sensors for physiology

Breathing monitor **** / +

A dedicated device that shows the breathing rate or in some designs, the breathing movements. The latter types are more interesting as they show the depth of breathing too. However, with these you have to count the peaks on the screen to get the breathing rate – this is no bad thing. As with the pulse sensor, some designs are not too disturbed by body movements and allow you to show the change in breathing during exercise. There are numerous varieties – some respond to the stretch of a chest belt, some to the temperature of air under the nostrils. They tend to focus the attention of those actually wearing it - it's more fun to watch yourself than others!

Pressure Sensor **** / ++++

A surprisingly useful sensor which is usually on the expensive side. They come in various ranges and while no single range handles all uses you can settle on a mid course. Some measure air pressure well, some measure very high pressures such as arterial blood pressure. They are good tools for gasometry in chemical reactions as well as showing the relationship between temperature and volume. Some are sensitive enough to monitor the respiration of mealworms and changes in osmotic pressure - in fact these find several uses for biology. Attached to a ‘stethograph’ – a chest belt they can be used to show breathing movements. Pressure sensors are very reliable and some brands warn you to take care not to exceed the sensor's range - colleague Rod Taylor suggests set ups involving a pressure release valve - a mere balloon attached to a side-arm flask. For everyday convenience, store the sensor with a selection of pressure tubing, bottle tops with delivery tubes, push-on connectors and syringes.

Heart rate **** / +

A handy device for showing the pulse rate over time. Some systems are designed to monitor pulse rate during exercise and have a probe that is not too disturbed by body movements. A few offer the option to show the pulse wave - the pulsing of blood through capillaries. With this you can often spot the dicrotic notch where the aortic valve closes. Some work by radio transmitter over a distance (telemetry). Students may need to be reassured there's no risk to them – some get anxious about using them and this sets the pulse going!

Electrocardiogram (ECG) **** / +

Used to show the ECG wave and the pulse rate. Fortunately, it is very hard to get diagnostic information from these or domestic ECG devices – a diagnostic ECG uses six to twelve electrodes and need special skill to interpret the result.

General sensors

Balance **** / ++

Balances and interfaces have for a long time tried to find a common language for talking to each other. A few systems have found this and offer a balance adapter that works with your regular data logging software. Typically measuring mass over time suits monitoring transpiration and chemical reactions where a gas is evolved.

Conductivity sensor * / +

This sensor is used in conjunction with a conductivity cell. It tends to used as a stand-alone meter to measure salinity or total dissolved solids in water. Offers some enhancement when used to monitor precipitation reactions on screen.
Keep the conductivity cell as far as possible from the computer to minimise electrical noise that the cell can pick up. When transferring the cell from one solution to another, rinse in distilled water and shake rather than wipe to remove drops. After use wash in distilled water and store wet or dry. For absolute conductivity measurements, you may need to take account of the cell constant – a value may be marked on it.

Humidity sensor ** / +

A less widely used sensor that nevertheless shows interesting results when monitoring environments over time. Place one in a polythene bag with your hand, or a plant and see how the humidity changes. The range of the sensor varies between manufacturer, and it is within the range 10-90% humidity. Acetone and organic solvent vapours are harmful to the sensor while wetting with water leads to unreliable readings.

Magnetic field sensor * / +

Used like a wand and moved in magnetic fields. Interesting in the way it measures the unseen. Has a niche use in applications showing magnetic field changing over time or some electrical variable.

Oxygen *** / ++

Sensor is used in conjunction with an oxygen electrode. Good for demonstrations where you monitor photosynthesis, fermentation or where you re-breathe the air in plastic bag.
Before you use the electrode for the first in a long time, fill the membrane cap with electrolyte without introducing air bubbles. Connect the electrode to the sensor, switch on and leave it in air for up to twenty minutes to stabilise. It is easier to calibrate the sensor in air, although some prefer to use an aquarium pump to aerate water for an hour and use this as a 100% saturated standard solution. When you have finished, keep the electrode suspended in de-ionised water to prevent the electrolyte from drying out. The usual advice is that the electrode should only be kept like this for a week before taking it apart, washing with soapy water and rinsing in de-ionised water. Many say they've kept it in a ready-to-use state for months. But do take great care of the membrane caps - physical damage to the polythene membrane may be a cause of poor readings. Other snags are due to a poor connection between the electrode and the adapter, cleanliness of the electrode tip and condition of the electrolyte. Do allow time for the electrode to stabilise and appreciate that movement of the liquid you are testing is highly recommended. A few goldfish will make useful stirrers for an aquarium.

pH **** / +++

A versatile sensor used in conjunction with a pH electrode. It makes creating acid-base titration curves easy and there are biological applications in monitoring photosynthesis, respiration, fermentation and the activity of lipase. These uses aside, compared to a regular pH meter it can good value as a pH measuring device. The main issue is that in many places, pH electrodes are so rarely used that they suffer during storage. The key piece of advice is to keep them wet and never wipe or dry them.

Position or Angle sensors **** / ++

This sensor allows superb and easy to do investigations into the swing of a pendulum leading on to studies of harmonic motion and damping (See page 49). It allows you to record the period of every swing of a pendulum, instead of timing ten and dividing by ten. This in turn strikes us as more convincing. There are ways to do this experiment which ensure that your graph axis are centre screen and also that sets of pendulum swings will all start at the same part of a swing. These are features to look for in the software. Other reported uses include recording the rise of bread dough or as a lever arm responding to movement. You can use it to measure plant growth over time, though it is worth exploring ways to set this up as a lot of plant growth is due to the slip of the thread holding the plant!

Radioactivity - Geiger Counter * / +

Uses a separate Geiger probe to measure radioactive counts or count rate. Most useful are those that show the count rate at a point in time – with a fast decaying source you can plot a decay curve in real time. Its other use is for a visual display of the effect of distance, or materials on radioactivity. The types which work purely as a Geiger Counter - which accumulate counts - are best used as stand alone meters rather than with a computer. In its defence, the sensor may be better value for money than a scaler box.

Voltage and current sensors **** / +++

The scope for electrical measurement as obviously as big as the subject itself. Data logging systems tend to measure changes over time that suits these sensors to measuring the life of a battery, induced emf as a magnet falls through a coil, discharge of a capacitor or surge current when switching on a lamp. There is great learning potential in seeing the way that the current through a bulb, resistor or diode changes as you slide a variable resistor. Likewise use them to see how the current and voltage in a circuit are related (see page 56). These uses are good, but using sensors as simple meters needs to be assessed carefully. It seems wise to look at the economics of replacing inexpensive meters with equipment specially designed for a computer. Otherwise these sensors connect into circuits just as their respective meters do. Check the instructions to see if you need to use a ‘common return’ – this means you connect the return lead of the current sensor to that of the voltage sensor.

Choosing sensors

"Treat technology like milk - get what you can use - stock piling it doesn't make sense"

Long before you ever unwrap some sensors, you will have used other sensors many times over. These suggestions add of bit of strategy to buying sensors.

Soon	The future
For general science up to age 11	
A sound sensor to monitor noise levels. A light sensor to monitor day and night Two temperature probes for work on hot and cold	Switches (pressure pad, light gate) for timing jumps and toy cars
For general science age 11 to 14	
Pulse and breathing sensor Two temperature probes for work on insulation etc A light sensor as a day and night marker A sound sensor for noise levels. Pair of light gates for timing	Class set of pairs of full range temperature probes Class set of pairs of light gates for work on forces topics
For general science age 14 to 16	
Temperature probes - about three Pair of light gates for timing Distance sensor for measuring motion Voltage and current sensors Pressure sensor Light sensor to use as a colorimeter A selection of individual sensors	Class set of pairs of full range temperature probes Class set of voltage or current sensors Class set of pairs of light gates or other motion sensors for work on forces Class set of pressure sensors
Biology - ages 16 to 18	
Temperature probes - about three pH sensor and probe Oxygen sensor and probe Light sensor to use as a colorimeter Low Pressure sensor One or two other sensors - especially for physiology	Scale up according to interests
Chemistry - ages 16 to 18	
Temperature probes - about three pH sensor and probe Light sensor to use as a colorimeter Pressure sensor One or two other sensors according to interests	Scale up according to interests
Physics - ages 16 to 18	
Temperature probes - about three Pair of light gates for timing Pressure and position sensors A selection of sensors - especially for motion Voltage and current sensors	Scale up according to interests

Section 2 - experiments and data handling

What you will find here:

- Class experiments
- Experiment notes
- Teacher demonstrations and projects
- Teaching notes for special topics
- Data handling exercises with graphs

All arranged loosely by subject:

- Physics topics start opposite
- Chemistry topics start at page 83
- Biology topics start at page 115

Teaching about motion

In schools everywhere, pupils use stopwatches to time a vehicle rolling down a ramp. They measure the effect of friction as the vehicle moves on different surfaces. The measuring errors are huge - so huge there should be cause for concern. Yes, the experiment teaches them how to control variables well. But it also teaches children, all over the world, how to measure things badly. It is the kind of science we ought to leave well alone. Let them do it in social science, but please, not physics.

Technology offers a wake-up call to experimentation in forces topics. Sensors from light gates to sonar distance sensors are key tools. Dynamics pulleys, force sensors, shock sensors and accelerometers offer great promise.

Light gates are digital sensors that record ***when*** an event occurs rather than the detail of the event itself. In fact the sensor is really just a switch. You can find other digital sensors. There are pressure mats you can stand on to close the switch and there are sensors that consist of a pair of crocodile clips - you simply touch these together to record an event. For example, you could time how long a card took to drop - you hold it in a peg with two contacts and a squeeze breaks the circuit and records the event. Another sensor in this group is a sound switch and it records when a sound was made rather than its volume. Handling digital sensor measurements merits and requires the special approach of 'timing' software unlike that used with other sensors.

A teaching sequence

The diversity of tools to measure the same sorts of thing offers many opportunities. It needs skilful handling. It calls for a judicious sequencing of activities. Here is one such teaching order for discussion.

i Use a light sensor in your data logging software to time how long it takes to walk round the room. Walk past the light sensor at the start of the journey, circuit the room and pass the sensor at the end. The interval between the two peaks is the journey time. Use this to work out your average speed.

ii Use two light gates to measure time. For example, measure your reaction time as you watch another person break the beam of the first light gate. Or swap the light gates for pressure mat switches that you stand on to trigger the software and measure reaction time. (e.g. See the section Motion - measure your reaction time)

iii Use two light gates (or pressure mat switches) to measure average speed. Tell the software how far apart the sensors are and then say, walk between the sensors. Or measure the average speed of a trolley running down a slope. (e.g. See the section Motion - measuring speed)

iv Use a light gate to measure speed as a card (or rectangular section vehicle) runs past it. Appreciate why the software needs to know the length of the card and how it then works out the speed. Appreciate too how this measurement is different - it offers a better description of the motion than measuring the average speed with two light gates. Similarly see how fast a card falls when it is dropped from different heights. Look for a relationship between the height and the velocity. (e.g. See the section Motion - changing speed and also Motion - Velocity in free fall)

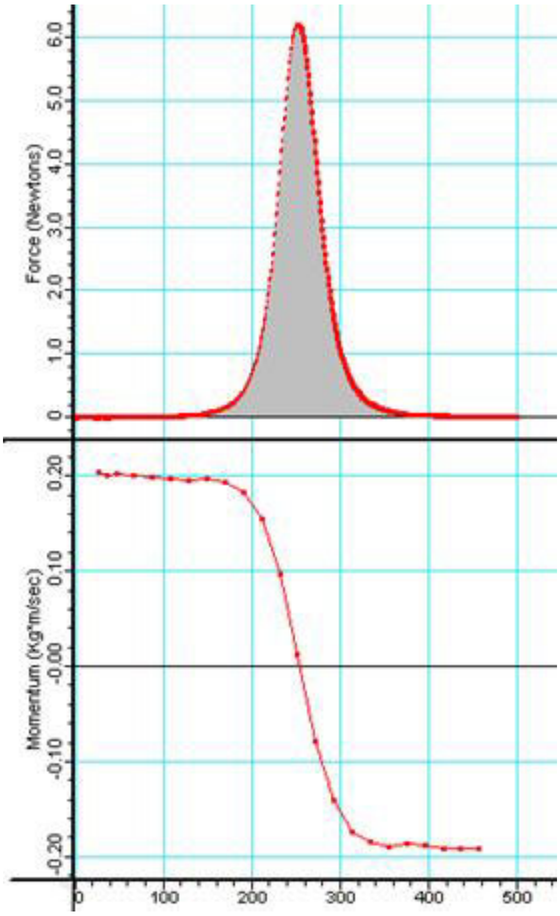
v Use two light gates to measure speed as a vehicle runs past each of them. Decide whether it is speeding up or slowing down. Appreciate that the speed changes as the vehicle passes each gate in turn. (e.g. See the section Motion - momentum)

vi Use a light gate to measure acceleration as a trolley runs down a ramp from a standstill. Or measure acceleration as you drop a double interrupt card.

vii Use two light gates to measure acceleration as a trolley runs through the gates. Or measure acceleration as a card is dropped from above them. Appreciate why (and this is hard) the distance between the gates is immaterial. (e.g. See the section Motion - force, mass and acceleration)

Questions

- Suggest a teaching sequence for using a distance sensor to measure distance, speed and acceleration.
- If you were to also use a distance sensor to measure distance, speed and acceleration where in the above would you add these activities?

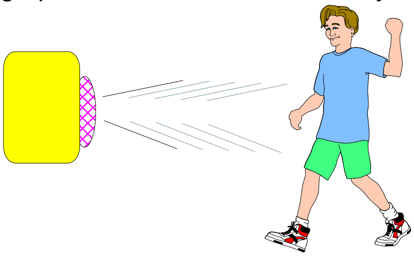


- The first trace in the graph above shows the force (over time) as a trolley hits a force sensor. The area under this provides the impulse, while the impulse, should equal the difference in momentum measurable from the other trace. The sensor measures something not seen by light gates and distance sensors. What are its uses for teaching motion? Where do these fit into the scheme of things?

(Results by PASCO's Science Workshop and force sensor www.pasco.com)

Motion - distance - time graphs

Activities with a sonic range finder sensor can help students appreciate displacement-time graphs. They see how these relate to velocity-time graphs.
The following investigation is elegant, physically easy and only limited by resources. Use it as part of a circus, though the fun element causes a bottle-neck.
Put a set of displacement-time graphs on the board or overhead projector. Ask the students to 'walk' these graphs. Get them to copy the graphs and write down what they did.



What you need

Sonic range finder sensor clamped at chest height, prepared graphs or DIY graph files.

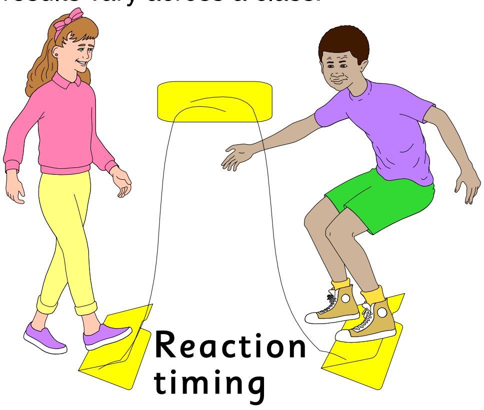
What to do

Copy these graphs, walk them and write down what you did.

- A straight line rising from left to right
- A straight line, gently rising from left to right
- A straight, level line
- A straight line, falling from right to left
- A straight line, gently falling from right to left
- The letter 'V', an upside down 'v', the letter 'W', the letter 'M'
- A curve like a deck chair, and its reverse
- A bouncing ball graph
- Can you walk: the letter 'O'? the letter 'I'? a parabola?
- How will the graphs look as velocity-time graphs? Either draw them, or get the computer to calculate them.

Motion - measure reaction time

This is a fun and valuable way in to work on forces and motion. Measuring reaction time serves to introduce the sensors you use for experiments with forces. As well as making measurements that are normally difficult to make, it provides the familiarity with the software and equipment that will benefit later work with velocity and acceleration.
One pupil triggers the sensor by breaking the light gate beam and the other follows suit as quickly as possible. See if practise improves the time. Next find out whether they react faster to a sound stimulus (a pupil hits the table as they trigger the sensor out of view). The second pupil responds to the noise. You can explore whether doing some exercise or drinking cola improves the time. See how results vary across a class.



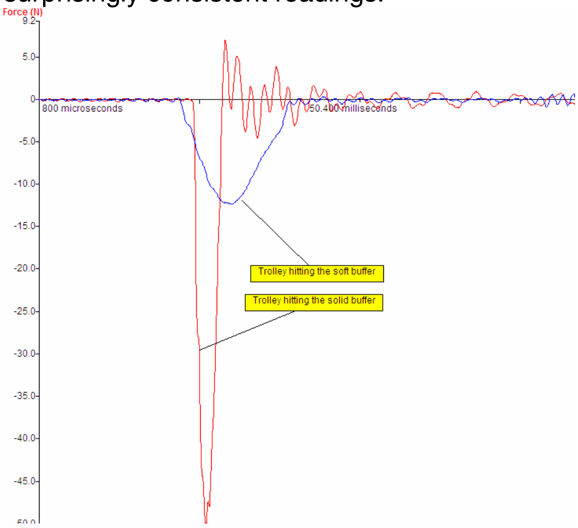
What you need

Two digital switch-type sensors such as light gates or push button switches, timing software.

Motion - measuring speed circus

Motion - collisions

Here's a good result from the use of Data Harvest's force sensor. One of the graph traces shows what happens to the force in a collision between two hard surfaces. To get the second trace, they repeated the collision with the same mass and at the same speed but 'cushioned' one surface. Interestingly the area under each graph is the same. There's no 'fluke' either as this little-known sensor gives surprisingly consistent readings.



Thanks to Barbara Higginbotham at www.data-harvest.co.uk

Motion - measuring speed circus

If technology is about addressing peoples needs, you would rightly ask why you never have as much as you need. If you can pull together a couple of computer systems, you can run a circus of related activities to get round the resources problem. It will involve a computer activity or two, some traditional approaches and some paper exercises - it is the kind of classroom scenario that best suits topics where a variety of experience or evidence helps to build an idea. Learning about the particle theory, food tests, separating mixtures and measuring speed or acceleration are good candidates for this sort of treatment. In this example, developed by Kirsty Hunter of Millthorpe School in York, we see a set of activities based around measuring speed. Like any circus of activities, it involves effort beyond the call of duty, called for support though success is its reward.

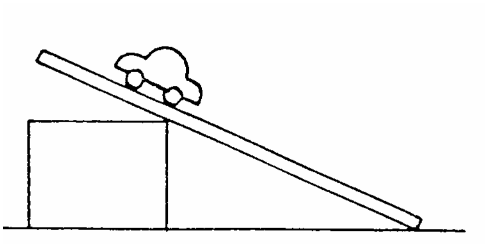
With thanks to Kirsty Hunter, Millthorpe School, York, UK - visit www.yorkschools.org.uk for further examples and worksheets from the York Schools Science and IT Together Project. Thanks for additional guidance from Chris Sharples.

Teachers note for the following pages

This is part of a Forces topic for pupils aged 13. They had 'done speed', so here they went about measuring it. In the first ten minutes of the lesson, the teacher explained the activities, protocols and pitfalls. The activities were organised by a worksheet which offered pupils ideas on how to record their answers. The teacher allowed about ten minutes per activity including writing up. Some of the activity stations were duplicated to help with bottlenecks. Some of the work, such as drawing the diagrams was completed for homework. In the final 10 minutes of the lesson the teacher discussed and compared the methods the pupils had used.

Motion - measuring speed circus

How fast is the car?

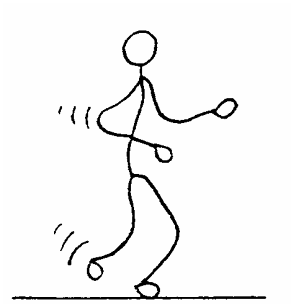


Roll the car down a ramp and measure
a) the distance it travelled b) the time it took
Calculate the speed of the car. Repeat this three times.
Discuss any problems with this measurement.

What you need

Ramps and toy car, 2 x metre rule, stopwatch, calculator. Teacher note: errors are due to our reaction time; the speed down the ramp is not uniform

How fast do you walk? 1

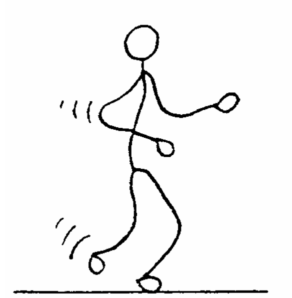


Use a tape measure and stopwatch to find your walking speed. How fast do you walk? Explain your maths. What units will you use?

What you need

Tape measure, stopwatch. Teacher note: do this last. Pupils should realise that they need to walk a reasonable distance to get a good measurement.

How fast do you walk? 2

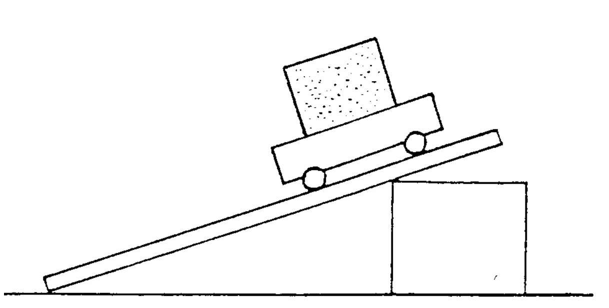


Use a distance sensor to measure your walking speed. What units will you use?

What you need

Distance sensor

How fast is the trolley? 1



Use the computer and light gates to measure:
The speed of the trolley at the top of slope
The speed of the trolley at the bottom of slope
Repeat your measurements three times.
Explain how the computer worked out the speed

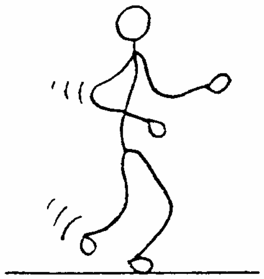
What you need

2 x light gates, ramp, trolley with interrupt card, metre rulers to guide trolley, bean bags to stop trolley, clamps and stands.

Teacher note: light gates start and stop timing when the card breaks the beam. Some pupils will appreciate that the computer must be told the length of the interrupt card in order to work out the speed.

Motion - measuring speed circus

How fast do you walk? 3

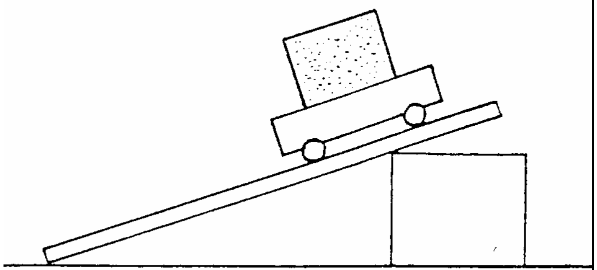


Step on the pressure pads to measure your walking speed

What you need

two pressure pads or light gates placed a distance apart

How fast is the trolley? 2



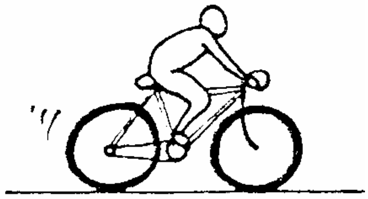
Place a light gate at the top and the bottom of the slope. Use the computer and light gates to measure the overall speed of the trolley from the top to the bottom of the slope
Repeat your measurement three times.
Explain how the computer worked out the speed

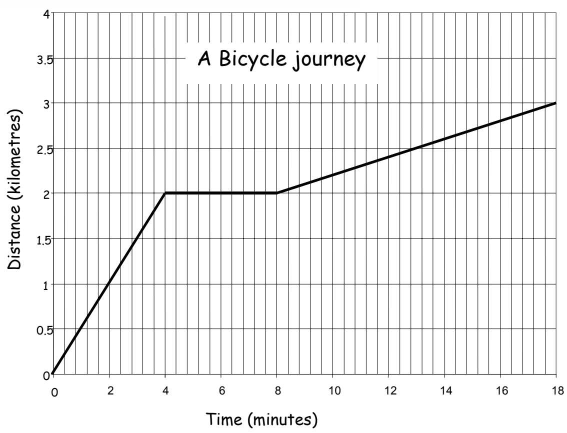
What you need

2 x light gates, ramp, trolley with interrupt card, metre rulers to guide trolley, bean bags to stop trolley, clamps and stands.

Teacher note: this approach measures the average speed of the trolley. Attach an interrupt card to the trolley with drawing pins. Use Blu-tac to fix two metre rules to guide the trolley down in a straight line. Use a bean-bag to stop the trolley at the bottom.

A Bicycle Journey





Look at the graph of a bicycle journey and answer these questions:
How far did the cyclist travel?
How long did the whole journey take?
Calculate the cyclist's overall speed.
At what time did the cyclist stop at traffic lights?
What was the cyclist's speed on the first leg of the journey?
What was the cyclist's speed on the last leg of the journey?
Why are there three speeds for this journey?

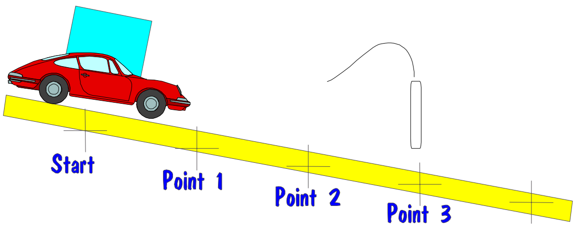
What you need

Printed graph or graph on an overhead transparency, OHP

Motion - changing speed

A car speeding down a hill certainly has energy. The energy affects its speed, and the speed is different when you start the car from different points on the hill. To be scientific and we decided to investigate.

In this example, you use a light gate and timing software. You can use your regular data logging software with other sensors such as an accelerometer, dynamics pulley or distance sensor.



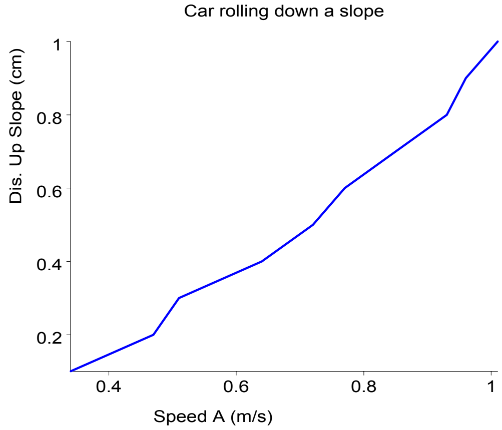
What you need

Light gate, interrupt card, trolley, clamps, ruler.

What to do

Let a car roll freely down a slope. Try again, but this time let the car roll from points further down the slope. Each time use light gates to measure the speed of a car at the bottom of a slope. Record the distance the car rolled each time.

Results



This graph shows how the speed changes depending on where we let the car roll from on the slope. Find the file and open it in your data handling software.

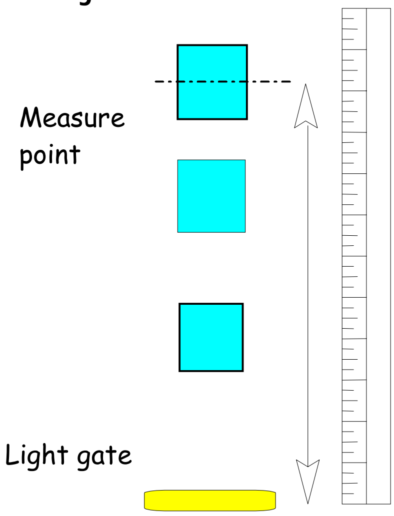
Look at the results

1. How does its distance up the slope affect the car's speed?
2. Which kind of energy depends on the speed of the car?
3. How does the distance up the slope affect this energy?
4. Which kind of energy depends on the car's distance up the slope?
5. How is this energy affected by the car's distance up the slope?
6. Does the graph show you a straight line or a curve.
7. Fit a line to the graph using your software. The function equation for the curve is $y = ax^b$.
8. What is the value of b to the nearest integer? What does this tell you?
9. What can you say about the energy of the car before it is released? What can you say about its energy at the bottom of the slope?

Results by Martin King, formerly of Verulam School, Hertfordshire. Developed for Schools Online Science at Sheffield Hallam University. On the Internet with a link at www.rogerfrost.com

Motion - velocity in free fall

You can measure the speed of a free falling object and see how its velocity changes as it falls. For example, does it fall twice as fast if you drop it from twice the height?



What you need

Light gate in a clamp, metre rule, weighted card

What to do

Drop the card from different heights and measure its velocity. Do this enough times to achieve reproducible results. Take the height as the midway point on the card. Handle the data as follows:

1. Plot a graph of height (x-axis) against velocity (y-axis). Discuss the pattern you see.
2. Fit a function to your results. Try a quadratic curve and note the gradient and intercept.
3. The velocity obviously increases with height, but does it increase linearly?
4. Calculate the square of the velocity (~ kinetic energy). Now plot height (x-axis) against this.
5. Does velocity squared increase linearly with height?

Extra

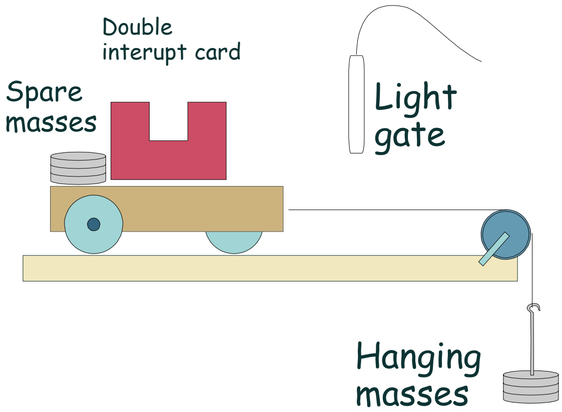
- Find out if using a heavier card affects the relationship.
- Use the software to measure the kinetic energy and see how this varies with height. (You need to know the mass of the card)
- Plot the kinetic energy against the potential energy (calculate this using mgh) and look for a relationship.

Teachers note

This activity would suit a demonstration or class experiment and, computers aside, is light on equipment. Abridged from Insight 2 software Teaching and Learning guide published byLogotron. Thanks to Laurence Rogers.

Motion - force, mass & acceleration

How does the size of a force affect a vehicle's acceleration? You can find out if you vary the force acting on a trolley and measure its acceleration. In this example, you measure using timing software and light gates.



What you need

Two light gates, a double interrupt card, trolley - weighed, pulley, ten 50g slotted masses, clamps, string or fishing line, rule, timing software. You can use regular data logging software with sensors such as accelerometers, dynamics pulleys and distance sensors.

What to do

Set up the apparatus - there is no need to get the surface level.
You will use a double interrupt card to measure acceleration. Tell the timing software the length of the interrupt card segments.
Start with a single mass on the hanger, let the trolley run and measure its acceleration three times. Do this enough times to have confidence in your result. Move a mass from the hanger to the trolley and measure the acceleration again three times. Repeat until you have about six sets of readings with different accelerating forces.

Results

Your results should be in a table like this:

Measured acceleration	Force (Newton)	Average of three acceleration readings

1. Plot the averaged accelerations (y-axis) against Force (x-axis).
2. Describe how the force affects acceleration.
3. Use your software to do a linear regression or straight line fit on this graph.
4. What causes this line to miss the origin? Is some force lost somewhere?
5. If F=ma, what does the gradient of the graph measure?
6. The gradient is a measure of the mass in motion (trolley plus all the weights). As $\frac{a}{f} = \frac{1}{m}$ the gradient must be $\frac{1}{mass}$.

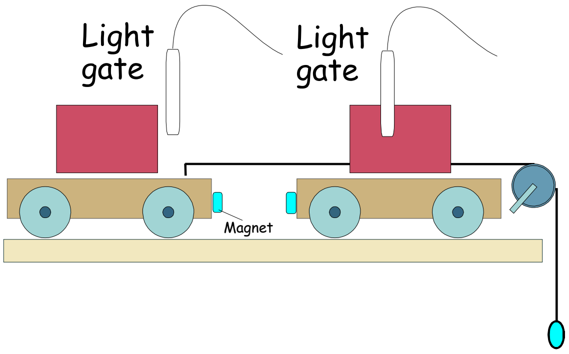
Teachers note

This is about Newton's second law or F = Ma. Demonstrate this or use it as a class experiment. A bar chart display of the results is telling - you should see the bar double in height as the force is doubled and so on. You will find the graph intercepts the y-axis - you can make the line pass through the origin if you adjust the slope to compensate for friction. You can also find out how the mass of the trolley affects the acceleration.

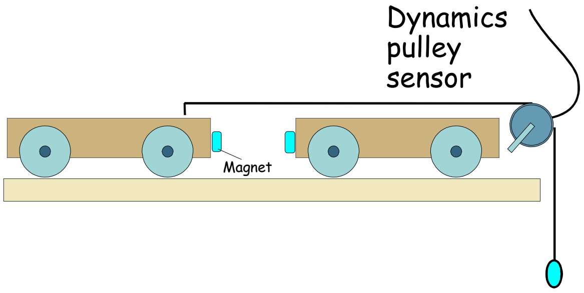
Thanks to Laurence Rogers, Leicester University. Additional ideas from John Gipps - see his work at Monash University and his books supplied by Tain Electronics www.tain.com.au

Motion - momentum

Here are two ways to show that momentum is conserved during a collision.



An alternative you might try:



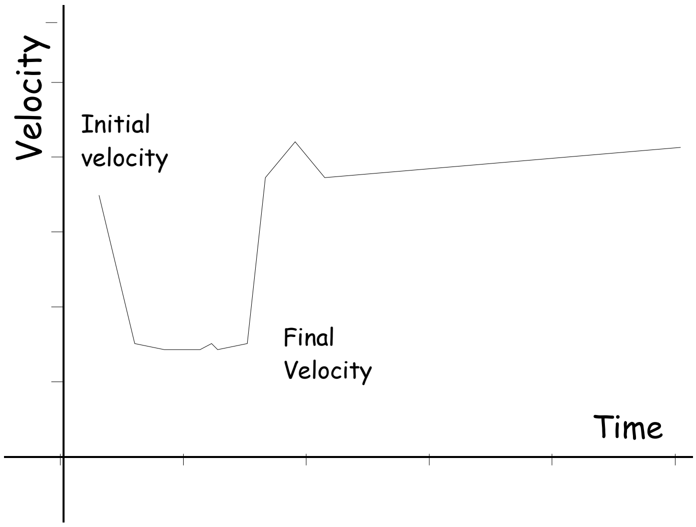
You need

Two light gates with timing software, interrupt card (or a dynamics pulley) or dynamics trolley, magnet, plasticine, clamps and stands, fishing line. Alternatively use a linear air track and two pucks.

What to do

Weight the line with enough plasticine so that the trolley moves at a constant velocity.
Measure the initial and final velocities of the trolley.
Calculate the total momentum before and after they collide.

Results using an electronic dynamics pulley



Teachers note

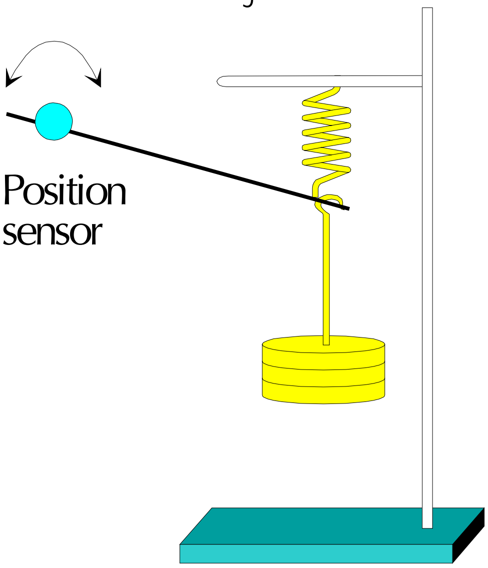
Based on Peter Adams results with Tain's dynamics pulley and software - see www.tain.com.au.

Pendulum and oscillator

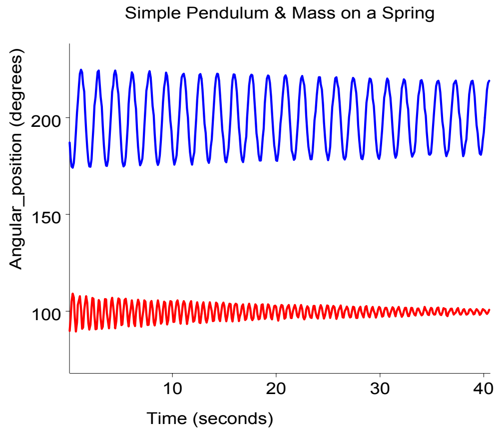
There's something almost magic about oscillations. Here we set about using a special way to study them.

What to do

Use an angle (turn or position) sensor connected to the computer and record the bumping of a metal rod and a weight on a spring. Try again with a pendulum made of a metal rod and a weight.



Results



The top trace shows the oscillations of a metal rod and a weight. The bottom is a weight on a spring.

Look at the results

1. Open the file in your software.
2. Describe and compare the shapes of the two graphs.
3. What does this tell you about the nature of the oscillations?
4. Does the amplitude of the oscillations vary with time? Why is this?
5. Does the frequency of the oscillations vary with time? Why is this?
6. How might this information be useful in designing a clock?
7. What do you notice about the shape of the "envelope" of the oscillations in each case?
8. How might this information be useful in designing a car suspension system?

What you can do

Try for yourself: see how the oscillations change when you damp the motion of the mass using a card vane, a beaker of water and a beaker of oil.

Results by Martin King, formerly of Verulam School, Hertfordshire. Developed for Schools Online Science at Sheffield Hallam University. Visit the Internet link at *www.rogerfrost.com* ***to obtain the results file. Software: Insight 2 from Logotron.***

Exploring pendulum swings

Pendulum swings - exploring some data

What you need

You can choose between:

Slotted mass to hang from a spring, clamp and stand, position sensor.

Sturdy fuse wire, pendulum bob, clamp and stand, position sensor.

Sturdy fuse wire, pendulum bob, clamp and stand, Blu-tac and stiff card, distance sensor

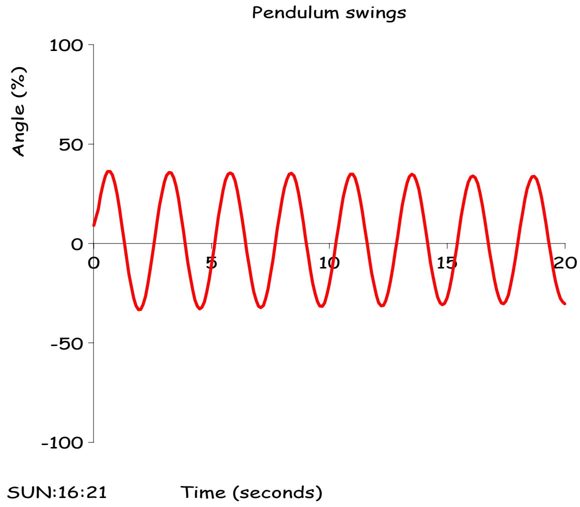
Tennis ball, elastic, distance sensor

What to do:

Predict what the graph you obtain will look like. For example, will 'up' be up on the graph? Swing the pendulum, bob the mass or bounce the ball. If you use a sonic distance sensor, its range starts at half a metre. It prefers a hard target such as a piece of card.
Finally, explore your data.

Period of a pendulum:

What can you say about the period of each swing? Measure the time interval between the peaks.
See if the amplitude and frequency are affected by the amount of swing. Build up a set of graphs on the screen - look for a 'trigger' feature in the software that starts each run from the same point on a swing.
If you start with greater swings, could the time interval between each swing be affected?

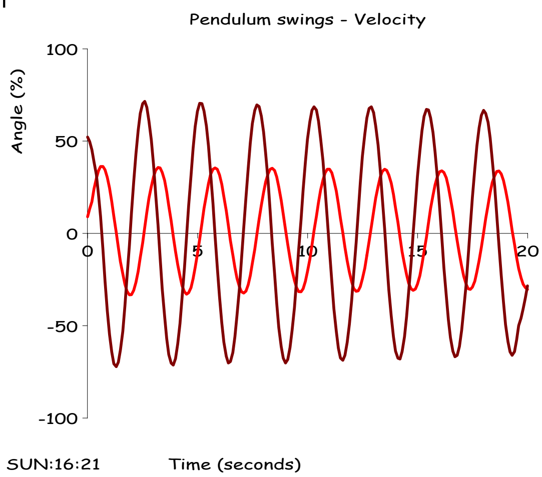


Damping and amplitude:

A swinging pendulum will eventually slow down. Could air resistance affect the time interval between each swing? Attach a piece of card and make two sets of swings, one damped, and one not.

Displacement and velocity:

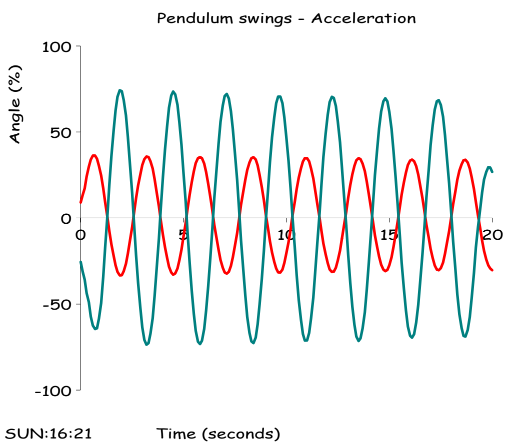
Think about how the velocity changes during each swing: where is the velocity largest and where is it smallest? Test your idea by measuring the gradient (i.e. the velocity or rate of change) along a displacement graph.
You can instead plot all the gradients along the time axis. Take the displacement line and do a derivative or dy/dt calculation in your software. Plot this line (i.e. the velocity) against time. What does this show? How does it match with the displacement line - is it in phase with it?



Exploring pendulum swings

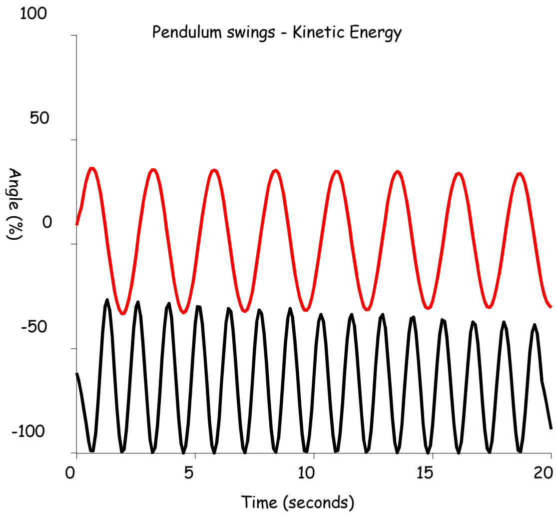
Displacement and acceleration:

Think about how acceleration changes during each swing: where is the acceleration largest and where is it smallest? Test your idea by measuring the gradient along the velocity graph. This gives the rate of change of velocity or acceleration.
You can instead plot all the velocity gradients along the time axis. Take the velocity line and do a derivative calculation in your software. Plot this line (i.e. the acceleration) against time. What does this show? How does it match with the displacement line - is it in phase with it?
What is the acceleration at the point where the velocity at a maximum? Explain this.
What is the velocity at the point where the acceleration at a maximum? Explain this.



Displacement and kinetic energy:

The kinetic energy is directly proportional to the velocity squared. Think about the kinetic energy the bob must have at the end and middle parts of its swing. Then predict what a graph of kinetic energy against time will look like. Take the velocity values and square them using a calculation feature in your software. Plot this line (i.e. ke) against time and re-scale the graph as it may be off-screen.
What does this show? The displacement and velocity go negative during the swings, so why doesn't the kinetic energy ever go negative?
Measure the kinetic energy (velocity squared) at zero displacement; half maximum displacement and maximum displacement.
Predict what a graph of kinetic energy (y axis) against displacement (x-axis) will look like. Plot this graph with your software.



Finding a value for 'g'

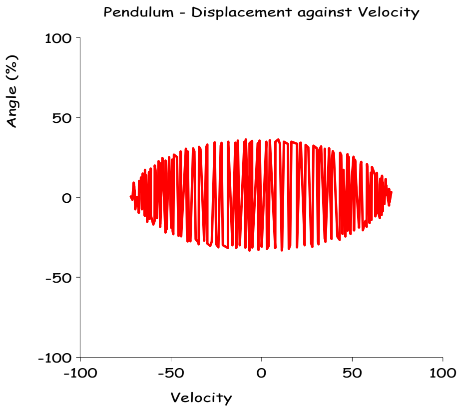
When the bob or ball starts from rest the equation $s = \frac{1}{2}gt^2$ applies because there is no initial velocity. Do a quadratic fit on the distance graph. Use this to calculate 'g'.

(See www.datadisc.co.uk for more on this)

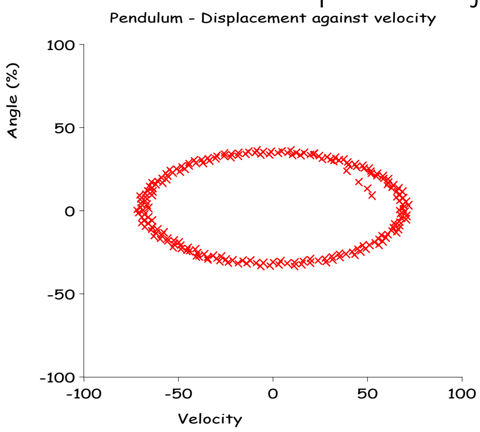
Exploring pendulum swings

Displacement and velocity:

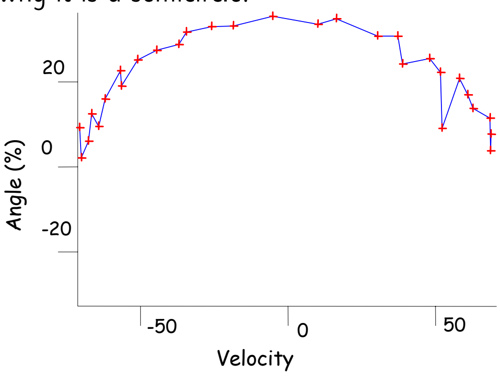
Plot displacement against velocity - this produces a messy ellipse. The plot has no time information so the software criss-cross plots the data..



This looks better when the points aren't joined

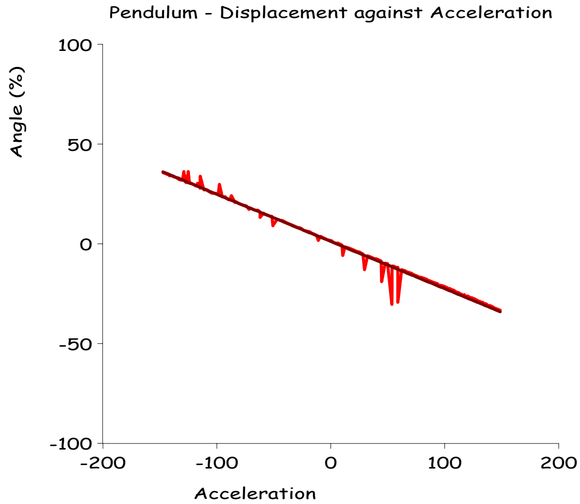


If you can sort the data on displacement or velocity, you can approach a circular plot. I put the data in a table, sorted it and discarded the top half to produce this plot. Think about why it is a semicircle.



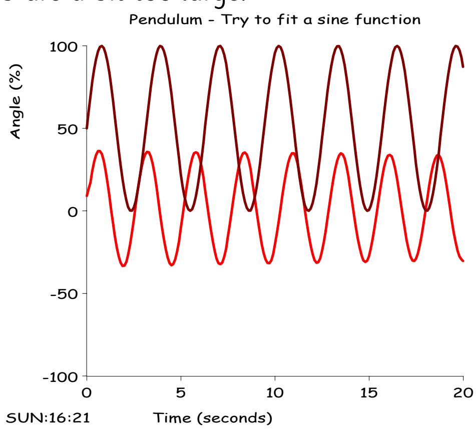
Displacement and acceleration:

Plot displacement against acceleration. This gives a negative slope straight line because acceleration varies in proportion to displacement and in the opposite direction.



Fit a sine function

When you find a regular pattern in a graph, it helps to guess at a formula or function that describes the graph. Look for a sine function in your software. Try to match the sine wave to the results - you may need to change values in the formula to make it fit the original data. Here we tried $a \times \sin(bx) + c$ where a is the amplitude, b is the frequency and c is the intercept on the y-axis. As the graph shows, c is 50 and it needs to be zero while both a and b are a bit too large.



Pendulum - potential and kinetic energy

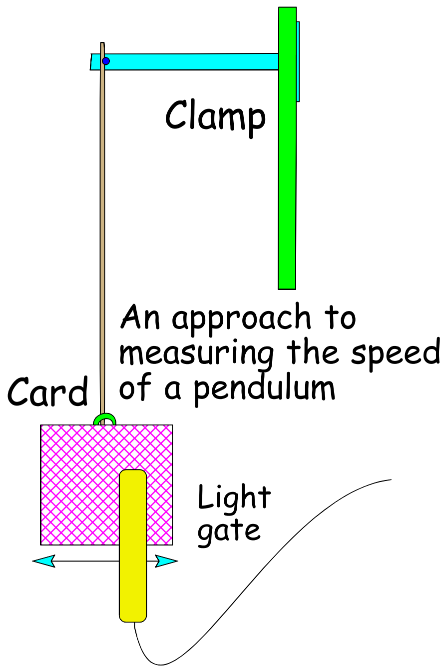
As a pendulum swings, its potential energy turns into kinetic energy. If it swings from higher up, it starts with more potential energy than before and produces even more kinetic energy. But how can we measure its potential energy and kinetic energy? These formulae tell us how:

potential energy = mgh so we will measure its mass and the distance it falls

kinetic energy = $\frac{1}{2}mv^2$ so we will measure its velocity

What you need

Pendulum made from a slotted mass attached to a stand, a light gate and a measured piece of card to break its beam.



What to do

Tell your timing software the length of the card in metres.
Pull back the pendulum, let it drop from 4cm and measure its velocity. Do this three times and repeat as you drop it from 6cm, 8cm 10 cm and 12cm.

Questions

1. Does the velocity increase or decrease as you drop the pendulum from higher and higher?
2. What should this do to the potential energy and the kinetic energy?
3. Use your software to work out the potential energy in joules:
   Pe = mgh where m is the mass of the pendulum and h is the height you dropped it from in metres
4. Use your software to work out the kinetic energy in joules:
   Ke = mv^2 joules where v is the velocity of the pendulum.
5. Plot potential energy against kinetic energy
6. Compare your two sets of readings. Is all the potential energy converted to kinetic energy?
7. Complete this: _______(more/less) potential energy is converted to kinetic energy when the height of the drop is larger.

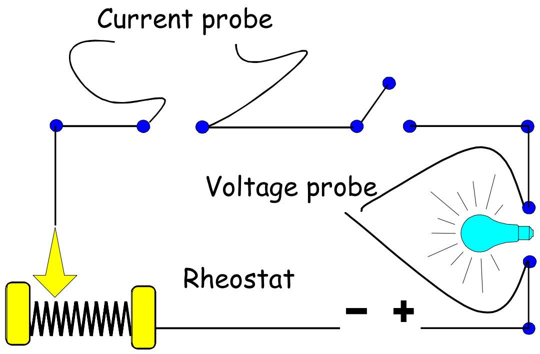
Teachers note

Thanks to Laurence Rogers, Leicester University. Additional help from materials by John Gipps - see his work at Monash University and his books at Tain Electronics www.tain.com.au

Electricity - current and voltage

Current, voltage and electrical components - teacher

This demonstration is about the way that current varies with voltage in resistors, filament bulbs, diodes, light dependent resistors and thermistors.

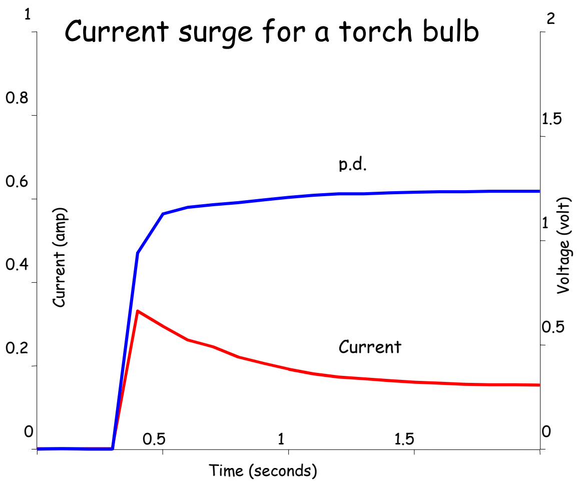


What you need

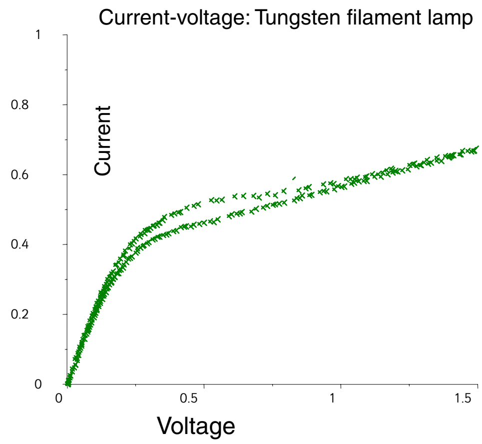
Lamp (3.5V), cell, silicon diode, 10 ohm resistor, rheostat, wires, sensors to measure amps and volts.

What to do

- How does a fuse work? How do fuses vary? Why do mains lamps, like the OHP bulb, tend to blow when switched on? Discuss your ideas for a few minutes.
- Look at the current surge when a lamp is switched on. Set up a 3.5V lamp in series with a toggle switch, a cell and current measuring sensor. Record the current surge.



- What might cause the surge? Recall Ohm's law: if the voltage is the same, what must have changed?
- Set up a circuit to record the current and voltage for the lamp. Use the rheostat as a potential divider and monitor current and voltage. Move the slider up and down once over 10 seconds and the lamp will brighten and dim. Discuss the result.



- Plot current over voltage. As a low voltage changes to high, note how rapidly the current increases. Current is on the y-axis because it is the dependent variable (in the previous lesson you plotted voltage against current).
- Keep the axis as they are, start recording and move the slider up and down as before. You will see two separate lines.
- Repeat for a resistor and a diode.
- Draw current-voltage curves for a lamp, resistor and diode. Under each graph explain the differences between them.

Extra

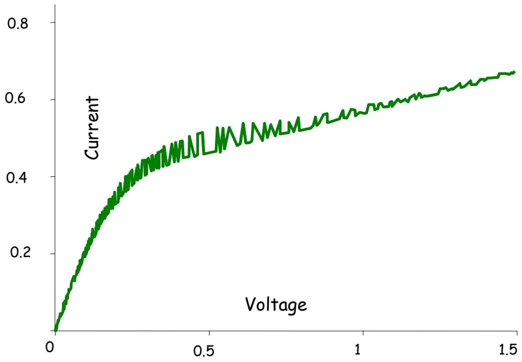
- How can we reduce current surge? (The answer is in the type of switch).
- There are two lines for the current – voltage plot for a tungsten lamp. One line is for the bulb coming on. What is the other line? Why are there two lines?
- What might a resistor be useful for?
- What might a diode be useful for?

Teachers note – see over

Electricity - current and voltage

Current, voltage and electrical components - teacher note

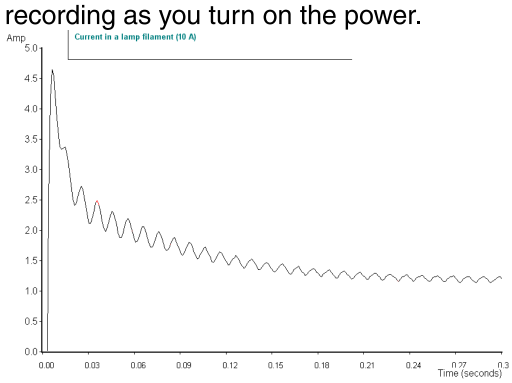
Roger Walton devised the demo (previous page) having seen how pupils so often misunderstand current surge – he notes that many think of it as a release of charge built up at the switch. In his first lesson, the class plotted voltage against current and used the graph gradient to estimate resistance. In the next they did the activity shown.
Note how the graph shows both warming and cooling phases of the bulb. If you ask the software to join the points you'll get 'criss-cross' plotting as shown below. This happens whenever the data loses its time element.



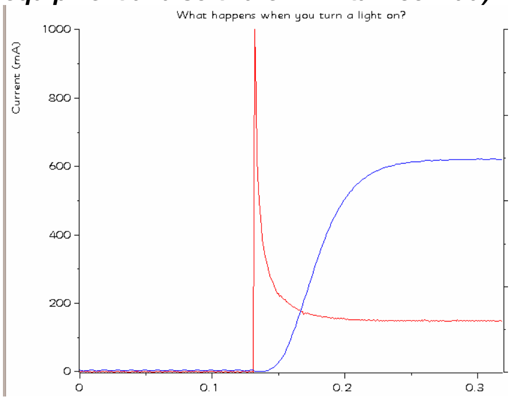
With thanks to Roger Walton, head of science at Lowfields School, York, UK - visit www.yorkschools.org.uk for further examples from the York Science and IT Together Project.

Electricity - current surge in a lamp

Here's a similar but different example of measuring current surge. Peter Adams used a fast data logger measuring 1000 current samples per second to show a large surge on this car lamp.
To do this, set up a circuit with a 12v 18 Watt lamp, regulated power supply and current sensor in series. Set up the data logger to record as fast as you wish and tweak it to start recording as you turn on the power.



The graph shows a current surge as the power is switched on. From this you can calculate how many times lower the resistance is at the start. You can also calculate the power dissipated by the lamp during the surge. Why does its resistance increase? What other devices show a decrease in resistance with temperature? ***(Results and details by Peter Adams using Tain equipment and software www.tain.com.au)***



Here's another nice result, this time by Data Harvest's Sue Plant. One sensor measured the current, the other measured light level.
Many thanks to www.data-harvest.co.uk

Electricity - battery power

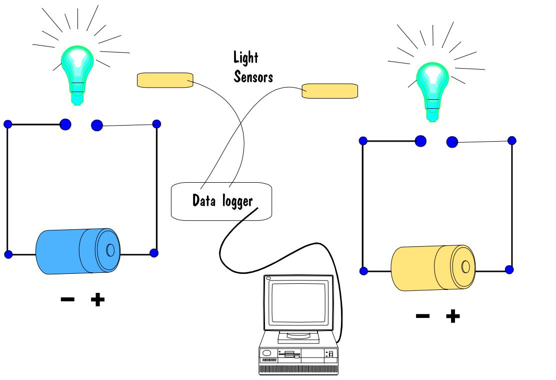
The difference in power output between standard cells and rechargeable Ni-Cd cells is of major significance. For taking readings over a few days, data loggers are invaluable. As a project or demonstration this adds value and interest to electricity topics.
Set up a circuit with a switch, lamp and cell. Connect the current and voltage probes in series with and across the lamp. Use Blu-tac or similar to fix a light sensor near the bulb, switch on and start recording all three sensors. Continue recording until the cell is exhausted or instead put the cell through a suitable duty-cycle. Peter Adams suggests three hours on and 21 hours off. He notes that cells recover to some extent during the breaks - this would entail some interesting graph analysis. He adds that the light intensity of the lamp falls much more rapidly than does the power (calculated as V * I). In the final duty cycle, even though the lamp glowed feebly, the measured power output was still adequate. Nominally Ni-Cd cells offer 1.2v, lower than the 1.5 of standard cells, though Peter found that their potential was not that much lower in practice. ***(Thanks to Peter Adams, Australia. He used standard cells and Ni-Cd cells, 2.5v lamps, switch, voltage and current probes, light sensor, leads.***

Electricity - battery for the job

Batteries are a handy source of power. Think of the things that use them - phones, clocks, even computers. There are different kinds of batteries, some are good for some jobs, and some for others. To see how different batteries behave, we use them until they discharge.

What you can do

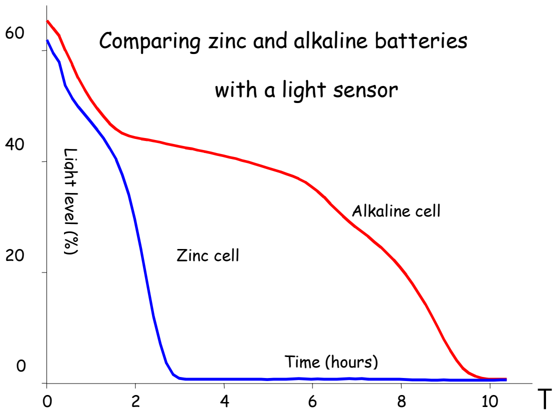
Set up the two circuits as shown below - one has a zinc cell, one has an alkaline cell. Use a light sensor to measure the brightness of the lamps until they are used up.



What you need

Light sensor, two flashlights / torch with two types of battery or circuits as shown, card box. Use a rotation sensor or pulley to measure how a battery powers an electric motor Use a sound sensor to test a cassette player. You can of course use current and voltage probes to measure changes in the circuit.

Results



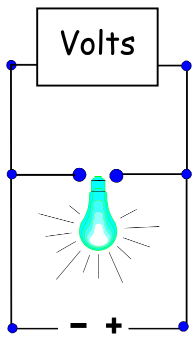
The graph shows the life, and death, of the two batteries. Open the file in your software.

Looking at the results

1. How long did each battery take to become exhausted?
2. We could not remember which battery is which. Have you any ideas?
3. They say that alkaline batteries work for longer and then fade away quickly. Zinc batteries work for less time and fade away steadily. Does this help your choice?
4. The alkaline battery cost three times as much as the zinc battery. Use the graph to calculate which battery offers the better deal.
5. How does this experiment help you choose a battery for a wall clock?
6. It seems that one of the batteries isn't very good. Do you have any questions about how reliable these results are?

Extra

Single cells come in several different sizes - A cells, AA cells, AAA cells. Do you get more battery power for your money in a larger battery?



Instead of light sensors, you might have used voltage sensors. These measure the potential difference across the battery. This drops as the battery is used up. Choose the best way to find which type of battery is best for a torch, and which is better for a portable cassette player.

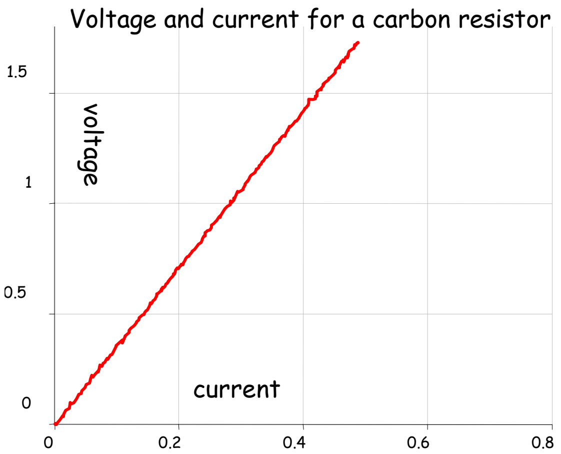
Results by Laurence Rogers, University of Leicester. Developed for Schools Online Science at Sheffield Hallam University. On the Internet at www.shu.ac.uk Software: Insight 2 from Logotron.

Teaching about current, voltage and electrical components

This note offers some ideas for handling the data from experiments like the previous one. The story so far is that current and voltage sensors were used to examine how changing the voltage affected the current through a lamp, diode and some resistors.

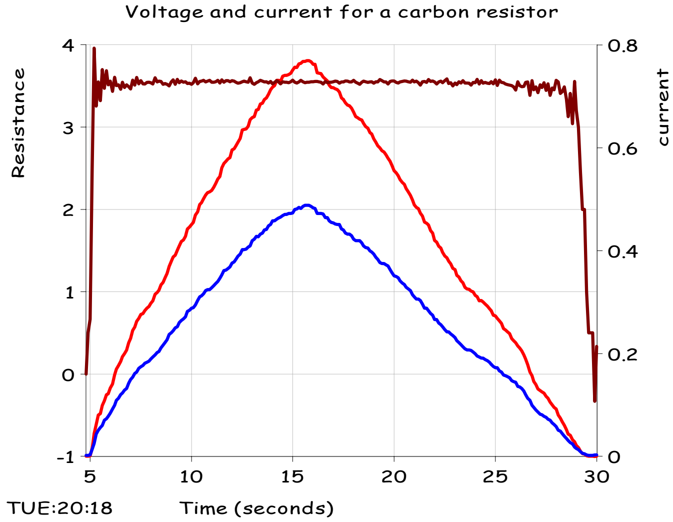
You see your results as two lines showing current and voltage over time. You can also choose to show it as Current over Voltage. The previous experiment shows how different these are. Appreciate how well the IV over time graph shows the pattern of change, even though the traditional graph is something to feel more comfortable with.

That result was for a lamp. Plain wires and carbon resistors produce straight-line 'current against voltage' graphs:



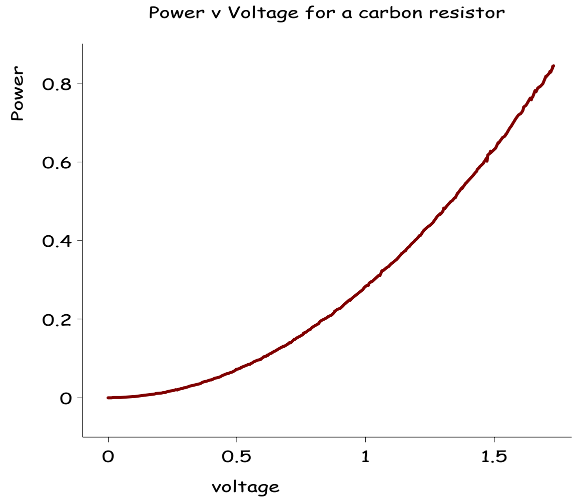
The gradient of this graph is a measure of the resistance so, for example, if you compare a 100 Ohm and a 200 Ohm resistor, the gradient doubles.

With some school groups you can use the software to calculate the resistance - just look for a 'x / y' equation and tell it which is voltage and which is current. Plot the resistance against voltage and you will see a flat straight line - the resistance doesn't change during the experiment. (Do the same for a lamp and of course it does).



A different resistor will show a second flat line, parallel to the one above. Read off the resistance value from the graph - this, no surprise, is the same value as the gradient of the straight-line VI graph.

Finally, use the software to calculate the power that the resistor dissipates (i.e. current x voltage) and then plot this against voltage. This should give a 'parabola' where you can show that the voltage doubles as the power quadruples.

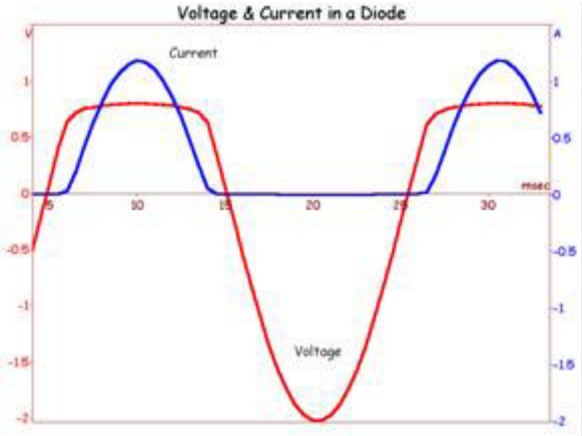


contd./...

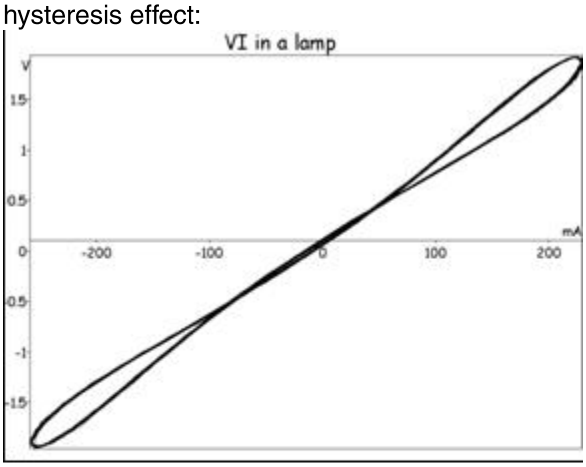
Teaching about current, voltage & electrical components

contd./

Components such as lamps, diodes and thermistors behave differently. Described as non-ohmic resistors, their VI graph is not straight. The extreme case is perhaps that of a diode where increasing the voltage has no effect until the diode's switch-on threshold is reached.



For example, in the previous section we said that the lamp would show two lines - one for warming and one for cooling. For interest, plot these against each other and you see a hysteresis effect:



Graph analysis ideas with thanks to Laurence Rogers, Leicester University. Software used includes ***Insight 2*** from ***Logotron*** and ***DBLab*** from ***Fourier Systems*** or ***Scientific and Chemical Supplies***.

Electricity - AC ripple

This demonstration makes a neat party piece as well as showing, very nicely, the frequency of the mains. It simply involves picking up the flicker from a strip lamp. As a bonus you may also be able to show the beats from strip lamps interfering and showing beat patterns. Set up your data logger to record for a second or so and as fast as it can. Use the logger standing alone rather than linked to the computer as it's very likely the computer cannot keep up with it anyway. Point a suitable light sensor at a strip lamp, start recording and download the results to the computer screen. You can often pick up the interference between a pair of lamps in the same light fitting. I've found no way of guaranteeing this sort of pattern, but we noticed it when we stood back from the screen and when the software did not join up the points. Nobody had been drinking, honestly!

What you need

Diode-type light sensor (these react faster than LDR types), fast recording data logger (or just try it anyway), strip lamp.

Electricity - solar cell - project

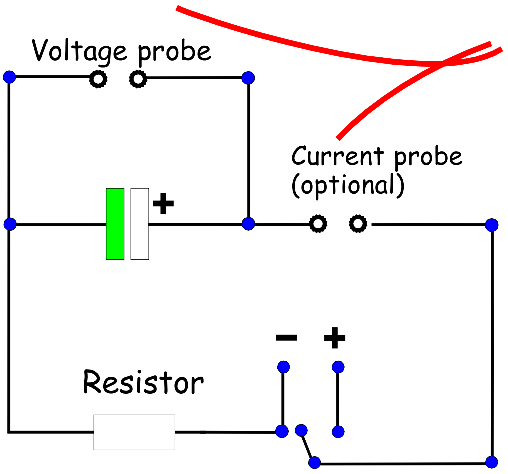
A simple circuit with a photo-voltaic cell and a volt meter can be the basis of a feature-rich student investigation. There are countless ideas to explore - for example, you can explore how the distance from a light source affects the output; or you can find out how different coloured light affects it. Use a data logger and replace the meter with a voltage probe and you can explore how the angle of the sun affects the output and try to find the best position to install it.

Details at Schools On Line Science at Sheffield Hallam University, www.shu.ac.uk

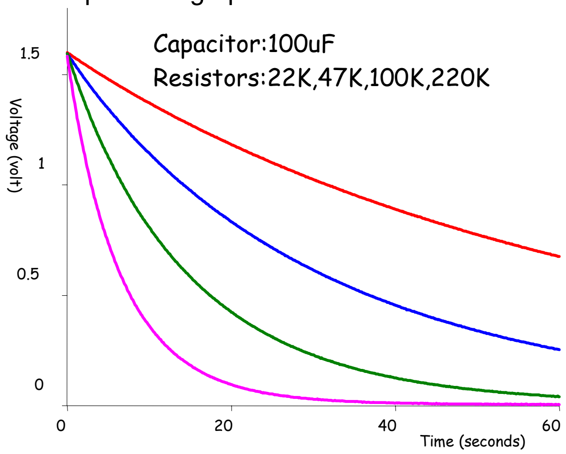
Teaching about current, voltage & electrical components

Electricity - discharge of a capacitor

If a data logger does anything especially well, it is that it can measure the discharge of a capacitor. You charge the capacitor and then measure the voltage across its terminals as you short it through a resistance. The results here serve to show the size of the resistance affects the rate of discharge. Which feature of the graph measures that rate?



Set up a charging circuit and a discharging circuit. You don't need the current sensor - it's optional. Charge the capacitor for 15 seconds, and start recording as you switch over to start the discharge. Some software will let you set a trigger, like the oscilloscope trigger, where it will start recording only when the voltage falls. This feature will be very handy when you want to compare the graph from several resistors.



It is common to take the voltage as a measure of charge because the two are related to each other by Q (charge) = V/C. As the graph hints, the discharge is exponential like a decay curve. Fit the appropriate function (e.g. $y=a\ e^{bx} + c$) to it with your software and read off the values for a and b. Other things being equal, appreciate that the component ratings may vary by five or ten percent.

What you need

Battery, 100 μ capacitor, several resistors (e.g. 22k, 47k, 100k, 220k), voltage probe, leads.

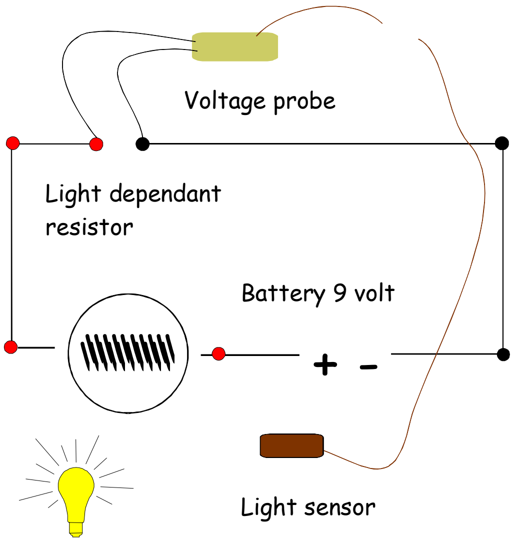
Results with thanks to Laurence Rogers, Leicester University. Software used was Insight 2 from Logotron.

Electricity - LDR and voltage

This elegant set up shows how the voltage across a light dependent resistor changes with the light level. Cover the lamp and watch the light sensor and voltage sensor respond on screen.

What you need

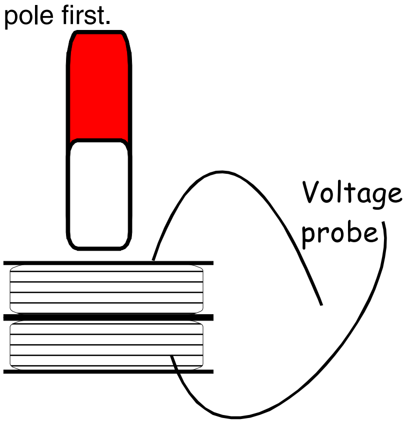
Ambient light, voltage sensor, light sensor, LDR, 9v battery and battery clip.



Thanks to David Palmer at DCP Microdevelopments manufacturers of LogIT at www.dcpmicro.com

Electricity - induction in a coil

The voltage induced as a magnet falls through a coil is one of the classics of data logging. It relies on the ease with which a logger can take numerous readings in a split second. It makes for a reliable, fairly straightforward demonstration. The main issue is trying to remember how you set up the system the last time you did it.
Mark the magnet, drop it through a coil and record the voltage transient. You can then consider what will happen when you turn the coil round or drop the magnet with its opposite pole first.

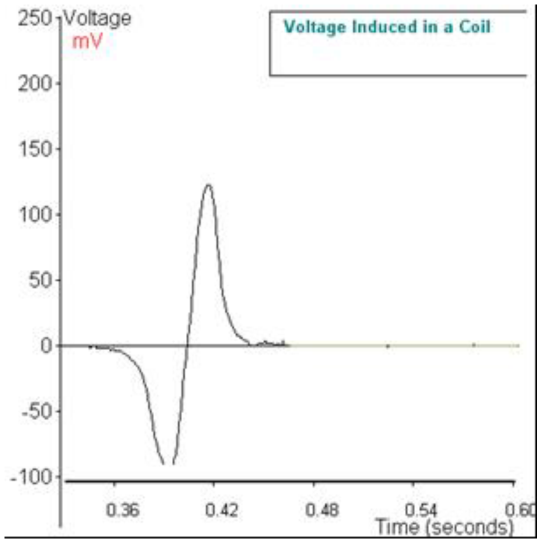


What you need

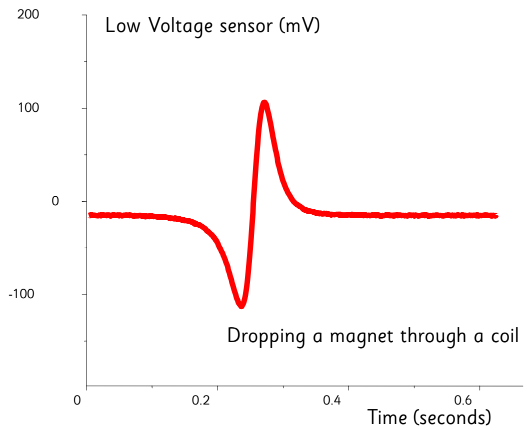
Leads, magnet, a Helmholtz or single wire coil, a voltage sensor - it should sensitive to 100 mV but add a voltage amplifier if you get little response from your sensor.

What to do

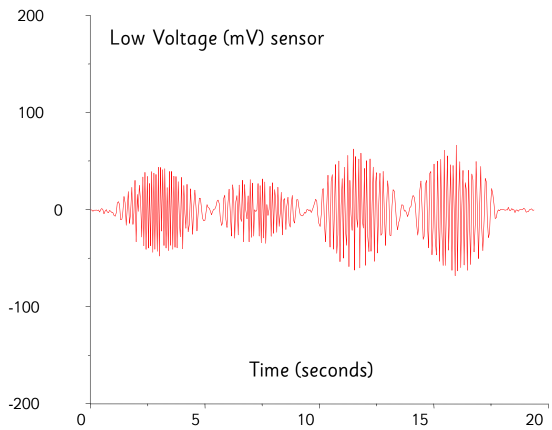
Hold the magnet in the air and test drop it through the coil - as a refinement you might drop it through a piece of plastic tube to guide the magnet as it falls. You need to set up your data logger to take as many readings as possible or around 500 readings a second. This rate usually means that your data logger will have to collect the data and then upload it to the computer. However, some brands can display the induction trace as it happens. Depending on your system, you may be able to get it to start recording or trigger at the point that the magnet falls through the coil. Do make a note of what you did for next time.
Extension idea: connect a large solenoid to a current probe. Connect a second solenoid to a battery with a current probe and a switch in series. Start data collection and each time you close or open the switch you can see the current induced in the first solenoid (from Vernier at *www.vernier.com).*



Results and method from Peter Adams - see his books at www.tain.com.au

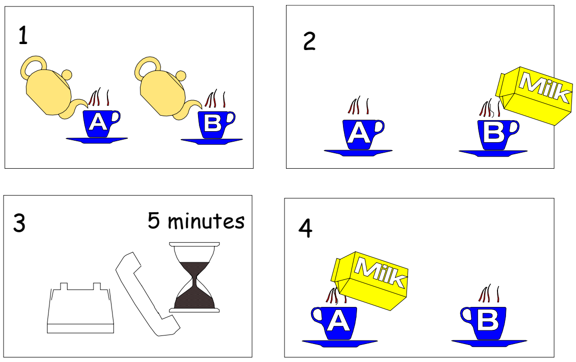


Results by Steve Allen of Data Harvest whose graph is clearly not the opposite of the Australian results above! Many thanks to www.data-harvest.co.uk. Steve adds, "Look what happens if you just dangle a magnet from a twisted rubber band right next to a coil." Results below:



Cooling - the coffee quandary

This exercise shows you how to handle data and illustrates some ideas about hot and cold things cooling.
The telephone rang as you made a coffee. Should you add the milk now or when you finish the call? One answer is to make a guess and hope you're right. Another is to deal with it scientifically and do an experiment.



What you need

2 x 250 cm^3 beakers, 2 x 10 cm^3 beakers, 100 cm^3 measuring cylinder, 2 x temperature sensors, clamps and stand to hold probes.

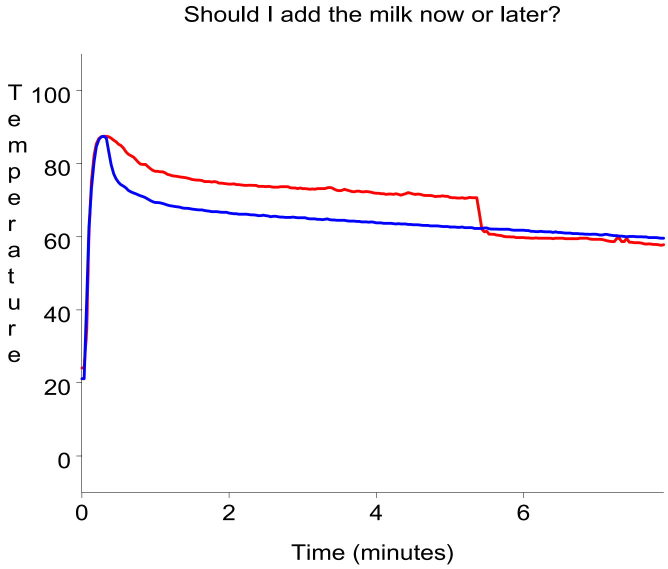
What you could do

Boil the kettle. Put a temperature sensor into each of two cups and start recording. Pour hot water into the cups and add milk to one of them. About five minutes later add milk to the second cup. After a few more minutes of recording save the results on the computer. Do not stir the cups.

Teachers note

This exercise is an introduction to handling data and investigating heat loss. A version, with a results file, can be found at Schools Online Science at Sheffield Hallam University. Find the Internet link at *www.rogerfrost.com.*

Results



Open the results file in your software to answer the following questions.

1. At what time did I add the hot water to the cups?
2. At what time did I add the milk to the first cup?
3. At what time did I add the milk to the second cup?
4. Which graph line shows the cup where I added the milk after a call?
5. Look back at the problem. If I wanted cooler coffee, would it be better to add the milk before, or after the call?
6. Take readings from the graph to see how much of a temperature difference this makes? What do you think? Was it worth the trouble?
7. Do you think I should have stirred the cups?
8. As a good kitchen scientist, I made sure the experiment was done very scientifically. List things that I must have done that I didn't tell you about.

What you might find out

- Would it be better to pour the water from the kettle before, or after taking the call?
- Which cools faster in the fridge, a bowl of warm jelly or a bowl of hot jelly?

Cooling and size - big and small

Cooling and size - big and small

The effect of size on cooling crops up everywhere it seems. There are a variety approaches to investigating it and all lead to the finding that small objects cool faster. The reason is to do with the ratio of surface area to volume - though the explanation depends upon whom you are teaching.
Straightforward as the experiment may be, the use of temperature sensors shows up errors in experimental technique. For example, it helps to put the cooling objects in a water bath so that they start at the same temperature. It helps to start recording before you let the objects cool, as students gain a clearer record of what they did. Also where you place the temperature probes, where you place the objects, what they stand on, whether they are covered and whether you stir liquids in beakers are all variables to consider if you are aiming for perfection. I mention this, not to create problems, but to make the point that it is usually more important that students know how to do the experiment than it is to 'discover' that large animals cool more slowly.
Don't be distracted by the young contexts we have used as you can cover high level science here. Set work to do as pupils wait 30 minutes for things to cool down. Ignore this and watch the pupils experience a fairly high level of boredom!

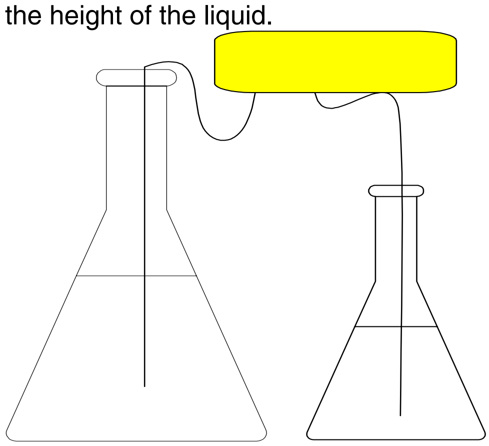
Do large animals stay warmer than small animals?

What you need

Large and small plastic bottles (500 cm^3 and 100 cm^3 beakers), two temperature sensors, clamp and stand to hold the temperature probes in place, warm water and a water bath or plastic bowl.

What to do

Fill the containers with water and place in a water bath until everything has reached the same starting temperature. Start recording and remove from the water bath to let them cool over 15 to 20 minutes. If you do not cover them the differences in temperature are small but if you do I'd say it makes for a fairer test.
If you use containers with a regular cross section, you can extend this experiment to a project in which you quantify the relationship between surface area and heat loss. Treat the bottle as a cylinder: measure its diameter and the height of the liquid.



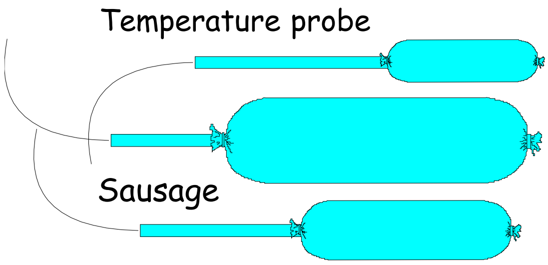
Results

See if your 'people' started cooling from the same temperature. Explain why they should. Measure how much the temperatures dropped over 10 minutes. How do your 'people' compare.
Tricky question: how much would their temperatures drop over an hour?

Cooling and size - big and small

Do babies become cold more easily?

How large and small animals cool can be investigated in the same way as the previous example. Junior schools use large and small plastic bottles, and then put say, decorated heads (styrene foam balls) on the top to make a head. Others have used sausages - which you have to give credit for.



What you need

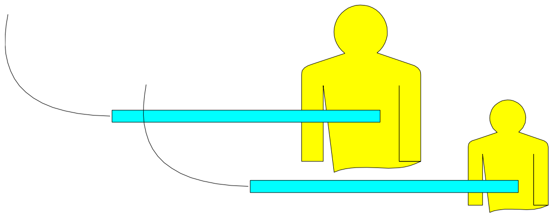
Three sausages of different sizes and three temperature sensors inserted into each.

What to do

Place the three sausages in a bowl of hand warm water to get them up to temperature, remove them and then start recording. Alternatively, ensure the three sausages are at the same temperature and then place them with their temperature probes in the fridge to cool for 30 minutes. You may need some tape or something to hold the fridge door shut. And, to get value for your sausage money, compare the cooling of wrapped up and bare sausages.

Cooling and survival - a variation

Here is a variation on the cooling theme - a welcome change from comparing beakers of water:
"The Titanic has hit an iceberg, who would cool faster in the cold sea - the adults or the children?



What you need

A beaker of ice water, a beaker of luke warm water, a temperature sensor placed in a 20 g piece of Blu-tac as the child, a temperature sensor in a 60 g piece of Blu-tac as the adult. Another temperature sensor can be placed in the ice water as a control.

What to do

Start recording and place the probes and Blu-tac in a beaker of warm water.
Wait for the system to display a reasonably steady temperature and then transfer the warm people to the icy sea.
At a higher level you might determine the percentage difference in the rate of cooling.

Thanks to John Gipps - see his books at Tain Electronics www.tain.com.au

Huddling emperor penguins - a variation

Warm-blooded animals, such as emperor penguins, try to reduce their heat loss by huddling together. An activity to measure the value of this strategy can be used to teach ideas such as controlling variables, adaptation, conduction, heat transfer and its connection to surface area.
Either of the two examples here could be a class activity. Alternatively, you could use the computer and let the class do the experiment using thermometers.
The exercise has more value as a 'science investigation' at say, age 13 than a data handling exercise, as the amount of data analysis is limited at this level.

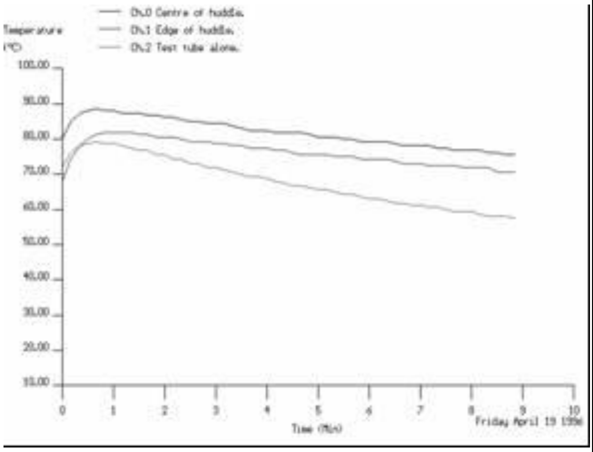
What you need

Three temperature probes, eight 20g 'penguins' made of Blu-tac.

What to do

Place one penguin on its own and surround another with the other six - assemble them on a small sheet of plastic. Push a temperature probe into the lone penguin, the huddled penguin and one of the 'outside' penguins. It may be best to record a steady room temperature using the software, then place the penguins into a bowl of ice water.

Results

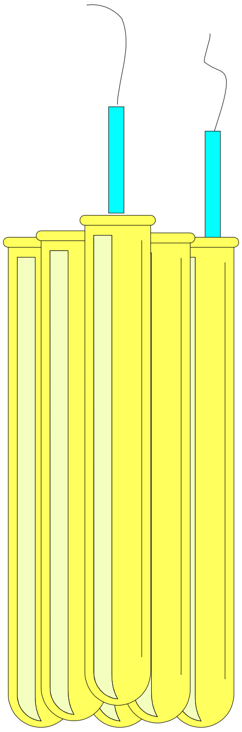


(Results and activity by Peter Adams using Tain software and equipment - see his work at *www.tain.com.au.**)***

Huddling animals - test tube method

What you need

Three temperature sensors, eight test tubes, elastic bands, bowl of ice water, bowl of warm water or a water bath, beakers, clamp and stand.



What to do

Make a bundle of seven test tubes with one in the centre. Place temperature sensors in the centre tube, an outside tube and a lone tube. Fill all the tubes with water and place them in a water bath. When you have recorded a steady 'body' temperature, place the tubes into a bowl of ice water.

Handling the results

- How does the graph show which animal cools the fastest?
- What measurement can you make from the graph to show this?
- Do the 'outside' animals stay warmer than a lone animal? Does huddling make a significant difference?
- Find more analysis ideas on page 64

Goldilocks & the three bears

To recap on the story: father bear's porridge in a large bowl was too hot, mother's was middling hot, but the porridge in baby bear's small bowl was just right. Why should that be?

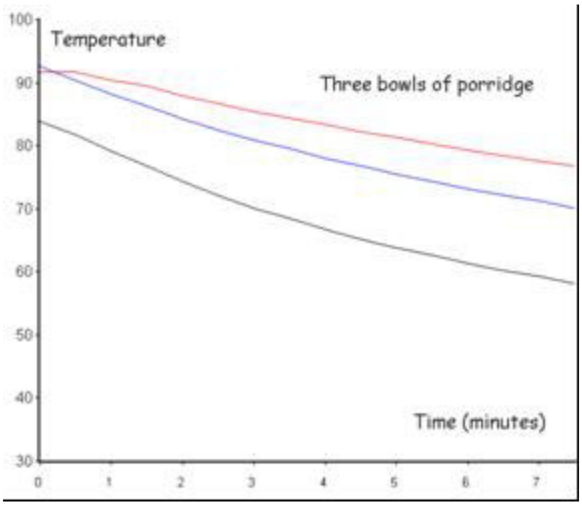
What you need

Three cereal bowls or beakers of different sizes, hot water and three temperature sensors.

What to do

Suspend the temperature probes in the cereal bowls or beakers with a clamp or masking tape.
Fill each container with hot water (or porridge). Place in a large bowl of hot water to equalise the temperatures.
Measure the temperatures over 15 to 20 minutes.

Results



The graph here shows a result of the Goldilocks and the three bears story - try these questions:

1. Which graph shows the cooling of the large bear's porridge? Add labels to the graphs to say which trace is which.
2. How do you know that the bowls of porridge all cooled from the same starting temperature? What could have been done about this?
3. Replay the experiment by moving a cursor over the graph, then ask: How do the graphs show that the bowls cool at different rates?
4. There are several ways to show how the bowls cool differently. Your teacher will show you one of these ideas:
   - Measure how many degrees each bowl drops in temperature.
   - Measure how long it took for the temperature of each bowl to drop by 10 °C.
   - Measure the average temperature of each trace to show which stays hot the longest.

Extra

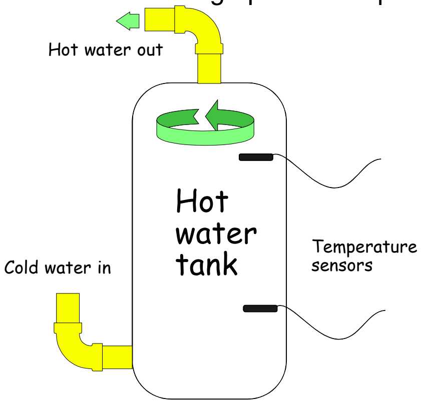
- Measure the area under each trace to show which stays hot the longest.
- Measure the average gradient (= the rate of change of temperature) of each trace.
- Fit a function (a line or a curve equation) to each trace and use an equation to give a measure of the cooling.
- Find an indication of Newton's law of cooling in the graph. In other words, can you fit a power regression line to the graphs here. You will see a better curve by changing the scale of the time axis.

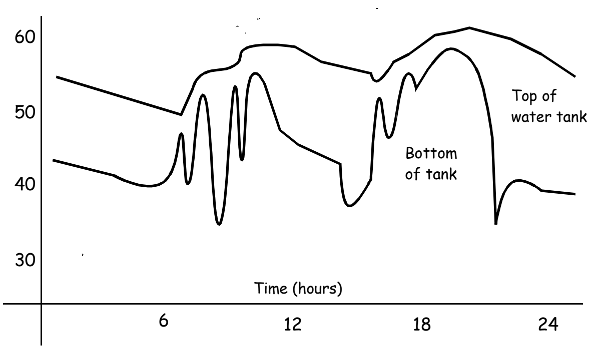
Teachers note

This experiment models the fable by monitoring the temperature of three containers of porridge. The lower trace is the cooling curve of the tiny bowl of porridge. One point in passing is that having taught students to religiously keep the variables in an experiment the same some insist on using the same amount of water in each beaker.
(Results by Peter Adams using Tain equipment and software - www.tain.com.au)

Heat - hot water tanks

Many houses keep a store of hot water in a tank. A separate boiler heats the tank for a while in the morning, and again in the evening. When someone draws hot water it leaves by a pipe at the top of the tank and is replaced by cold water which enters through the bottom. As part of a maths project, they recorded the temperature of the tank for a whole day. One temperature probe logged the temperature at the top of the tank, and one logged the bottom. The graph is shown here and the questions show how this scenario was used to introduce graphical interpretation.



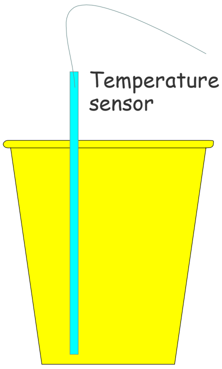


- At what time was the hot water first run?
- When is the demand for hot water heaviest?
- During which hours did the boiler work?
- Use the graph to suggest when the heating should best come on and go off.
- Why does one graph vary more that the other?

***(Adapted from 'Everyday Graphs' at The Shell Centre, Nottingham University. Nice ideas at** www.nottingham.ac.uk)*

Cooling- do hot things cool faster?

A straightforward exercise that shows how fast things cool and leads into a topic on energy and insulation. Here you place hot and warm beakers of water in the freezer and measure the rate of cooling.



What you need

Freezer, up to 4 hours, plastic beakers with hot and warm liquid, two temperature sensors, tape to hold the probes, data logger and mains power adapter. Monitor the temperature for a few hours.

Results

The hot beaker cools faster - you can measure the rate of temperature change in a variety of ways - for example fit a line to the trace and read off the gradient. Whether it will freeze faster is another matter - just remember that you are measuring the performance of the freezer. For example, placing a hot liquid in a freezer may cause the thermostat to switch in and keep the compressor at work. In that sense a hot liquid could well freeze faster.

Heat - comparing insulation materials

So many investigations on ways to keep warm feature the classic beaker experiment - two beakers, hot water and of course keep everything the same. But one day someone started selling cardboard model houses and several teachers started using them to investigate double glazing, insulation, ceiling fans and so on. The flat pack houses made by Peter Chamberlain's 'TASTE' project in North London cost very little and opened up all sorts of investigative possibilities. This note is a reminder of them and a worked example is offered in 'The IT in Secondary Science Book'. Some results from a related experiment are on a following page. Set up the houses with some form of heating such as a car lamp. Start recording temperature and note how the fabric of the building gets up to temperature and stabilises. One house can have loft insulation the other not or one can have double glazing the other not. The houses might even be in rooms with different outside temperatures but whatever variable distinguishes them, the next step might be to turn off the heating and see how they cool.

What you need

Cardboard model houses (e.g. try IKEA shops or ASE* www.ase.org.uk*), two small lamps as house heaters, acetate film as window material, scissors, masking tape to fix the windows, two temperature sensors.

More insulation experiments

Here are a few more 'insulation experiment' ideas. Compare beakers 'wearing' one vest with two thin vests; wearing thick fur and thin fur; fur and wool; fur and oiled fur. Or compare one plastic cup with two stacked cups; compare thick and thin pipe insulation. Junior schools often use soft drink bottles instead of beakers to add realism. Many types of bottle have a neck that prevents heat escaping through the top. Fix a ping-pong ball on top to make it look a bit more human. No need to dress it up with plastic bubble wrapping, as normal materials should produce a measurable temperature difference.

What you need

Beakers or bottles, choice of insulating material, elastic bands to fix the material, clamp and stand to hold two temperature probes, plastic bowl or water bath, hot water.

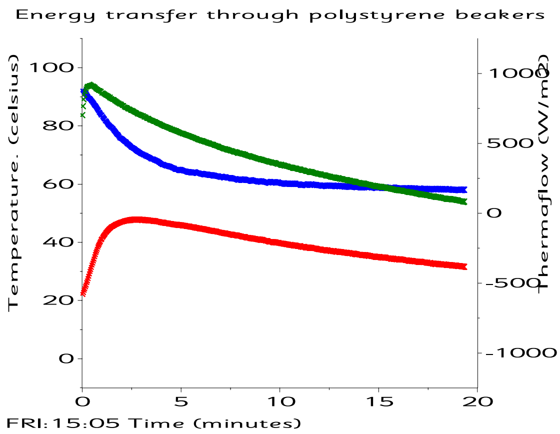
Heat - using a heat loss sensor

Typically we measure heat loss as a change in temperature: we set up two beakers filled with warm water, insulate one and see how their temperatures change over time. But today there is another sensor, one of the most intriguing of all, called a heat loss sensor. Were you to place the sensor against each beaker, what you see on the screen is unique and almost unheard of in school science: you see not its temperature but how much heat is 'flowing' out of it. So instead of degrees, it measures in watts per square metre.

With hundreds of thermistors within it, the sensor costs a great deal to produce and demand seems not to be bringing the price down. Were it not for the high cost of producing a sensor, it could be as ubiquitous as the temperature sensor itself. It can help you compare heat loss from different areas of the body, or compare the same through brick wall and a window pane. Like any new technology, it will take time before the use of the heat loss sensor becomes embedded in science teaching. However, here are some ideas:

Demonstrations with a heat loss sensor

- Study the cooling curve of stearic acid in a container with flat sides (because this flat sensor works best on a flat surface. Record both the temperatures of the stearic acid and the heat loss through the container. (See also Cooling curve page 105)
- Who said a tie doesn't keep you warm? Set the software to record heat loss for a minute or two. Place the sensor against your shirt: note the extreme deflection. Place the sensor against your shirt and tie: it should deflect less. Turn the sensor round and so place the 'back' of the sensor against your shirt: note how the deflection reverses. Note: The Heat Loss sensor is extremely sensitive and so your readings will easily go off scale
- Use a 12-volt car lamp as a heat source and compare the heat loss through a thin wool jumper, a thick wool jumper and a cotton pullover.
- Study the heat loss from different parts of the body: neck, front and back of your hand, inside elbow and the back of your knee. Do the fatty parts lose more heat?
- Compare the heat loss from your skin insulated with a shirt, shirt and jacket, shirt and jumper.
- Compare the heat loss from your head, your head with a hat. Dare to find a balding member of staff and experiment on different parts of their head.
- Compare the heat loss through a wall at ceiling and floor level
- Compare the heat loss through the top, bottom and walls of a cup of coffee. Does the cup lose more heat through the surface or the sides? Does a cork coaster affect this?
- Compare the heat loss through a single glazed window and a double glazed window. Or make a cardboard house and use double and single acetate film as window material. Compare the heat loss through materials that might be used for secondary window glazing. Try glass and box-walled polycarbonate used for roofing as great claims are made for the latter.
- Compare the heat loss from "pizza boxes" made with different layers of card.



- Based on work by Roy Barton of University of East Anglia, the result above very nicely shows the transfer of energy during cooling. The top line shows the temperature of water over twenty minutes. The middle line shows heat loss through its container which soon decreases to a steady value. This is echoed by the lower trace showing the temperature of the environment. The difference between Temperature 1 and Temperature 2 plotted against heat flow forms a pattern. Thanks to Sue Plant. See Data Harvest's 1999 Newsletter at www.data-harvest.co.uk

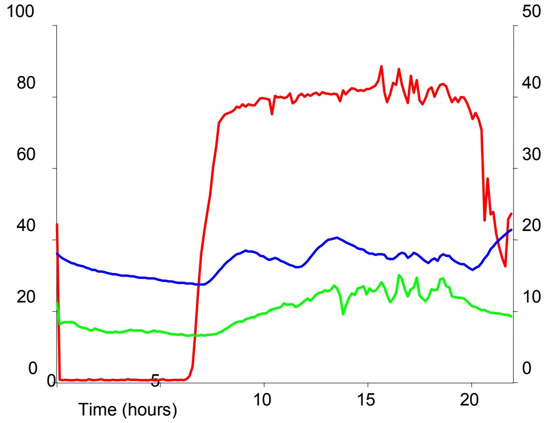
Heat - central heating

The time of year when the air temperature is at some extreme is a good time to use temperature probes to examine how well the heating (or cooling) system is working. For example, your school heating timer may be set to switch on a couple of hours before people arrive in school. This begs the question: what is the evidence to say when the system should switch on and off. Logging the room and the radiator temperatures over a day or so provides the answer.
The resulting graph can serve as an introduction to temperature and graphs. You can set questions about the graph for homework. If you have access to a computer suite the class might analyse the data as shown opposite.
This idea has been used on countless in-service data logging training courses. It gives confidence in collecting data away from the computer, in annotating graphs and in uploading data to the computer. Typically, we set up our data loggers in the hotel bar and measured temperature, light and sound levels through the evening. From these you might find the room warming up, the bell ringing for 'last orders'

What you need

A data logger, light sensor and two temperature sensors. The light sensor acts as a day / night marker and if you include a sound sensor you will gain an idea of when the room is occupied.

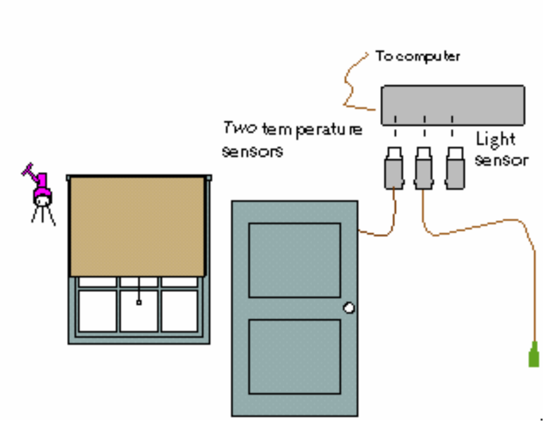
Results



1. Study the graph and label the places when
   a) the heating switches on
   b) the room reaches a comfortable temperature
   c) the room is in use
   d) the heating switches off
   e) the room temperature falls to an uncomfortable level.
2. How long does it take for the room to warm up after the heating is turned on?
3. How long does it take for the room to cool down after the heating is turned off?
4. How long does it take for the people in the room to increase its temperature? Do you think people make useful heaters?
5. What advice would you give to the school administration about their heating policy?

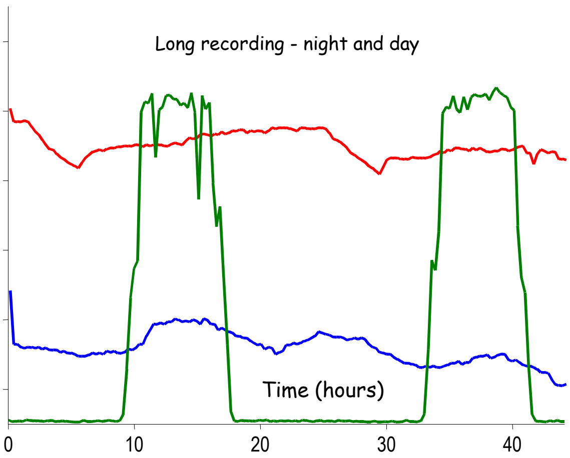
Heat - day and night graph story

It was a cold day and the central heating was keeping us cosy indoors. We knew that the heating system has a thermostat and it cuts off a boiler when the room is warm enough. But there's just a thin piece of glass between the outside and us and we wondered if it really helped keep the heat in.



What you could do

Put a light sensor and a temperature sensor outside a window. These measure the light level and temperature. Put another temperature sensor indoors and connect the three sensors to a data logger. Get the data logger to take readings from the sensors for two days and nights.



Graph shows the temperature and light level starting at midnight. Find the file and open it in your software.

Results

1. Label the traces that show the temperatures inside, outside and the light level.
2. What happens to the temperature in the small hours of the morning?
3. When does the heating turn on?
4. Do you think the heating is 'on' for too long?
5. Which of the two days was warmer and sunnier?
6. Why do you think the light level trace 'wobbles'?
7. At what time of day is the light level greatest? Is this what you expected?
8. When does it start to get warmer outside?
9. What time does it get light in the morning.? What time does it get dark at night?
10. How long it is between daybreak on one morning, and daybreak on the next?.
11. What is the temperature difference between the inside and outside? How does this vary during the day?
12. Estimate how long it would take for the inside temperature to match the outside if the heating was not working.

Extra

- Compare a room that is heated with an outside store that is not.
- Compare a room that gets lots of sun with one that gets little.
- Compare the inside and outside temperatures with double and single glazed windows.
- Find out how long it takes for the heating to warm up the school.

Teachers note

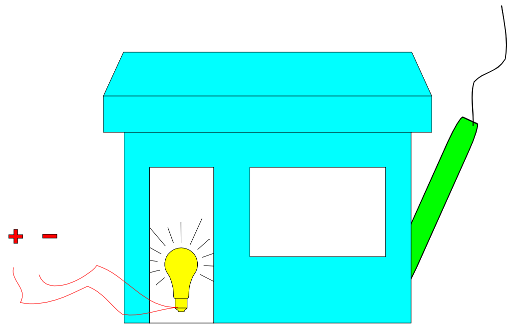
This exercise serves as an introduction to graphs as well as handling ideas about insulation and heat loss. A version with results can be found at Schools Online Science at Sheffield Hallam University on the Internet - find the link at www.rogerfrost.com

Heat - keeping warm

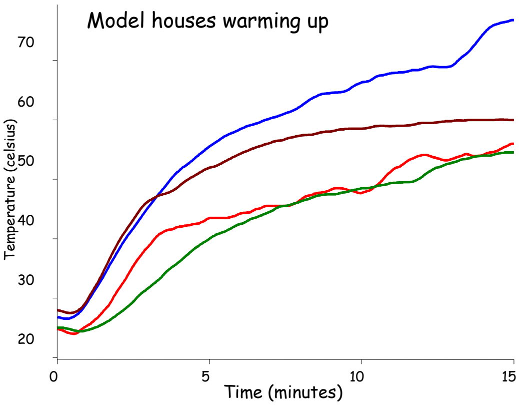
We need to keep our homes warm in cold weather and as economically as possible. There are ways to insulate your home and keep the heat in, and in this investigation you can try some out with cardboard model houses. Here you can see the effect of wall and loft insulation, as well as compare single and double glazed windows. For our model central heating systems we used electrical light bulbs. To measure how quickly the houses got warm, we used temperature sensors connected to the computer.

What you could do

Set up two single-glazed houses, one with loft insulation and one with loft and wall insulation.
Set up another two houses, one with double-glazing and one with single glazing.
Switch on all the heaters at the same time and get the computer to record how they warm.



Results



These graphs show how the houses warm up. From top to bottom the graphs are: loft and wall insulation then loft insulation, double-glazing and then single glazing. Find the file and open it in your data handling software.

Look at the results

1. Why are the temperatures of the houses increasing?
2. Why do the graphs seem to level off instead of continuing to rise forever?
3. How do the graphs tell you that wall insulation helps?
4. How do the graphs tell you whether single or double-glazing is better?
5. Tricky this: which of the graphs tells you that loft insulation helps?

Extra

6. Measure the temperatures at which the graphs level off. Do these help you to compare the usefulness of loft insulation.
7. Measure the average gradient (or steepness) of the graphs. Do these help you to compare the usefulness of loft insulation?
8. Which is the best way to compare these graphs: by their levelling off temperature or their steepness?

What you might do

- Try a similar experiment but warm your houses until they reach a steady temperature. Then measure how fast they cool. Is this a better way of studying insulation?
- There are other ways to heat the houses. You might instead place a hot block of metal in each house and see how well the house keeps it warm.
- Find out how much double glazing cost and how much heat energy you can save by using it. Calculate how long it would take to pay for its installation.

Teachers note

This is a graph handling exercise looking at insulation and heat loss. Find details of how to build a spreadsheet to calculate insulation gains and costs in 'The IT in Secondary Science Book'. Thanks for the experiment results to Martin King, formerly of Verulam School, UK. A version of this page can be found at Schools Online Science at Sheffield Hallam University - a link is available at www.rogerfrost.com on the Internet.

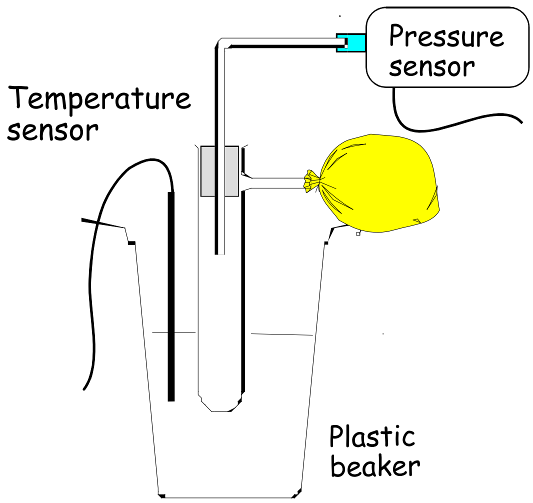
Gas laws - pressure and temperature

Understanding the relationship between pressure and temperature of a gas is one of those key ideas for personal safety throughout life. So how does temperature change affect pressure?

What you need

Pressure sensor, temperature sensor, large beaker, tube with bung and delivery tube, clamps and stand, stock of hot water, small balloon.

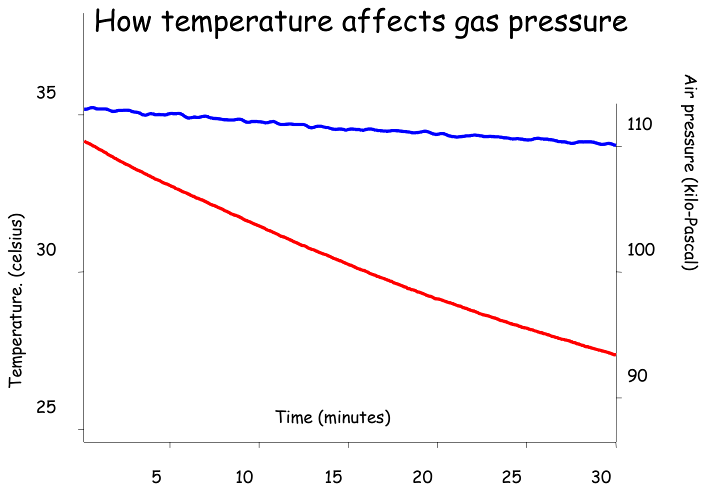
What to do



Set up the apparatus with cold water in the beaker. Start recording temperature and pressure. Add a hot water a little at a time to the beaker, continue recording until it is full.. To protect the sensor, check that your readings do not go off screen.

Results

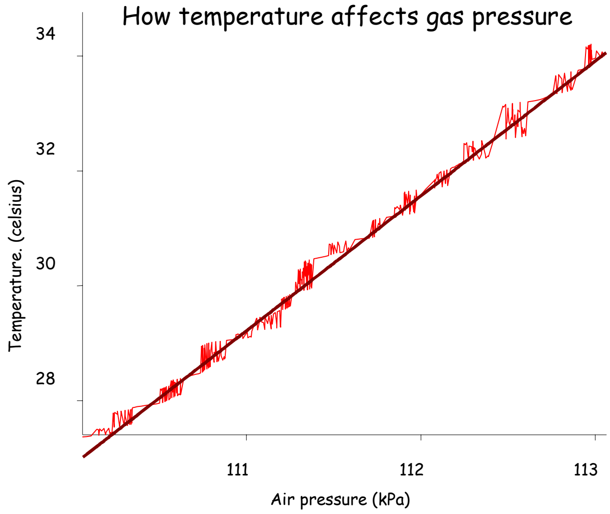
1. Sketch a graph showing how you think the temperature will change over time. Do this for pressure too. (Don't assume that your results will look like this. It is a slightly different experiment).
2. How does the graph show the temperature changes over time?
3. How does the graph show the pressure change over time?



4. To find out how the temperature affects the pressure use your software to plot temperature against pressure. Look at this graph and complete this statement "When the temperature falls, the pressure ________. When the temperature rises, the pressure ________. "

Extra

5. Fit a function such as a straight line to your results.
6. If y=mx + c is the equation for the line, what variable is 'y' and what is 'x'?
7. In theory the intercept c should be absolute zero or -273°C



Teachers note

See over

Gas laws - pressure and temperature

Contd./

Gas laws - Teachers note

I forget who said that pressure seems like an abstract idea until something blows up in front of you. But there's hopefully none of that here as we take a traditional experiment and provide a useful picture of the relationship. Notes are provided to take it to a higher level as required. Many reports of this experiment involve adding hot water or heating from cold. Some reverse this and leave things to cool - but this takes more time. Some recommend using a pressure relief valve - as simple as a balloon attached to the system.

(***Thanks to Brett Laniosh in Measurement & Data logging at Key Stage 3 & 4 - a practical guide, Dudley LEA, UK. Results with thanks to Laurence Rogers. Software is Insight 2 published by Logotron)***

Gas laws - heat from a bicycle pump

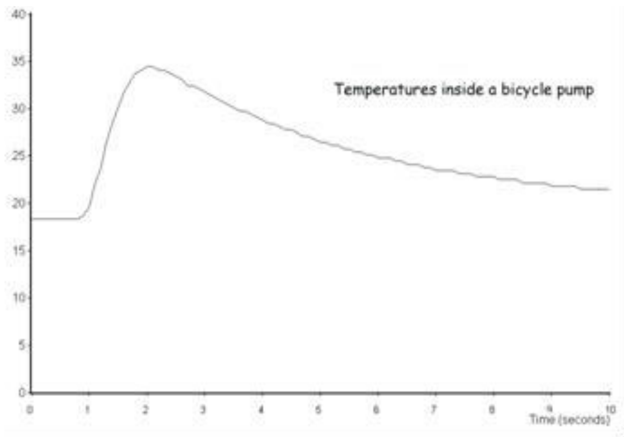
Here is a way to demonstrate the relationship between temperature and pressure of a gas. It requires some DIY effort though the question is interesting enough: when you pump up a bicycle tyre, the pump heats up, but is this due to friction or something more?

Place a temperature probe in a bicycle pump and pump the handle. Note not just the general rise in temperature but the temperature rise and fall with each stroke. Next pump rapidly and hold the plunger in to keep up the pressure. Watch the temperature fall over the next 25 seconds, then pull the plunger back. You should see a sudden temperature drop followed by a steady return to room temperature.

What you need

Place a thermistor inside the end of a bicycle pump, seal with PTFE tape and epoxy cement.

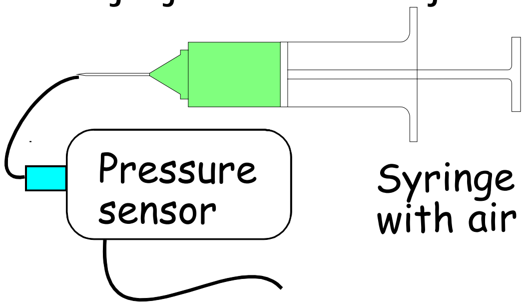
Results



(Results by Bruce Saunders using Tain equipment and software *www.tain.com.au****)***

Gas laws - pressure and volume

This experiment shows the relationship between pressure and volume of a gas. You connect a syringe to the nipple of a pressure sensor, squash the air inside step by step as the sensor measures the resulting pressure. You type the volume on the syringe barrel into the software.



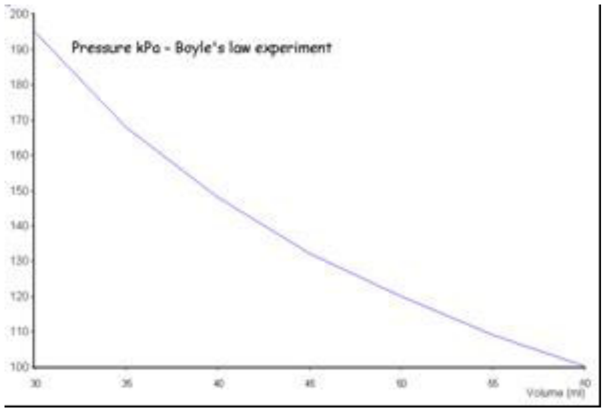
What you need

Syringes - ask for 5 cm^3, 10 cm^3 and 20 cm^3 sizes to cope with the different range sensors, tubing to connect the syringes to a pressure sensor. Do check that you are in the working range of the sensor: pull or push the syringe barrel and see the effect on the pressure readings on-screen. Use volumes that produce a pressure that will stay within the scale on screen. Otherwise, check the sensor documentation, as excess pressure can damage some pressure sensors.

What to do

You need to look for a software feature where you can tell the software the volume on the syringe as it plots the pressure reading. You change the volume, type in its value and the machine plots another point and so on.
Some data logging software expects that you measure pressure over time whereas you really want to measure pressure against volume. Instead you can record pressure against time: squash the gas in the syringe by a fixed amount every ten seconds - that is, at 10 seconds the volume is 1 cm^3, at 20 seconds it is 2 cm^3 and so on. Finally, take the readings off the screen and transfer them to a spreadsheet where you can handle and graph the data. It's clumsy, but the software obviously wasn't designed for this experiment.

Results



1. Eventually you will have data pairs of pressure readings at several volumes. The graph here shows a typical result.
2. Plot the pressure against volume. Add this statement as a label somewhere on the graph "As the volume decreases, the pressure ________."
3. Look at the graph: What is y, the vertical axis? What is x, the horizontal axis?

Extra

4. Is the plot a straight line or a curve? Choose an equation to fit to the graph - that is, make a regression line:
   For a curve use this equation $y = ax^b$
   For a straight line use $y = ax + c$
5. When you double the volume, what happens to the pressure?
6. When you half the volume, what happens to the pressure?
7. When you treble the volume, what happens to the pressure?
8. Is the relationship between volume and the pressure direct or inverse?
9. If the relationship is inverse, multiplying the pressure by the volume will give a constant. Use the software to calculate P x T for each of your readings. What do you find?
10. If the relationship is inverse, volume is inversely proportional to pressure. Use the software to calculate 1/V and plot this against pressure. Fit a straight-line to your data.

Contd./

Gas laws - pressure and volume

Gas laws - teachers note

Measuring pressure as you change the volume of a gas is one of the easiest sensor investigations to do. Set beside the traditional method using U tubes and mercury the technology approach is amusingly brief - and saves hair loss.
(Idea and further detail thanks to ***PASCO's Science Workshop*** at www.pasco.com Also thanks to the ***Texas Instruments-Vernier Software*** - ***Experiments with the CBL*** manuals, where they use this method to compare air and butane for 'non-ideal' behaviour. Look for this at www.ti.com. The results were by Peter Adams using ***Tain*** equipment and software www.tain.com.au

Radiation

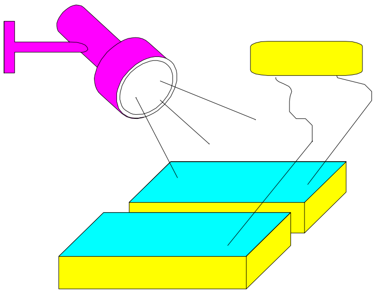
This idea from Australia, adds some extra colour to the topic of heat transfer by radiation.
During a fire rescue, fire-fighters may cover people with shiny blankets to protect them from the intense radiant heat. To find out how effective this is, shape three 60g pieces of Blu-tac into people, cover one with foil, one with fabric and spike them with temperature probes. If you have an extra probe, see how cotton wool covered with foil works to deflect heat.
Place the 'people' near a heater and record the temperatures over several minutes. Use the software to measure differences in their rate of warming and their average temperatures.
Thanks to John Gipps - see his work at ***Tain Electronics*** www.tain.com.au

What you need

Radiant heater, Blu-tac, shiny foil, fabric and three temperature sensors.

Radiation - climate by the sea and on the land

Which warms faster under the sun - the land or the sea? Which cools faster at night? The answers may help us understand the climate



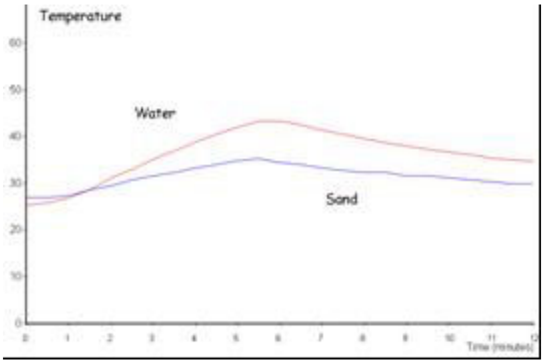
What you need

Tray or margarine tubs filled with sand and with water, desk-lamp, two temperature sensors, clamps and stand.

What to do

- Run the software and check that the temperature sensors respond to warmth. Set up two trays as the land and sea, place a temperature probe in or just above each and start recording.
- Sketch the graph that you think will appear when you switch on the 'sun'.
- Continue your graph to show what you think will appear when you switch off the 'sun'.
- Turn on the lamp and when the temperature stabilises, switch it off and record for a while longer. This can take about 20 minutes.

Results



1. Which heats up faster during the day?
2. Use your software to measure how much the temperature rises over 10 minutes.
3. Which cools down faster during the night?
4. Use your software to measure how much the temperature falls over 10 minutes.
5. Use your results to compare the climate
   a) by the sea
   b) inland
   c) inland in a large continent.

Extra

6. Find the point on your graph that tells you the temperature in the room.
7. Use your software to subtract the temperature in the room from each of your two graphs.
8. Part of your graph shows a cooling curve. Use the software to fit a line or curve to the graph. Do both the land and sea cool in the same pattern?

Teachers note

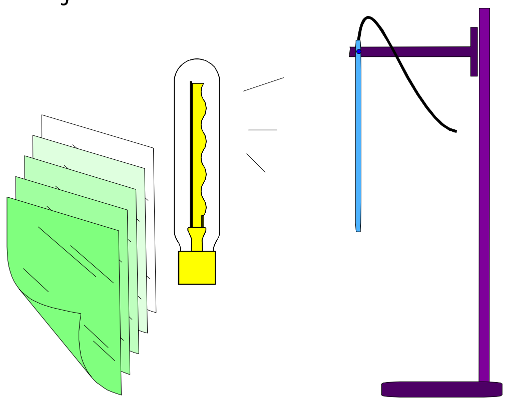
This activity tells us about radiation, climate, energy transfer and cooling in different materials.
(Abridged from Insight 2 software Teaching and Learning guide published by Logotron. Thanks to Laurence Rogers. Results by Peter Adams using Tain equipment and software www.tain.com.au)

Radiation - heat absorption by clothing

They say that wearing light coloured clothing in hot weather helps you to stay cool. To test this idea, we will heat different coloured fabrics with a lamp and record their temperatures.

What you might do

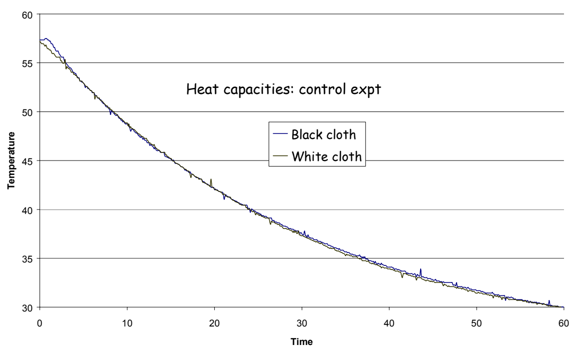
Hang one piece of coloured material from a clamp stand, about 300mm from a radiant lamp. Start recording and switch on the lamp. Measure the temperature of the fabric over the next few minutes.



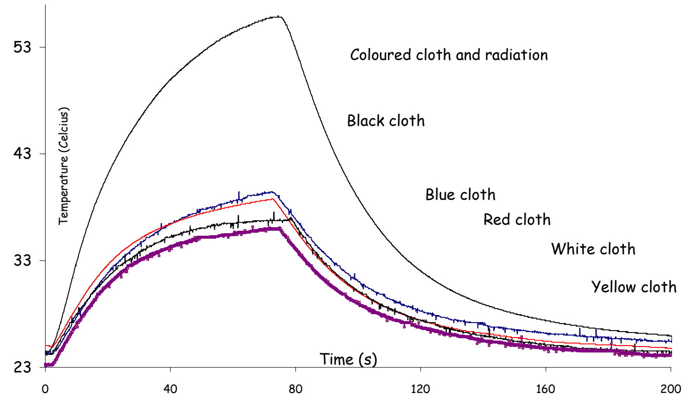
Teachers note

One suggestion is to attach the material around the barrel of a slide projector lens with a rubber band, or instead hanging the material in air about 300mm from a floodlight. Start the illumination from 'off' rather than leaving it on all the time. Illuminate the material until its temperature starts to plateau - then repeat with each different colour for the same length of time. Consider how you can analyse the data and where in this set of questions you would stop.

Experiment results using Tain's small thermistor temperature sensors - with thanks to Tom Howard. Download the software and data from www.tain.com.au. The data was exported to MS Excel. The graph below shows that the heat capacities of the fabrics were similar.



Results



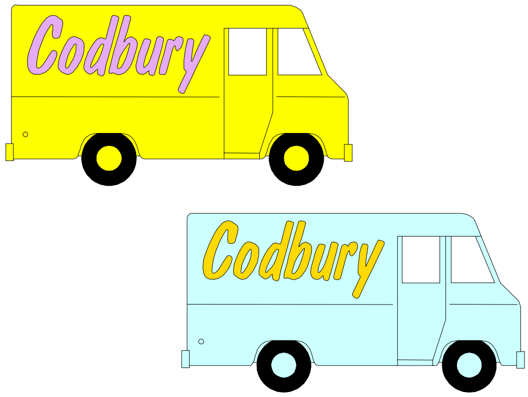
1. Which colour fabric gets the hottest in this experiment? How does the graph show you this?
2. Which of the coloured fabrics would be best to wear on a hot day? How does the graph help you to choose?
3. The fabrics were illuminated for the same length of time and then allowed to cool. At what time was the lamp switched off?
4. Which part of your graph shows how well the fabric absorbs heat? Which part of your graph shows how well the fabric loses heat?
5. Take a reading from each graph to compare the fabrics. How do the fabrics compare?
6. You might use other ways to compare the fabrics: the average temperature, the rate of temperature change or the area under each graph. Try these and report what you find.

What you need

Temperature sensor (e.g. small sensitive type), light source such as a slide projector or 150W floodlight, coloured pieces of fabric of the same material - 100 mm or more square, clamp stand, bulldog clips or clothes pegs.

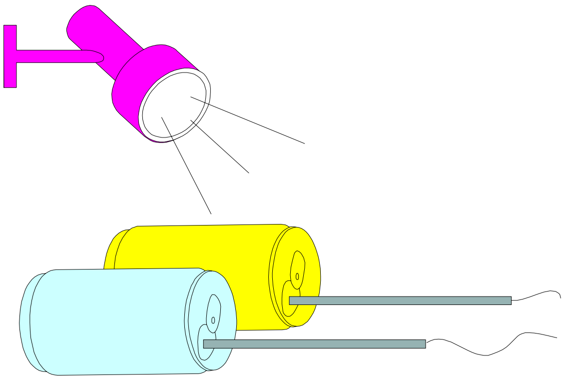
Radiation – best colour

The chocolate company's delivery van is yellow lettering on purple, but it has been suggested that it would be better as purple on yellow.



What you need

Cans painted yellow and black (or other shades to taste), desk lamp, 2 temperature probes, tape or Blu-tac to hold probes in place.



What to do:

Set up two cans that have been painted two different colours. Fix a temperature probe fairly centrally within each can. Start recording as your arrange a desk lamp the same distance from each can. When the temperatures are equal and steady, switch on the lamp for 10 to 20 minutes. Switch off the lamp and continue recording as the cans cool down.

Result

1. How does the graph show there is a difference between the two cans?
2. Use the software to find a measure of how fast each can warms up.
3. Does the graph show that the can colour affects how fast it cools?

Extra

- Look at your graphs and measure the temperatures at the points where the cans started to cool.
- Use your software to subtract these temperatures from each of your two graphs.
- Use the software to find a measure of how fast each can cools.

Teachers note

A variation on the 'which colour is best theme' but with a neat scenario. With thanks to Liz Singleton, Science adviser, Leeds LEA

Noise and sound waves

Sound - measuring noise

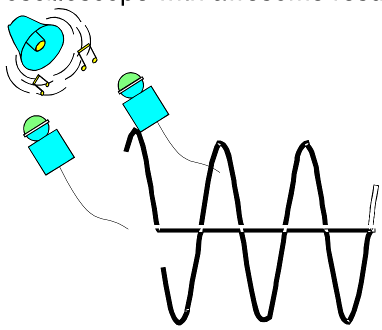
Introduce a topic on sound, using a sound sensor. Use the software to set up a digital meter, gauge or bar display to respond to the sensor. Test the noise of a TV, portable stereo, musical instruments, the supply teacher next door or the glazier repairing the window (a common feature of my school).
You may have the audacity to measure the class noise level. You can negotiate an acceptable noise level above which they will miss break. I am told it's a set up to have handy - should you ever need to pop out of the classroom or manage two classes at once. The graph will give you a running record of the classroom noise level. You can point to a noise peak and ask 'who did that?' You might also use the software to calculate the average noise level of the class. The point to this outrageous suggestion is that there is fun to be had while learning about graphs, decibels and meters. The class might also learn who is in charge - but I jest.
All this reminds us that there is a difference between a transient and a continuous noise. First display your readings as peaks on a time graph, a digital meter and a bar graph. If the time graph shows a flat, steady peak you probably have a reliable reading. If there's a transient, use the software to calculate the average sound level over this section of the graph.
Use the sound sensor whenever you long term recordings. The sound trace acts as a marker on the graph. For example, you can measure the temperature of the classroom over a day. Measuring sound helps clue learners into seeing when it is day (noisy) or night (quiet). Graphs are good for science - Laurence Rogers suggests recording the temperature and sound level of an electric kettle; the sound reaches a crescendo and then subsides as boiling point is reached. The sound sensor also records the final click of the power switch too. You can measure the noise levels inside and outside a window and show the recording on a time graph. In this way you can introduce graphical interpretation. Print out graphs and use them as homework sheets. Ask pupils questions such as:
"Look at the sound level trace. What happened to make the trace change? Label each part of the graph."

What you need

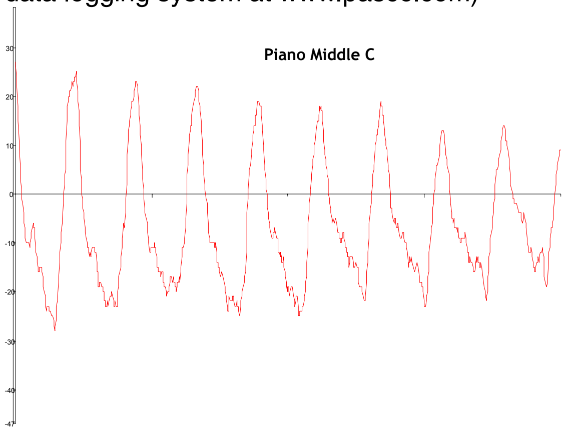
Sound sensor, musical instruments and noise.

Sound waves and phase - demo

A fast data logger is very much a physicists tool. For most work it might seem superfluous but some very fast systems (e.g. 20,000 -200,000 readings per second) allow you to use the computer like an oscilloscope with awesome results.



Take a sound source and two microphone sensors and start recording to see the waveform recorded by each on the screen. Note the wavelength of the sound and then separate the sensors by a full and a half wavelength to see how the traces on the screen move out of phase. (Reference: PASCO data logging system at www.pasco.com)

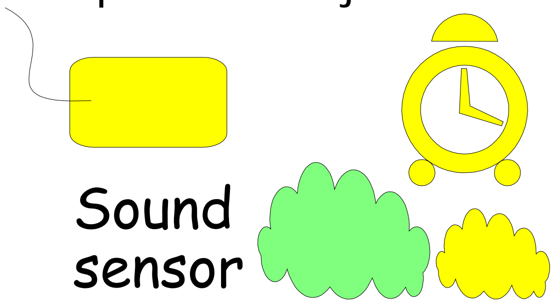


Above is a result from Data Harvest whose sound sensor recorded a waveform at 28,000 readings per second. The sound sensor normally gives a decibel reading, but when switched to 'mv' can log really fast. The sound is middle C of a piano. Use the Interval tool to find the time period from peak to peak = 0.003885. Dividing one second by 0.004s gives approx 260 which is the frequency of middle 'C'.

Thanks to Barbara Higginbotham at www.data-harvest.co.uk

Stopping sound

We call unpleasant sound 'noise'. There are materials that dampen or insulate us from noise. A sound sensor can be used to compare how well they do this.



What you need

Sound sensor, alarm clock buzzer or music keyboard, sound insulators such as cloth, cork, blanket, pillow, box, foam rubber. You need a sound source that produces a loud, continuous sound such as an alarm clock or music keyboard.

Questions

1. Find a quiet place to work and measure the sound level 50 cm away from the sensor. Test each material by wrapping it around the sensor and measure the sound level again.
2. Which material insulates sound the best?
3. Which material is least effective?
4. Is there much difference between the insulators?
5. Do sound insulating materials have anything in common?

Extra

Use an electronic keyboard to make a high-pitched sound and a low-pitched sound. Find out whether the high-pitched sounds or the low-pitched sound can be insulated more easily.

Teachers note

This investigation is aimed at small groups of younger pupils. Finding a quiet place to work is more the issue. It seems to militate against whole classes trying it simultaneously.

You might argue that we should insulate the sound source, and indeed this may work. You can instead place the sensor in a box and insulate the walls of the box, though I've found this troublesome.

Another issue is about finding a convenient way to record the sound levels. There's a difference between a transient and continuous noise. If the time graph shows a steady peak you have a reliable basis for recording a reading. If not use the average reading over a graph section. Some software will allow you to record a series of bars - one for each situation and this is a useful feature to look for.

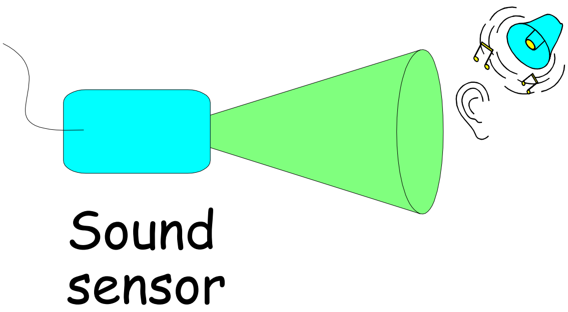
Activity based on 'Sensor' pupils materials by CPS, Holland at www.cps.nl and Gordon Associates, South Africa.

Sound investigations - hearing better

Deer have large ears and people say this gives them better hearing. Deer might use their ears to detect when predators are nearby. In this activity we will find out if big ears help to amplify the sound.

What you need

Sound sensor, alarm clock buzzer or music keyboard, cardboard, tape and scissors.



What to do:

- Make some ear designs, for example, with large and small auricles or long and short ear cavities. Ensure that the design can fit around a sound sensor.
- Make a continuous sound and measure the sound level from each of the ear designs.
- Ensure that the distance between the sound and the 'ear' is the same.
- Ensure that there is no background noise.

Questions

1. Which 'ears' can hear the best?
2. Draw a picture of the best and worst type of ear hearing the sound. Try to show why one is better than the other.

Teachers note

This activity is a small group exercise aimed at younger groups. It is based on one of many in the 'Sensor' pupils materials by CPS, Holland and Gordon Associates, South Africa. Another idea to try, in a road safety topic is to compare the loudness of bells or sirens for a bicycle.

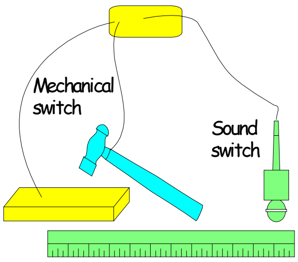
Speed of Sound

Speed of Sound - notes

To be frank, since I saw sensors used to measure the speed of sound, I no longer shout at walls and time my echo. Sensors do the job so well - with the constraint that you may need to hunt down the right ones. Off the shelf kits exist or your supplier may recommend one of these creative approaches.

What you need - method 1

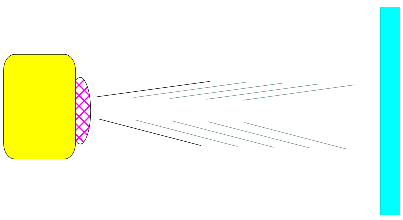
A speed of sound kit - or a simple switch sensor with two leads, a sound switch sensor.



In method one - a DIY approach but there are sensors for this - you plug a switch sensor into a digital input on your data logger. The switch has two leads, one is clipped to a metal bin, the other to a metal bar. When you bash the bin, the contact will make the computer start timing. To a second digital input you need to connect a sound switch - these are available to buy. Place the bin a measured distance from the sound switch. Finally, set the software to time the interval between the first switch and the second, and you can work out the speed of sound.

What you need - method 2

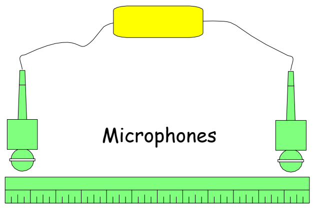
Sonar ranger or distance sensor, temperature sensor, clamp and stand.



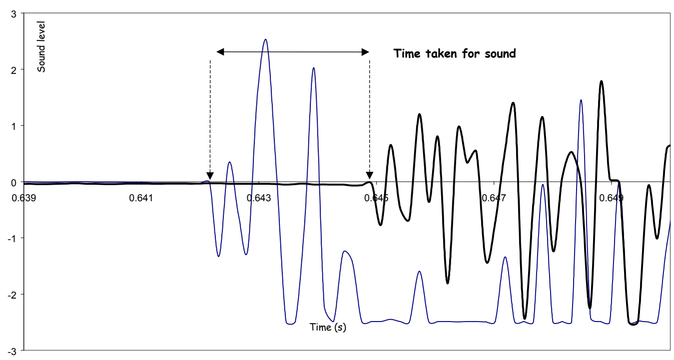
The sonar ranger or distance sensor depends on the speed of sound for its measurement of length. It sends out a beam of sound and notes how long the sound takes to return. It uses this to calculate a distance. You can also use the sensor to see how the speed of sound changes with temperature. It is recommended that you use a power adapter for the sensor as it uses up its batteries rapidly and then starts misbehaving but otherwise this sensor is one of the most reliable. You set up the sensor, facing a wall say, and then set it recording. At the same time you record the temperature between the wall and the sensor. Other things being equal, the distance the sensor measures will vary in step with the temperature. This works overnight but you could look for some short term results using a fan heater.

What you need - method 3

Two microphone sensors (fast response), fast recording data logger



Method three needs a pair of suitable sensors - meaning microphone sensors. (Sound sensors are 'A-weighted' to make them better noise meters - these may not work). Place them a measured distance apart and get the data logger measuring as fast as it can. Make a sound near one sensor and you should see two sound peaks with a time interval between them.



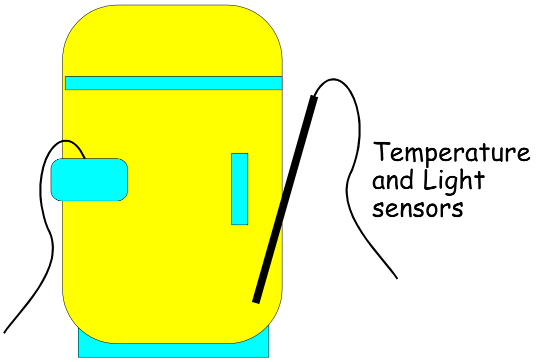
Results by Fourier Systems using Multilog microphone sensors and DBLab software from Scientific and Chemical Supplies.

Thermostats - refrigerator

Is the refrigerator working? This exercise shows how you can find out by using automatic measuring systems or data loggers. It is an example of the measurement that takes place in industry every day.

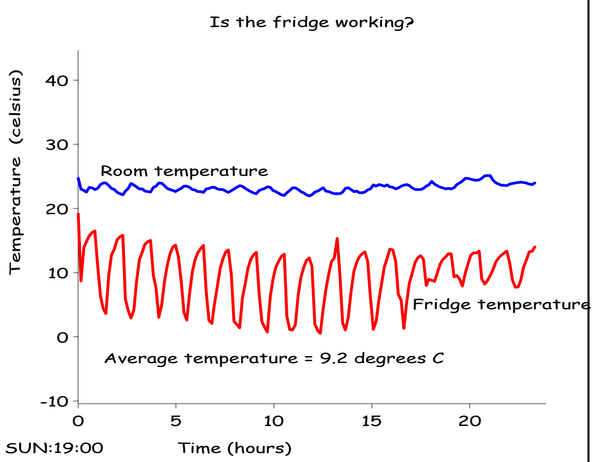
What you need

A fridge, up to 24 hours, one or two temperature sensors, light sensor, data logger and its mains power adapter.



What to do

Place a temperature probe in the fridge together with a light sensor. If you wish, add other sensors such as a sound sensor near the motor, a temperature sensor in the room or near the motor. The data logger and any sensor boxes need to stay outside the fridge to avoid condensation occurring inside them.



Results

1. What would be the value of measuring the light level inside the fridge?
2. If you measured the temperature inside your fridge every minute of the day, what do you think you would find?
3. Sketch a graph: Write 'time' on the x-axis and 'temperature' on the y-axis. Now draw a line across the graph - if the temperature rises, the line must bend up the graph. If it falls, it must bend down the graph.
4. Look at the graph of fridge temperature and room temperature. Which line do you think is which? Label the graph lines.
5. If you measured the light level: how many times was the fridge door opened? Label the graph to show when it was night.
6. What are the lowest and highest temperatures that the fridge achieves? What is the average temperature of the fridge?

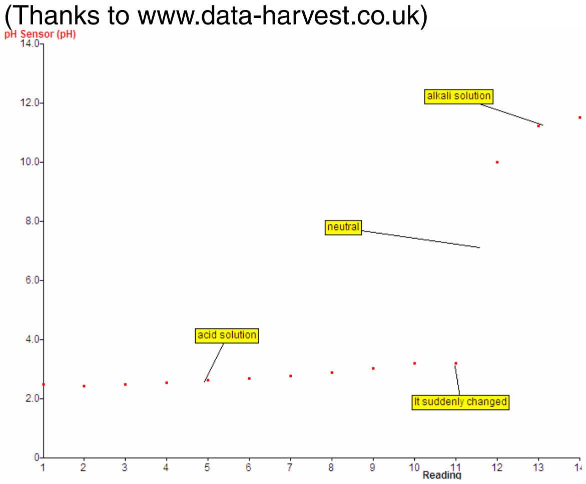
Teachers note

This exercise yields the intriguing piece of information that the temperature inside a fridge oscillates. Use it as an introduction to data handling. The idea of 'average' temperature in a fridge is made quite clear from the graph. Talk through such data when you teach about machines, thermostats or control systems. The range of temperature in this fridge is surprisingly broad and unhealthy. We thought that the thermostat was 'kicking in' too late so we bought a new one. A further test showed the average temperature of the fridge to be still too high. On that basis, we concluded that the fridge needing throwing away. A light sensor reassured that the fridge door was kept closed. A fellow investigator, Andrew Clark-Maxwell from Slough Grammar School, put a temperature sensor in a fridge and studied the temperature rise due to opening the door. He took out milk for coffee in two ways. Firstly open door, take jug, add to coffee, replace jug and close door. Secondly open door, remove jug, close door, add to coffee, open door, replace jug and close door. Results show how long the fridge temperature takes to recover and there are health-related issues arising from this particularly in the catering trade.

Acids - teaching notes

With countless readings to be taken, the acid-alkali titration is an experiment that merits help from a computer. There are various approaches to dripping acid into alkali and measuring the pH. In the examples that follow, we show how you can get very useful results if you allow acid to drip into alkali and make no effort to measure the acid volume. We offer three quick and painless approaches for three different school levels.

If you prefer, you can measure the acid volume. Since few of us have a ‘drop-counter’ or similar you do have to measure the volume of acid manually. You need to get your software to record one reading at a time. You add acid, press a button to take a reading, add more acid and so on. Here’s an example using Data Harvest’s software. You should be able to see the dot that is plotted each time. Having made the plot, you annotate it, print it and draw your best fit curve.
(Thanks to www.data-harvest.co.uk)



Other approaches follow

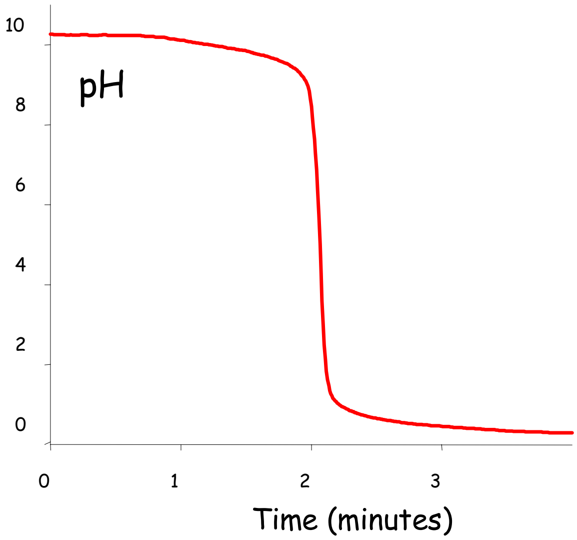
How to illustrate the basic idea about pH and neutralisation:

What you need

Burette with 0.1M hydrochloric acid, clamp and stand, flask with 0.1M sodium hydroxide, 20 cm^3 measuring cylinder, pH indicator and pH probe/sensor in a clamp. A magnetic stirrer helps but you will still obtain a pH curve without.

Place pH indicator and 10 cm^3 of alkali in a flask. Place acid in a burette and measure the pH as you allow the acid to drain out at full speed. This will give you a graph of pH against time that you can re-label as 'time that the acid dripped for'. The pH indicator is not essential, but it helps.

Titration - strong acid vs alkali



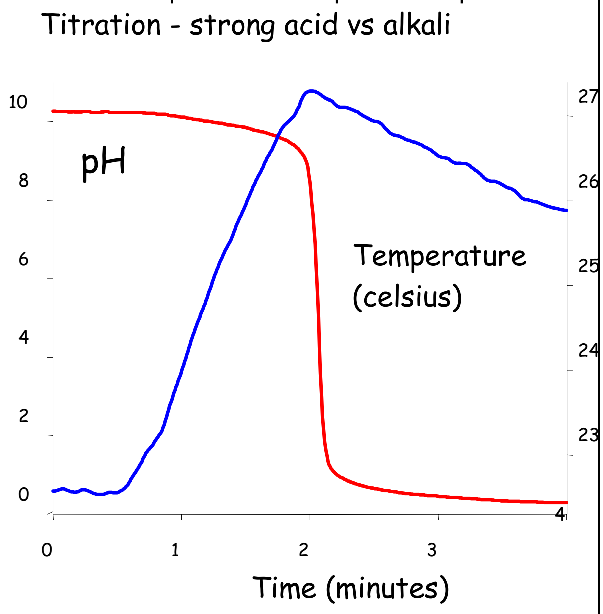
How to illustrate ideas about the heat of neutralisation:

What you need

Burette filled with 2M hydrochloric acid, clamp and stand, temperature sensor, flask with 2M sodium hydroxide, pH indicator and a pH probe/sensor. A magnetic stirrer is recommended.

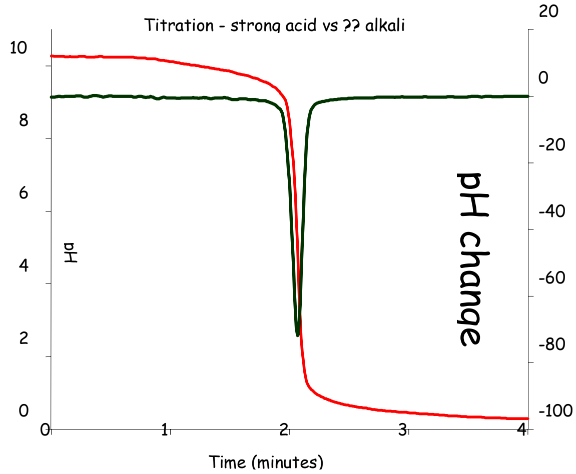
What to do

Place pH indicator, 10 cm^3 of alkali and a pH probe in a flask. Use more concentrated solutions. Place acid in a burette and measure both the pH and the temperature as you allow the acid to drain out rapidly. This will give you graphs of pH and temperature against time. The temperature of the flask peaks at the point of neutralisation - because after this point no heat is produced. After this point the solution cools, partly because of the added cool liquid. Mouse over the graph, discuss what happened and annotate the graph with these points. Zoom in on the temperature scale and discuss the reason for the temperature peak. The peak should correspond to the equivalence point.



How to find an equivalence point:

When you have a pH v 'time acid dripped for' graph, you can find the point at which the pH changed fastest using a differential plot. You ask the software to plot $\frac{\delta pH}{\delta T}$ or the gradient of the pH curve during the titration.



How to illustrate ideas about the shapes of titration curves of weak and strong acids:

Perform four titrations by allowing the burette to drain as you record the pH:

- Strong acid into strong alkali
- Strong acid into weak alkali
- Weak acid into weak alkali
- Weak acid into strong alkali.

This will show you quite good titration curve shapes and equivalence points without worrying about the liquid volumes required for neutralisation. See the tartaric acid curve overleaf.

What you need

Burette, 0.1M hydrochloric acid, 0.1M ethanoic acid, clamp/stand, temperature sensor, pH probe/sensor, flask, 0.1M sodium hydroxide, 0.1M ammonium hydroxide. A magnetic stirrer is essential.

What to do

Place 10 cm^3 of strong alkali and a pH probe in a flask. Pour acid into a burette and measure the pH as you allow the acid to drain out rapidly. Some say that you should maintain the head of liquid in the burette to give a steady flow rate - but this might not be necessary. Very soon you will have a graph of pH against time that you should save on disc. Repeat the experiment using 10 cm^3 of weak alkali and again save the result on disc. You may be able to add the second graph onto the first but appreciate that an error on the second experiment risks spoiling the first result - hence always save between runs. Many data logging programs will allow you to load in graphs from separate experiments.

When the acid has drained, rinse the burette with water, rinse again with weak acid, and then fill with weak acid. Now titrate this into 10 cm^3 of weak alkali and later into 10 cm^3 of strong alkali.

Results

You should have four graphs that you can mouse over in turn, discuss and annotate with the key learning points. Use the software to 'switch off' the four graphs and then discuss them two at a time. Find out:

- The pH of each of the four solutions
- The equivalence point of each of the four titrations by choosing the mid point of each curve
- The equivalence point of each of the four titrations by calculating the gradient of the pH curve during the titration or the differential $\frac{\delta pH}{\delta T}$
- The normal pH of the salt solutions from the four titrations

Illustrate ideas about volumes, concentrations and end-points:

What you need

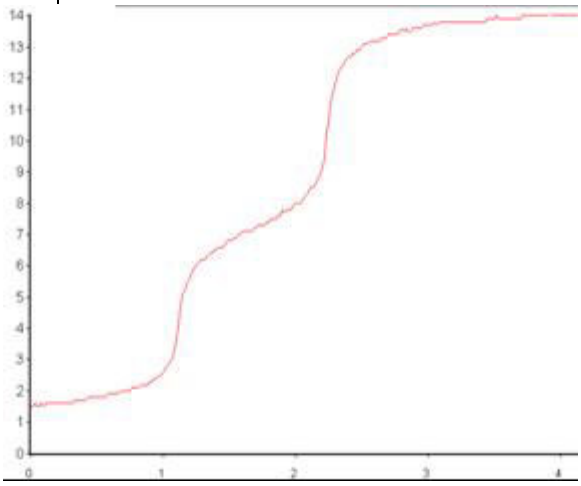
Burette, 0.1M hydrochloric acid, clamp/stand, temperature sensor, flask, 0.1M sodium hydroxide, pH probe/sensor and a magnetic stirrer.

What to do

Pipette 20 cm^3 of strong alkali into a flask with a pH probe. Set up the software to record against volume as opposed to time. Not all software can do this - and you may resort to recording and plotting results with a spreadsheet to overcome this serious glitch. On the other hand, it is worth considering what the computer is adding to the traditional approach. Some would say that if the purpose of the exercise is to teach that 20 cm^3 acid neutralises 20 cm^3 of the same concentration of alkali, you may as well do the experiment the traditional way. Others feel that the computer saves time and allows more work to be done. Fill a burette with acid, start recording and drain roughly 1 cm^3 acid into the flask. Get the software to plot a point as you record the actual volume of acid added. Continue recording and adding roughly 1 cm^3 volumes until you reach 18 cm^3. From this point on, add about 0.5 cm^3 of acid each time - but less is best. At some point the pH will change rapidly - shooting over this point in a manual titration can be disastrous, though here the software fills in the missing points and often saves the experiment. When you have added 22 cm^3, you can return to adding 1 cm^3 amounts.
Use the graph to find out how much acid neutralises 20 cm^3 alkali. You can do this by finding the mid-point of the fast changing point of the graph. You can also plot a differential to find the point where the pH was changing fastest. Use this point to read off the acid volume.

Acids - multi-protic acids

An impressive result for an experiment taking 5 minutes. Allow a burette full of sodium hydroxide to drain into a flask containing phosphoric acid and take pH readings with a pH probe. Unusually, this acid has more than one proton and behaves as if it was two acids.



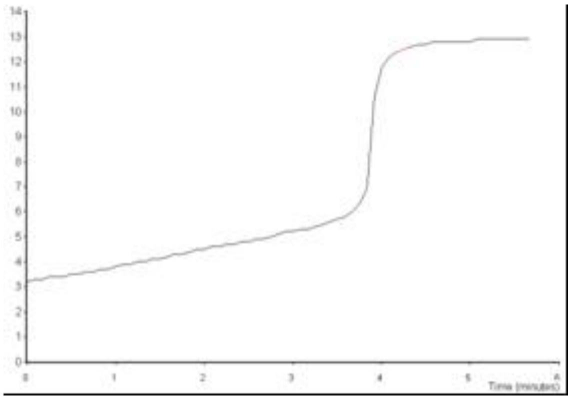
The two equivalence points of phosphoric acid are shown on the graph. You can find their actual pH values by plotting a differential of the pH readings. ***(Results by John Gipps using Tain equipment & software** www.tain.com.au**)***

What you need

50 cm^3 1M phosphoric acid in a burette - i.e. I would do this upside down, clamp/stand, 20 cm^3 1M sodium hydroxide in a flask, pH probe/sensor and a magnetic stirrer.

Acids - strong alkali and a weak acid

A classic result as a burette full of sodium hydroxide was allowed to drain into a flask with tartaric acid. The titration of a strong alkali against a strong acid would yield a neutral salt and an equivalence point at pH7. Tartaric acid is a weak acid and a solution of sodium tartrate will yield a slightly alkaline solution. The equivalence point correspondingly appears on the alkaline side of neutral as this result shows.



(Results by John Gipps using Tain equipment & software** www.tain.com.au**)

What you need

50 cm^3 1M tartaric acid in a burette - i.e. I would do this upside down, clamp/stand, 20 cm^3 1M sodium hydroxide in a flask, pH probe/sensor and a magnetic stirrer.

Acids - stomach acid

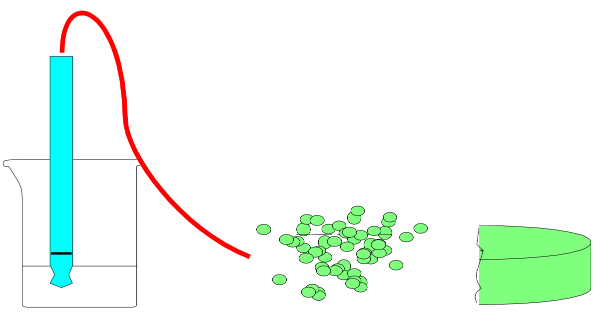
This is a quick and reliable demonstration to use in topics about digestion, or even rates of reaction. Half fill two beakers with 'stomach acid' or Cola drink and place a pH electrode in one. Start recording the pH and add the half tab of Alka-Seltzer record for a couple of minutes. Save the graph and repeat using the other beaker and a crushed half-tablet.

In this context, there is little you need to do with the data - it is yet another way into the business of graphs, change and measurement. However, you can note the starting and ending pH values and the fact that both experiments produce the same net change. You can also note the different rates of pH change. If you wish, use a rate of change feature in the software to go further. You could use the technique as a basis for comparing antacids.

More interesting is Barbara's finding that if you do the opposite, that is you put an Alka-Seltzer in water and then pour in Cola, there is no change. The Alka-Seltzer solution starts as neutral and stays neutral as you add the Cola. Explanations on an email please.

(Thanks to Barbara Higginbotham, Data Harvest, UK** www.data-harvest.co.uk**)

What you need



'Stomach acid' e.g. a can of cola drink, two beakers, an Alka-Seltzer tablet (half crushed, the other half solid), pH sensor/electrode.

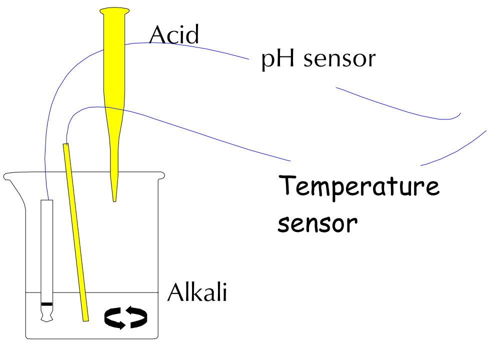
Acids - heat of neutralisation

When acid reacts with alkali not only does the pH change but the reaction gives out heat too. In today's activity, you will see these pH and temperature changes as we use computer sensors to display them as they change.

You may already know and expect that the pH will drop as the alkali is neutralised, but what do you think will happen to the temperature?

What you need

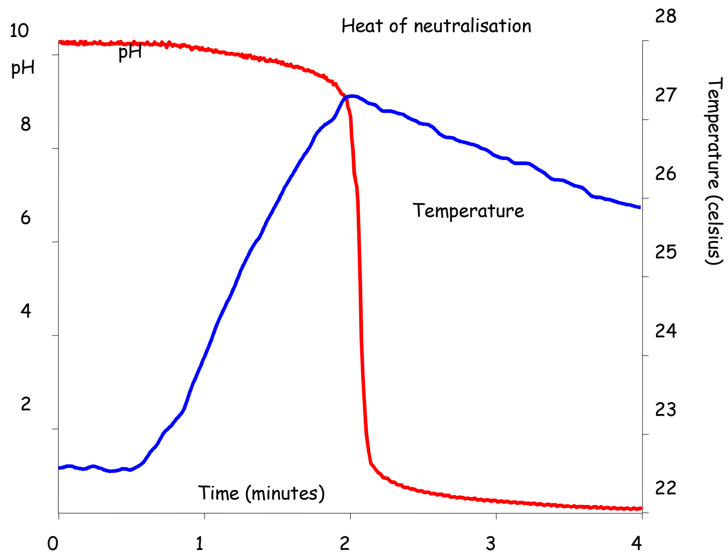
Burette with 2M hydrochloric acid, clamp/stand, temperature sensor, flask with 2M sodium hydroxide, pH indicator and a pH probe/sensor. A magnetic stirrer may be useful while a pH buffer solution will help to check the accuracy of the pH sensor.



What to do

Place pH indicator, 10 cm^3 of alkali, a temperature probe and a pH probe in a flask.
Fill the burette with acid.
Check the pH sensor reads correctly by testing a buffer solution with a pH we know.
Start the computer recording as you allow the acid to drain rapidly out of the burette.
A graph of pH and temperature against the time the acid was left to drain.

Results



1. What does the pH graph tell you about the reaction between acid and alkali?
2. Does the pH change most slowly - at the beginning, the middle or the end of the titration?
3. When does the pH change most rapidly?
4. How does the graph show you that the mixture is getting warmer?
5. If required, expand the temperature axis to show the changes more clearly. At what pH does the mixture start to cool?
6. Why does the temperature of the mixture appear to start to cool?

Extra

- Find the point at which the pH changes most rapidly by calculating an integral line from the pH graph. Change the axis if necessary to show this on the screen. What is the significance of this point?
- Similarly, find the point at which the temperature changes most rapidly. Does this, or should this match with the change in pH.

Teachers note

See the previous pages for the teaching context.

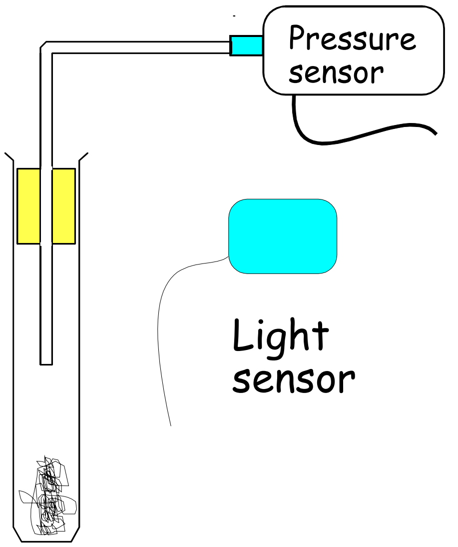
Corrosion - salt and steel

Corrosion - notes for teachers

Amongst the factors affecting the corrosion of steel are temperature and surface area. Although it is not required for rust to form, salt water increases the rate of corrosion. You can monitor rusting by measuring the volume change in a closed system with a pressure sensor.

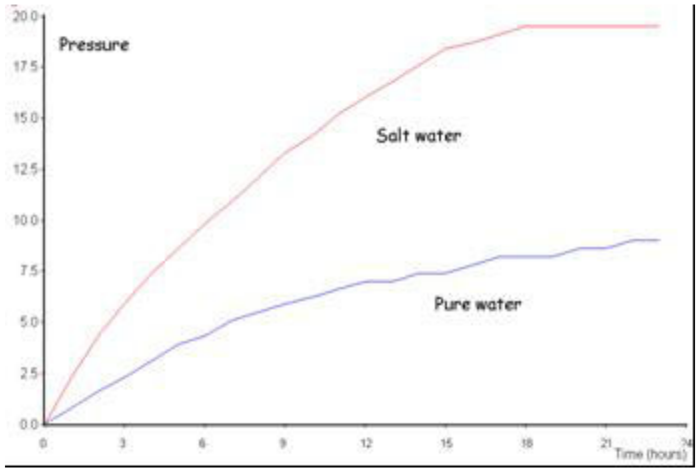
What you need

Piece of steel wool, salt water, tube with bung and a delivery tube connected to a pressure sensor. Place this in a water bath to accelerate the rusting.



What to do

Place known amounts of steel wool and salt water in a tube and measure the pressure change over 24 hours. Repeat the experiment using plain water.
Consider doing a project to investigate the rate of rusting at a temperature of say 80°C. How could you correct for the volume change due to the temperature?



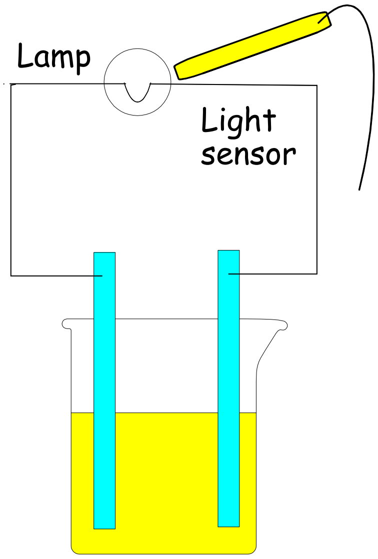
Graph shows the effect of salt on the rate of corrosion. You can obtain a measure of this as a 'rate' or average gradient of the graph.
(Results by John Gipps using Tain equipment & software** www.tain.com.au**)

Electricity - lead acid accumulator

The Lead acid accumulator is one of the most common stores of electricity. Here you can see how it is made and how much charge it can store.

What you need

Beaker half-filled with 0.5M sulfuric acid, two pieces of clean sheet lead as electrodes, 5v power supply, crocodile clips and wires, 1v lamp, light sensor. Safety goggles.



What to do

- Set up a circuit with lead electrodes in a beaker in acid. Charge the lead electrodes for exactly 3 minutes. Start the computer measuring light level, connect the electrode wires across a lamp and use a light sensor to record how long it stays lit. Save your results on disk.
- Repeat your experiment taking care that you do not disturb the lamp and sensor assembly. If your results are similar to the previous run, continue. Now repeat the experiment about six more times, increasing the charging time by 30 seconds each run.

Results

Collect the graphs of your results on the screen.
Discuss how you will use the graph to measure how much charge the accumulator held each time.
Use data handling software to plot charging times against your measure of charge on a graph.
What can we learn about charging an accumulator from this graph?

Teachers note

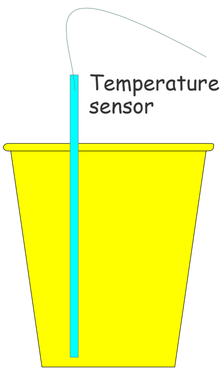
This is a class experiment for work on reversible reactions, energy from chemicals. (Method adapted from 'Classic Chemistry experiments' from Royal Society of Chemistry, London at www.rsc.org.uk)

Endothermic and exothermic reactions

In this activity you will measure the energy change in a chemical reaction. You mix measured amounts of the chemicals and monitor the temperature rise. A graph on the computer will show the temperature change.

What you need

Test tubes or styrene foam cups, 2cm^3 syringe, balance, spatulas, safety goggles, one temperature probe. These reactions may be suitable for study: anhydrous copper sulfate and water; zinc powder and 0.5 M copper sulfate solution.



What to do:

1. Place a temperature probe in a styrene foam cup and use a syringe to add 2 cm^3 water. Start recording. Weigh a spatula measure of anhydrous copper sulfate, add it to the cup and stir. Continue recording until the temperature stops rising.
2. Place a temperature probe in the cup and add 5 cm^3 copper sulfate solution. Start recording. Weigh a spatula measure of zinc powder, add it to the cup and stir. Continue recording until the temperature stops rising.

Results

1. Label each graph to show whether the reaction is endothermic and exothermic
2. Take readings from the graph to record the temperature change of each reaction
3. The calculation for one of the reactions has been started for you :

$$\text{Moles of zinc} = \frac{\text{mass of zinc powder}}{\text{atomic mass of zinc}}$$

Moles of copper sulfate =

$$\frac{\text{concentration of CuSO4 x volume of CuSO4 used}}{1000}$$

Symbol equation for this reaction =

Number of moles reacting =

Heat produced = Temperature rise x volume of liquid x specific heat capacity of liquid

Heat produced =

Temperature rise x vol of liquid x specific heat capacity of liquid

$$\text{Heat produced per mole} = \frac{\text{Heat produced}}{\text{Number of moles reacting}}$$

Teachers note

Use this to quantify energy changes in reactions with good precision. Pupils react a measured amount of chemical and monitor its temperature rise. They use a time graph to show the temperature change with precision.

Endothermic and exothermic reactions 2

Exothermic reactions - chemical foot warmer

This idea, featured in 'Data logging and control', makes an unusual, advanced level project.
A mountaineer might keep warm using a heat pack made with quicklime and water. When mixed, heat is given off, but it is given off too quickly. We can moderate the reaction with sugar so that it gives off heat for longer. There is a certain mix of water, quicklime and sugar that gives the best result.
A temperature sensor is an ideal tool to investigate with. It can monitor the reaction and software can find the highest overall temperature, the total amount of heat given off and the time that heat continues to be produced.

What you need

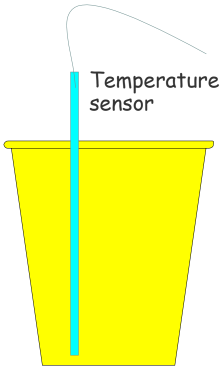
Fresh quicklime - must generate lots of heat with water, icing sugar, temperature probe, measuring cylinders, beakers, boiling tube.

Endothermic and exothermic reactions 2

Demonstrate this as a prelude to testing which chemicals give out or take in heat. The computer helps by providing a large display of the temperature change.

What you need

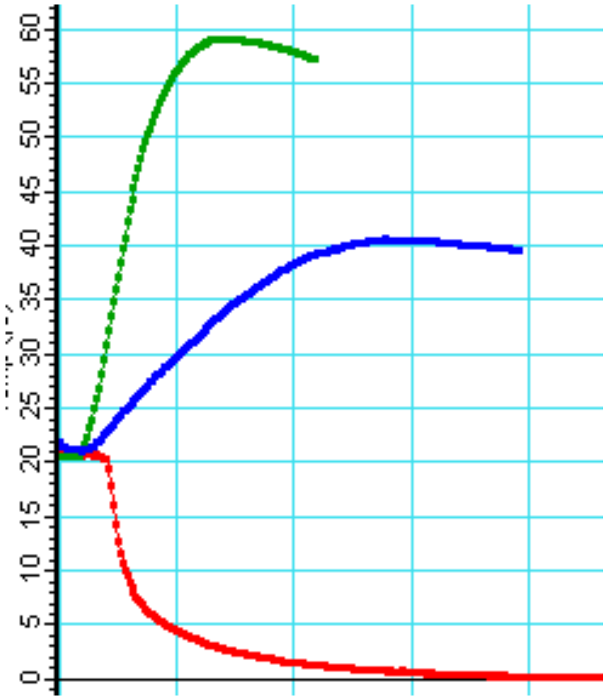
Examples of one endothermic and one exothermic heat of solution (e.g. add sodium carbonate to water), two temperature sensors



What to do

Display a time graph, large digits or bar graph on the screen. Show what happens when you warm one probe and cool the other.
Place the chemicals and a temperature sensor into each of two tubes. Start recording and add water. Ask for bets on what will happen. Use the terms 'endothermic' and 'exothermic' to describe the reactions. Write these words on the respective graphs. Class might then do the traditional experiment.

Results



Comparing the heat changes of chemical reactions over time.

(Results from PASCO's Science Workshop www.pasco.com)

Evaporation - how to make a drink cool

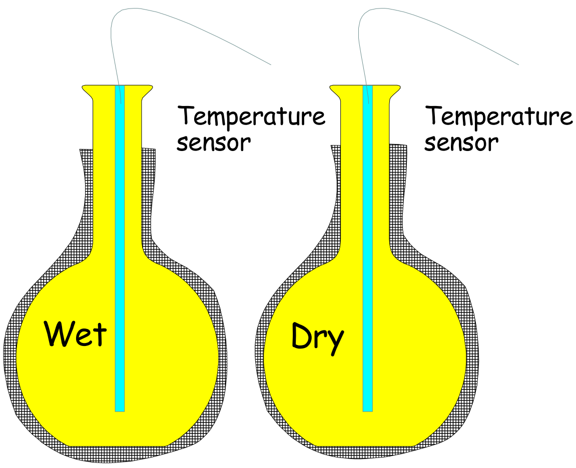
If you're going out and travelling light, the last thing you'd take is a cool box, let alone a fridge. What you need of course is an old sock plus the wisdom of centuries of people who lived in hot climates.

Before you need your drink, stick an old (and hopefully clean) sock over your drink bottle, wet it well and leave it in the shade. If you're lucky a breeze will be blowing and after a while the sock will have dried out. What is more, the drink will be cooler - even than the shade. Does this really work? Here's how we set about testing this in the lab

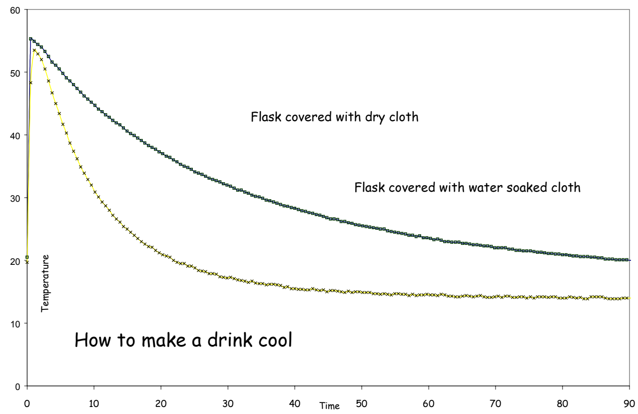
What you need

2 round flasks or drink bottles, 2 x clamp and stand, pipette, elastic bands, 2 x pieces of towel to fit flask, two temperature probes, data logger, paper towels, a desk fan and warm water.

What to do:



Clamp the flasks and wrap each flask with towel using elastic bands. Place a temperature probe in each flask.
Use the "Setting up" sheet to get the data logger ready. Start recording.
Fill each flask with warm water and soak the material around one of them.
Leave for at least 20 minutes - or until the temperatures are steady.
Load your results into the computer to print them. Pack away



Using the results

1. Add a title and label which line is which.
2. How does the graph show that the drink cools?
3. Which flask cools down more rapidly?
4. How long would you recommend leaving the drink before drinking? Draw a vertical line on your graph to show when the drink has become reasonably cool?
5. Estimate how many degrees cooler was the drink wrapped in wet towel?
6. Explain how this experiment was a fair test.
7. Explain how it works - remembering 'kinetic theory' and that temperature is a measure of how fast the molecules move.

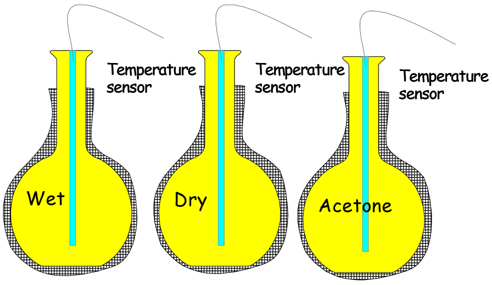
Teachers note

This is a demo or class experiment with homework. You could use it to teach about evaporation and cooling. (Idea and results from Chris Sharples, York, UK - visit www.yorkschools.org.uk for further examples from the York Schools Science and IT Together Project.)

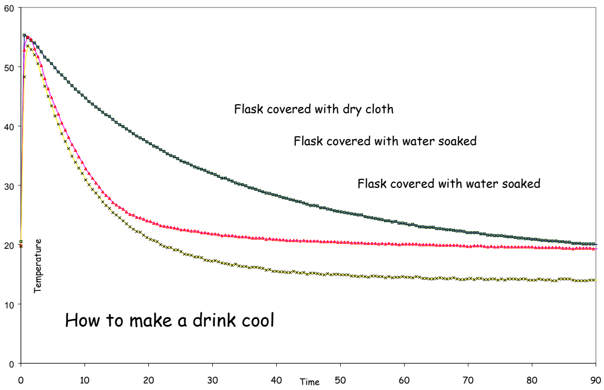
Evaporation - how to make a drink cool - data analysis

What to do

In this experiment we wrapped three warm drink cans with towel. We wet one towel with water, another with acetone solvent and then measured the temperatures of the three drinks for a while.



Results



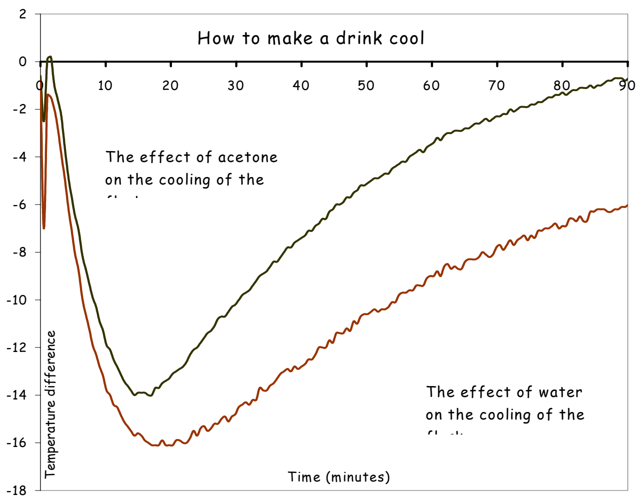
Use our data file in your software to answer these questions:

1. The acetone had evaporated after just 15 minutes while the water took over 90 minutes to dry. Use these facts to label which line is which.
2. How does the graph show that the drinks cool?
3. Which flask appears to cool down more rapidly?
4. How long would you recommend leaving the drink before drinking?
5. How many degrees cooler was the drink wrapped in the wet towel?
6. How many degrees cooler was the drink wrapped in the acetone towel?
7. How many degrees cooler was the drink wrapped in the dry towel? Why did it cool?
8. You could say that the best cooler achieves the coolest temperature the soonest. Which appears to be better for cooling, acetone or water?

Extra

You can handle your results in another, even better way. All three flasks have cooled down. The dry towel tells us how much the flasks would have cooled anyway. What we will do is to subtract its temperature from all the other temperatures.

1. Use your software to subtract the dry temperature line from the water temperature line.
2. Now subtract the dry temperature line from the acetone temperature line.
3. Plot your results to obtain a graph like the one below. The part of the line below 'zero' tell you how fast things cool.
4. Find a way of measuring how fast the temperature of each line falls.



Graph shows how much the acetone and water helped the flasks to cool.

Evaporation - strength of alcohol

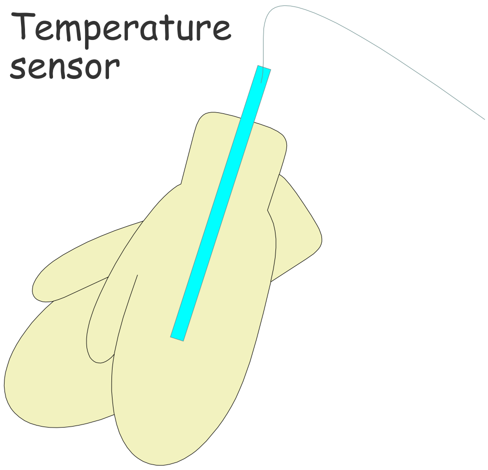
The evaporation of alcohol has long been used as a measure of the strength of spirits or 'proof'. Back in time, customs would put the spirit onto gunpowder and if the powder still ignited, the drink was called proof spirit. Here you can monitor the cooling effect of evaporating alcohol using temperature sensors. You can use the rate of cooling as a means to compare alcoholic drinks, or after-shave and perfume. The computer helps by taking many readings and plotting a line graph. With a button click, you can measure the rate of temperature change.

What you need

Two temperature sensors, desk fan, bottles with different strengths of alcohol labelled A, B, C

Evaporation - wet gloves

As skiers well know, wet clothing makes a dramatic difference to your body temperature and the wind greatly adds to the effect. You can show this well with temperature sensors and a desk fan. For example, to find out how cold your hands get when your gloves are wet, place a temperature probe inside each of two gloves. Wet one glove, fix both gloves in the path of a desk fan and measure the temperature change over a few minutes. If you wish, wear the gloves and experience the extreme cold!
Next, repeat the exercise, but this time wet both gloves. Set the gloves up as before and make sure they are at about the same temperature. Start recording the temperature. Show that the cooling is due to evaporation, by covering one glove with plastic as the fan blows.
As this exercise takes just a few minutes, you might use it as a demonstration to lead into a class experiment on evaporation.



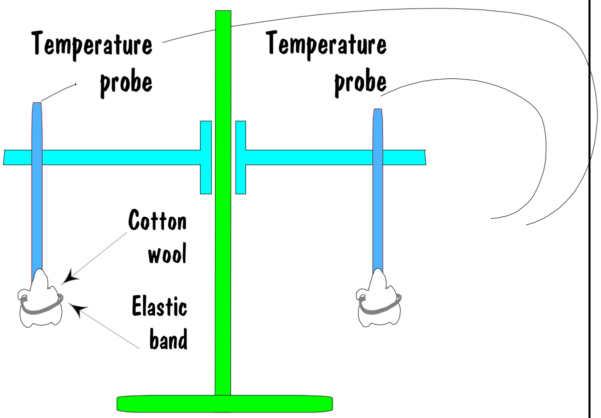
What you need

Two gloves, hot water, desk-fan, small polythene bag, two temperature sensors, clamp stand to hold temperature probes and gloves.

Evaporation -

Temperature probes show cooling due to evaporation very well. The change in temperature over time is very clear to see on the screen - and the effect of an air breeze is especially interesting. Before a class experiment, wrap cotton wool round a temperature probe, dip it in solvent and record the temperature over the next minute. Ask the group what they think might happen to the temperature if you blow hot air over the probe. They should find that the temperature actually drops before it rises.
With some groups you might measure the rate of change of a graph. You can ask:

- How long did it take for the temperature to drop to its lowest point?
- Which solvent cooled the most in any 10 second interval?

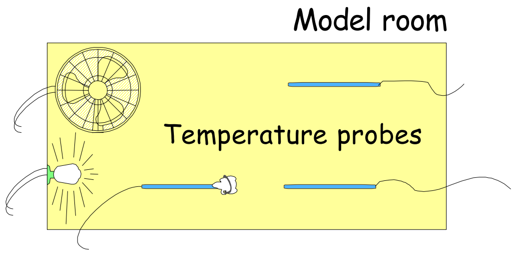


What you need

Dropper bottle of spirit or after-shave, cotton wool, elastic bands, desk-fan or hairdryer, test tube, clamps and stand, two temperature sensors.

A detailed experiment can be found on the Internet in 'Enhancing Science with IT Classroom activities' at the UK Virtual Teacher's Centre. Another approach can be found in the Insight 2 software Teaching and Learning guide available from Logotron.

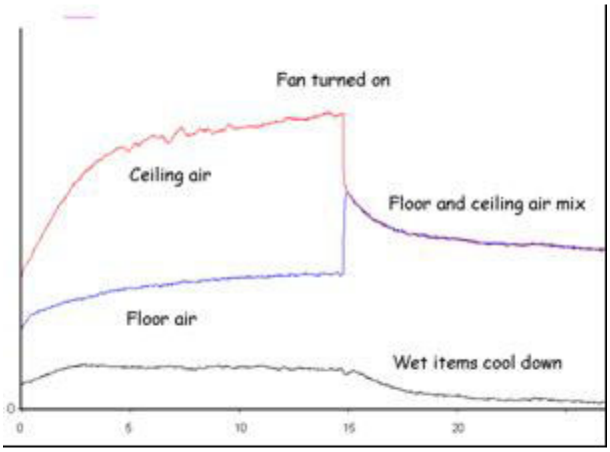
Evaporation - do ceiling fans cool us?



This demonstration idea from Australia generates an interesting result. People in the staff room felt that the fans were blowing hot air down from the ceiling and that it would be better if they worked in reverse. This led to an investigation with a model room (e.g. shoe box) and temperature probes high and low. A third probe was covered with damp paper to represent a sweating person. A lamp warmed the 'room' for around 20 minutes - until the temperatures were steady.

What you need

Temperature probes, model with lamp and fan,



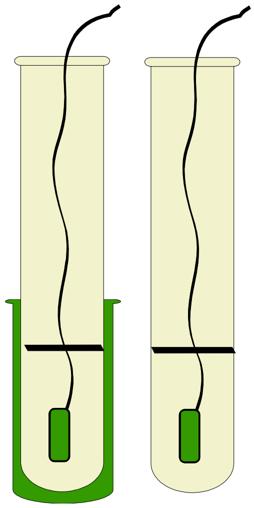
A difference between top and bottom temperatures can be seen in the graph. The fan was switched on causing mixing of the air and the damp probe showed the more significant change.
(Results by Peter Adams using Tain equipment and software www.tain.com.au)

Exercise - shiny blankets and athletes

For some reason, athletes and marathon runners find themselves wrapped in shiny blankets after a race. What does the shiny blanket do? Why would the athlete need it? In this experiment, you have temperature sensors to help record the effect of wrapping someone (or a test tube) in a shiny blanket.

What you need

2 x boiling tubes, aluminium foil with an elastic band, cotton wool plug to stop heat loss, warm or hot water, two temperature sensors, 2 clamp stands to hold temperature probes.



What to do

Wrap a tube in foil and then clamp the temperature sensors so that they are in the centre of the tube. Connect them to the data logger and start recording. Fill both tubes with water at roughly skin temperature and record for 10-20 minutes.
Sketch the graphs you expect to see appear.

Results

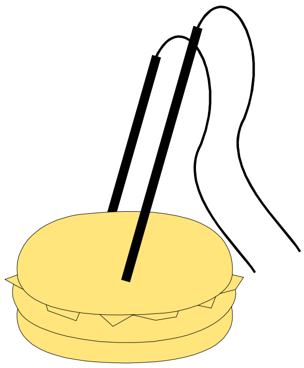
What was the temperature at the start of the experiment?
How much did the temperature change overall?
Say what happened and why the graph went up or down.
What does the shiny blanket do? Why would the athlete need it?

Freezing and melting

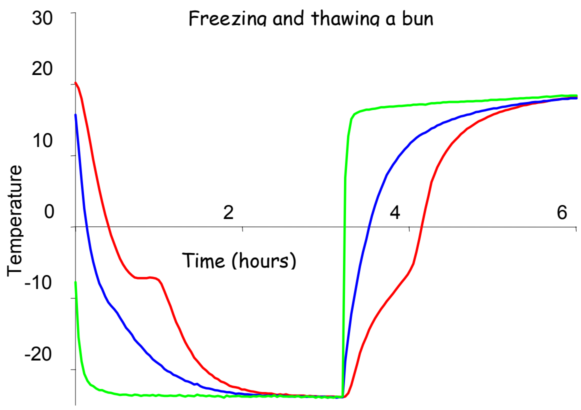
My scientist friend wanted to see what happens when things are put in the freezer. He took a bread roll and used sensors to see how the temperature changed as it froze and thawed.

What you can do

Take three temperature sensors and place one sensor deep inside a bread roll, one probe under its crust and one in the freezer itself. When the temperature is steady, remove from the freezer and allow to thaw.



Results



Graphs of temperature against time can show us how things freeze and thaw. Open the file using software that lets you take readings from a graph.

Look at the results

1. One probe was placed deep inside the roll, one probe was placed in the crust, and one was placed in the freezer itself. Look at the graph lines, and label which line is which.
2. What is the normal temperature of the freezer?
3. He had to open the freezer door, how long did the air in the freezer take to get back to normal?
4. You'll notice two kinks in the top line. What might be happening at those kinks?
5. There is water in the centre of the roll. What is its temperature and why doesn't it freeze at 0 °C?
6. Why isn't there a kink in the middle line?
7. Why might the kinks have different shapes?

Extra

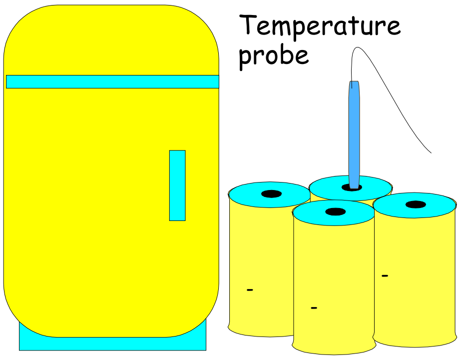
- What is the rate of temperature change for each graph during the cooling?
- What do these gradients tell you about packing freezing food for storage?
- How would those kinks be different if the freezer was more powerful and room temperature was warmer?
- How would your results look if you used fatty food?

Teachers note

This is a data handling exercise illustrating ideas about freezing, melting, latent heat and depression of freezing point. Results by Laurence Rogers, Leicester University Software Insight 2 published byLogotron. Activity developed for Schools Online Science at Sheffield Hallam University. A version of this page is available on the Internet from a link at www.rogerfrost.com

Freezing point - demonstration

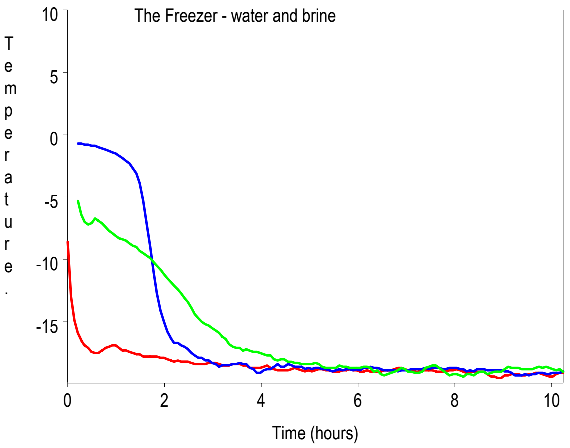
A data logger is ideal for looking at cooling liquids. It is an obvious tool for examining the idea that salts depress the freezing point of water. You can put temperature probes into ice cube trays containing plain water and salt water and see how they cool in the freezer. Set this up at the start of a lesson and discuss the results, about an hour later, near the end.



What you need

Freezer, three temperature sensors, cans or ice cube tray filled with salt water, water and fruit juice. Find a way of fixing the probes so that they sit in the centre of the liquid - for example, fix the probes through holes in a cardboard lid.

Results



A graph showing the readings from temperature probes placed in water, salt water and the freezer itself. The liquids, about 20 cm^3 of each, were placed in ice-lolly moulds in the freezer.
After a whole night in the freezer, the water had frozen solid but the salt water was still slushy. Had less liquid, and less salt been used, it's possible that the brine would have frozen. The moral is to keep a record of what you do to improve things next time. The bumpy graphs are not due to a fault or sudden changes in temperature - they are due to a mysterious thing called 'noise'. Appreciate that these temperature probes are only supposed to work down to minus 10°C , so they've worked quite well here.

Results

1. One temperature probe was placed in water, another in brine and another in the freezer itself. So which graph trace is which?
2. What is the normal, steady temperature of the freezer?
3. After closing the door of the freezer how long did the freezer take to get back to its normal temperature?
4. What does the freezing point of water appear to be? Can you explain that result?
5. What can you say about the effect of salt on the freezing point of water?
6. Why are the graphs shaped as they are?

What you might find out

- How is the freezing point of water affected by orange juice? Are fatty foods harder to freeze? For example, what is the freezing point of ice cream?

Teachers note

This is a demonstration to enrich class activities on the depression of freezing point.

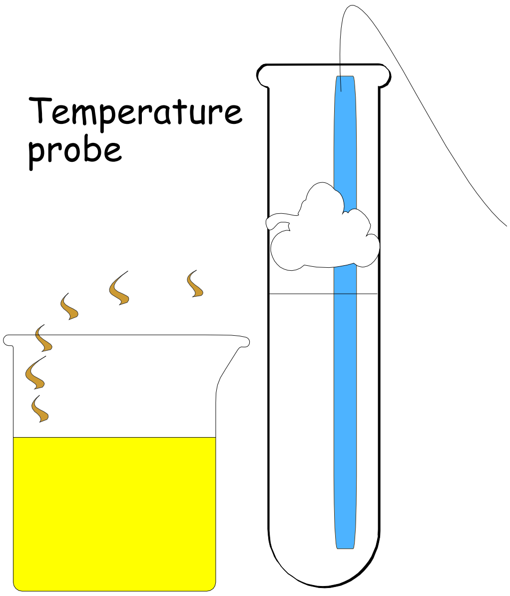
Freezing - energetics

Energy can be produced, or taken in, when substances change state. See what happens here when a liquid cools into a solid.

What you need

Test tube, temperature probe, hot tube holder, tuft of cotton wool, beaker of hot water, sodium thiosulfate pentahydrate. Safety goggles.

What to do



Half fill a test tube with sodium thiosulfate crystals and plug the top to keep out dust. Place the tube in a beaker of hot water to melt. Remove the tube and leave it to stand and cool.
Place a temperature probe in the liquid, and record the temperature as it turns solid again.

Results

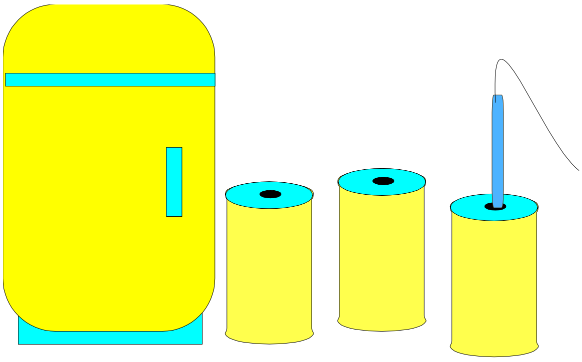
1. Does the thiosulfate cool steadily? If not, describe how it cools.
2. How does your graph show that the cooling produce heat or take it in?
3. Why does the thiosulfate keep cooling after it turns solid?

Teachers note

This is a class experiment for work on particle theory, states of matter and energy changes. Adapted from 'Classic Chemistry experiments' published by the Royal Society of Chemistry, London. See www.rsc.org.uk

Freezing - melting point of ice

Many chemicals, salt and alcohol among them, depress the freezing point of water. Using a data logger and temperature probes to take readings from a freezer offers students a chance to see something rare and real. You might demonstrate this one lesson and look at the results in the next. Set up your probes in cans or plastic containers in the freezer. Put equal amounts of liquid in each container, fix the probes centrally and leave to freeze and later thaw.



What you need

Sodium chloride, diluted ethylene glycol, blue methylated spirit, water, elastic bands to hold the wires, cardboard discs to hold the probes in the middle of the liquids,

Latent heat of the earth?

An intriguing report: the outdoor temperature was measured during a winter night. As expected the temperature dropped below freezing point and later rose. But the temperature versus time graph also showed that the temperature not only decreases, it stops falling when it hits 0°C then it continues downwards again. The same flattening occurred when the temperature rose past 0°C. The explanation was that this is the point where the environmental water freezes - and is due to the latent heat of the earth's water. The reference is long lost.

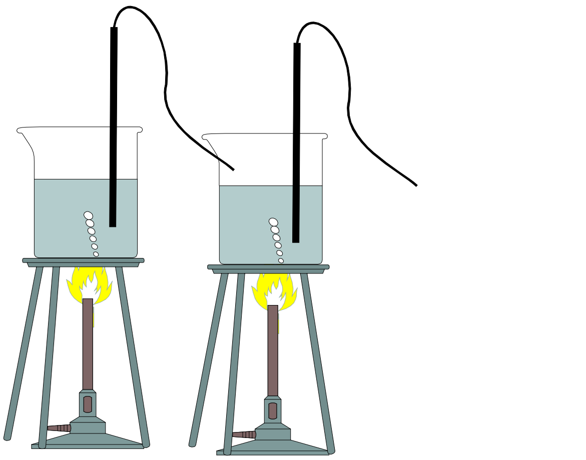
What you need

Data logger, light sensor as a time marker, temperature sensor

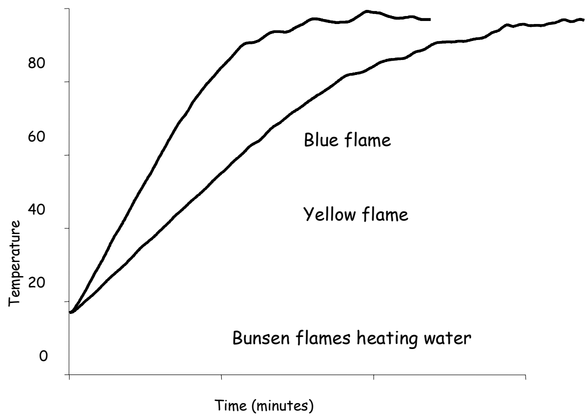
Fuels - comparing yellow and blue flames

Fuels - comparing yellow and blue flames

Traditionally, children's first lesson in the science lab has been to compare the blue and yellow flames of a Bunsen burner. But try this experiment in two other contexts, the first where you introduce measuring temperature, the second where you quantify the output of the two types of flame. In both cases you measure the temperatures of two beakers of water as they are heated. You can discuss ways to measure the rate of heating from the graph (for example, measure which flame produced the greatest temperature rise in any one minute). With older groups you can try other measures - the overall gradient, gradient of a best fit line, or even area under each graph.



Results

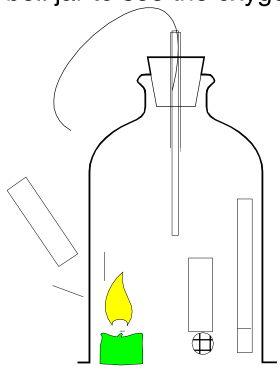


What you need

Two Bunsen burners, beakers, temperature sensors, clamps to hold probes, tripods and gauze.

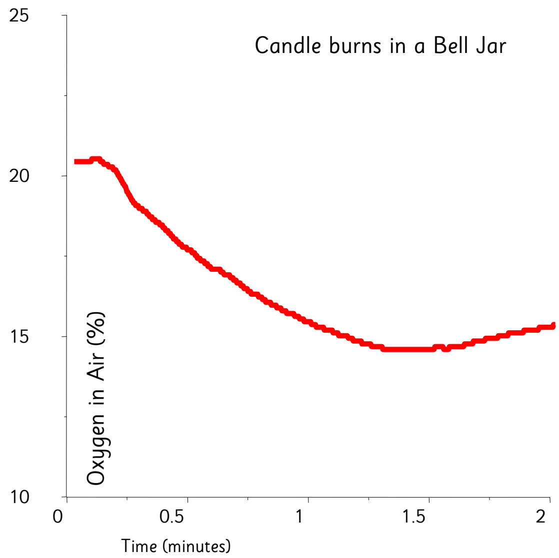
Fuels - candle burning

Burning a candle in a bell jar and seeing the oxygen level fall is a neat party piece. You need to have a well-treated oxygen probe that has had time to 'settle'. You can add other sensors – a light sensor to catch the point of extinguishing, a temperature sensor to record the energy produced and a humidity sensor to respond to the moisture produced. The extra sensors add to the difficulty but the oxygen one is key. When the readings start to level out, re-admit air into the bell jar to see the oxygen level increase.



What you need

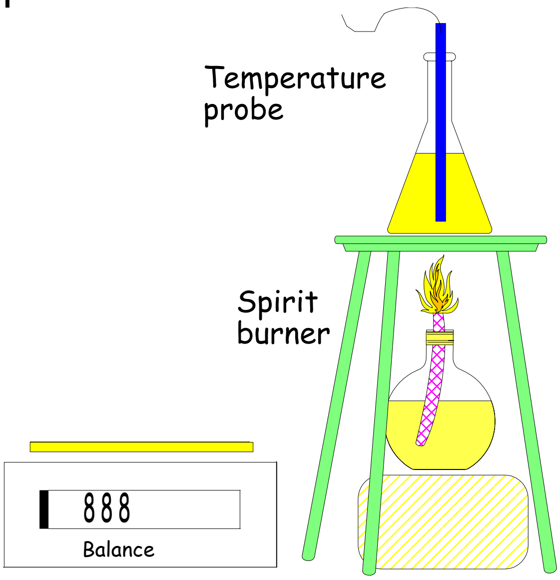
Bell jar, candle, humidity, temperature sensor, light sensor, oxygen sensor and probe



A candle burns in a bell jar as the oxygen level is monitored by a Data Harvest oxygen probe. Many thanks to Barbara Higginbotham at www.data-harvest.co.uk

Fuels - combustion of alcohol

In this activity you will measure the heat produced by an amount of burning fuel. A temperature probe will record the heat produced.



What you need

Spirit burners with methanol, ethanol, propanol, butanol, 250 cm³ flask, clamp and stand, temperature probe, 100 cm³ measuring cylinder, balance. Safety precautions.

What to do:

Weigh your spirit burner. Clamp a flask with 100 cm^3 water and a temperature probe above the burner. Start recording and light the burner. Extinguish the burner when the temperature has risen about 40°C. Weigh the burner and work out how much alcohol was used. Save your results

Results

Take readings from the graph to record the temperature change produced by the burning alcohol. You need to work out how much heat was produced per gram of fuel. Here is a calculation that allows you to compare the fuels

Temperature change produced per gram fuel = temperature rise / mass of alcohol used

Extra

Instead, you can calculate the actual heat produced per mole of fuel:

Heat produced =
Temperature rise x volume of water x specific heat capacity of water

$$\text{Number of moles of fuel used} = \frac{\text{Mass used}}{\text{Molecular mass}}$$

$$\text{Heat produced per mole of fuel} = \frac{\text{Heat produced}}{\text{Number of moles of fuel used}}$$

Teachers note

Use this in work on heats of reaction, bond energies. (Method adapted from 'Classic Chemistry experiments' published by the Royal Society of Chemistry, London. See www.rsc.org.uk)

Latent heat - cooling curves

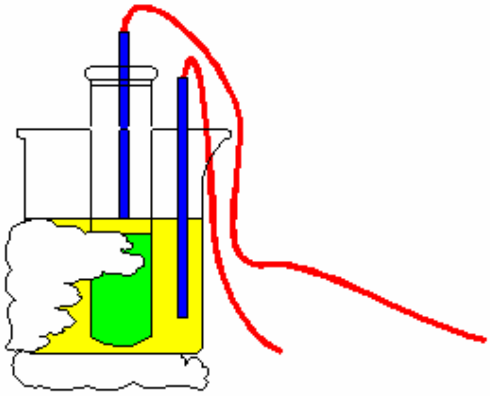
When a liquid changes state, cooling down is not so straightforward. The graph shows the temperature change as liquid stearic acid turns solid. As it sets heat energy is needed to make the solid. If that is not clear, this experiment aims to make it so.

What you need

Boiling tube with stearic acid or biphenyl, beaker insulated with cotton wool, elastic band, clamp for two temperature probes, beaker of hot water to melt the material.

What you could do

One-third fill a boiling-tube with stearic acid and put this in hot water to melt. Place temperature probes in the tube and another in an insulated beaker of water. The probes should hang in the liquids. Start recording - do not stir. Record until the two graphs meet.



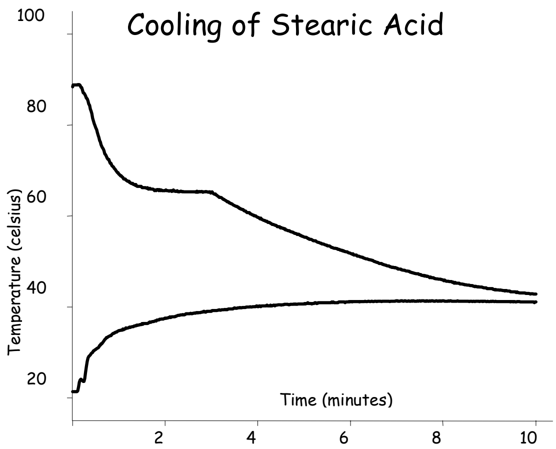
Two temperature sensors are used to measure the cooling. One is in the stearic acid, and one is in the water.

What do you think will happen to the temperature of the stearic acid during the cooling?

What do you think will happen to the temperature of the water during the experiment?

Now open the results file in your software.

Look at the results



1. How does the graph show you that the stearic acid is getting cooler?
2. Describe the unusual way in which the stearic acid cools.
3. How would the graphs look if we had taken results for another 10 minutes.
4. Stearic acid is a liquid at 90°C and solid at room temperature. At what temperature does it appear to set solid?
5. Why does the temperature continue to fall after it has set solid?
6. What happens to the temperature of the water all this time? How does the water gain its heat?
7. Why doesn't the temperature of the stearic acid change as it sets solid?
8. How do you know that stearic acid loses heat while its temperature doesn't change?
9. If you heated some ice, would it melt and produce a steady or a kinked graph?
10. If you froze some water, would it freeze and produce a steady or a kinked graph?

Teachers note

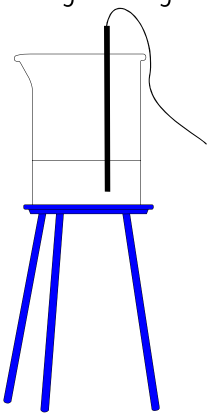
The stearic acid used here may have been impure. The water bath insulation and lack of stirring is a point of contention. Results for this data handling exercise with thanks to Laurence Rogers, Leicester University. Software Insight 2 published byLogotron. Developed for Schools Online Science at Sheffield Hallam University. A version is available via www.rogerfrost.com.

Latent heat - heating ice

You might think that when you heat ice it gets warmer bit by bit - but that is not exactly true. To see what happens we will heat some ice and use a sensor to take the temperature until it boils.

What you could do

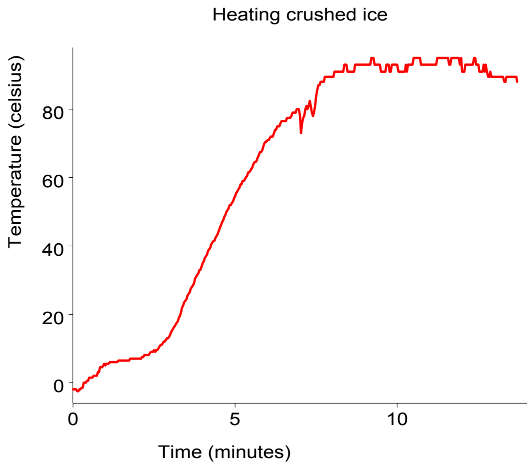
Heat a beaker of ice with a temperature sensor taking readings in its centre. Stir frequently.

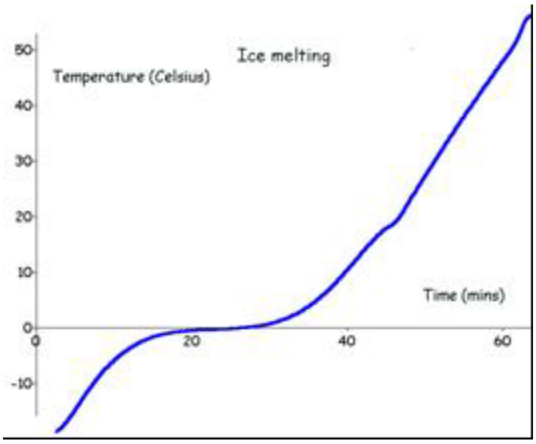


Teachers note

Use this data handling exercise (or class experiment) to look at the melting and boiling points of water and introduce latent heat. You could set up a second beaker look at the effect of salt on melting and boiling points. Similarly, with flameless heating, you could look at the behaviour of alcohol.

(Results by Martin King, formerly of Verulam School, Hertfordshire using Insight 2 Software from Logotron. Find the first results file at** www.rogerfrost.com. **The activity was developed for Schools Online Science at Sheffield Hallam University** www.shu.ac.uk. **Second results graph by Fourier Systems, Israel. This was heated slowly by an electric calorimeter. Recorded with DBLab software from Scientific and Chemical Supplies, UK).





The top graph shows what happens when we heat ice. We were not happy about the readings - the probe was resting on the bottom of the beaker. The second one is good though.

Look at the results

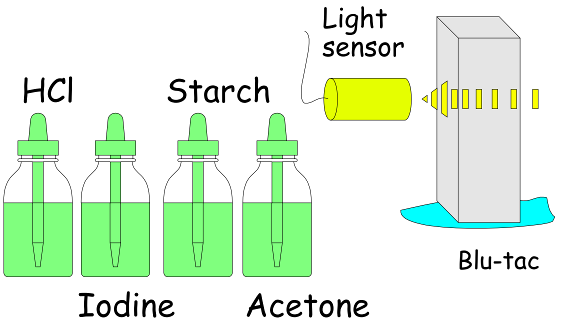
How long did we leave our water boiling for?
Why doesn't the temperature go on rising forever?
How many flat patches are there in the graph?
What is happening during these flat patches?
Why does the temperature start rising immediately after the first flat patch?
Something is wrong with our first experiment, what exactly do you think it is?
Why put the probe in the centre of the ice?

What you might do

Find out how the graph would look if salt was mixed with the ice before the experiment started.

Order of reaction

Acid catalyses the reaction between iodine and acetone. In this experiment, we double the concentration of each reactant in turn and measure the reaction rate. We should be able to find the order of the reaction with respect to each reactant. For example, if the rate doubled when the acetone concentration doubled, what would be the value of the exponent x, in this rate equation?
Rate = k[Acetone]^x [Acid]^y [Iodine]^z
(k is the rate constant)



What you need

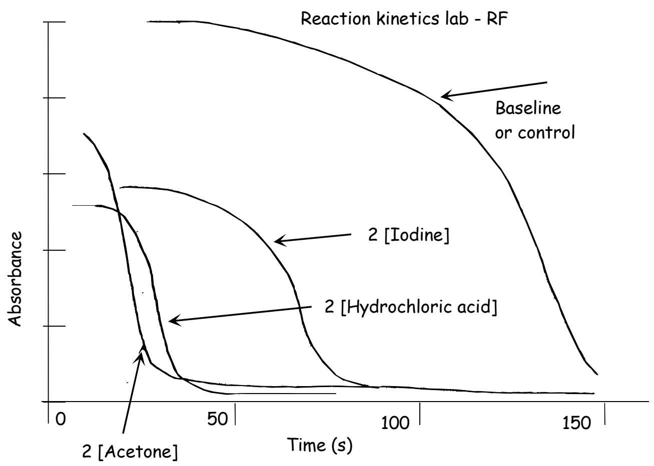
4M acetone, 1M hydrochloric acid, 0.0012 M Iodine (dissolve 0.32 g in 2 cm^3 of methanol, make up to 250 cm^3 with water), starch indicator, pipettes, cuvette, colorimeter sensor with red filter or light sensor set-up as one.

What to do:

Set out reagents in the order below. Add the drop volumes shown to a cuvette and start recording before you add the acetone. Mix well and record for about 3 minutes. When the iodine has been consumed, the starch will change from blue-black to colourless.

Drops to add	❶ Control	❷ 2x Acetone	❸ 2x Acid	❹ 2x Iodine
Water	10	-	-	-
Acid	10	10	20	10
Starch	10	10	10	10
Iodine	10	10	10	20
Acetone	10	20	10	10

Results



Find a suitable measure of the reaction rate from each of your graphs. You might use the slope, time, or x-axis intercept but whatever you choose, be prepared to come back and try another.
Pick out the reactions where everything is the same except that the iodine concentration in one is twice the other. Then plug your rate values into this to find the exponent:

$\text{Rate}_1 / \text{Rate}_2 = [\,[\text{Iodine}]_1 / [\text{Iodine}]_2\,]^z$

Repeat for the other two reactants.

Teachers note

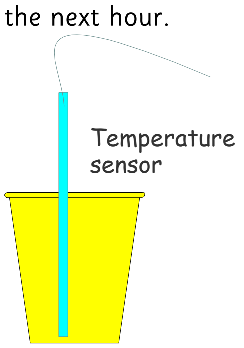
Good results are possible in this intricate experiment using the iodination of acetone as the tool to appreciate reaction kinetics. The computer offers a better chance of success because instead of relying on an end-point time, you have a graph of the whole reaction. You can use any aspect of the graph (e.g. slope, time, intercept) to quantify the reaction rate. Incidentally, you can similarly examine the kinetics of the reaction between bleach and blue food colouring. More detail on this can be found in the Texas Instruments CBL experiment booklets from which this is adapted. See 'Chemistry with CBL' manuals available through TI and Vernier Software- details at www.ti.com. The results above came from Vernier's colorimeter sensor and Graphical Analysis software. See www.vernier.com

Reactions - plaster of Paris

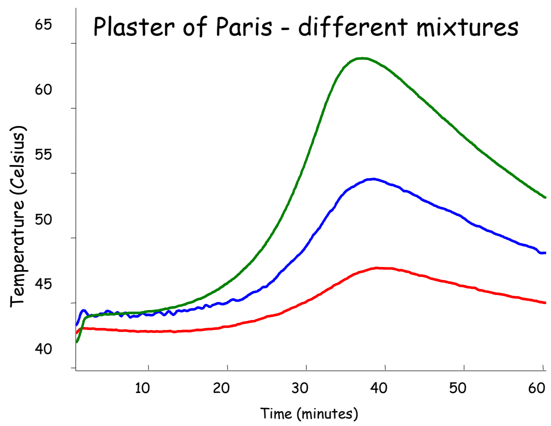
Plaster of Paris is that white powder you mix with water and pour into moulds to set. You can make models with it - hospitals make casts for broken limbs with it. When you mix them they give off heat - a sure sign that a chemical reaction is taking place. But does it matter how much water you use? Can water affect the rate of this reaction?

What you can do

Take three identical amounts of plaster of Paris and place a temperature probe in each. Cover the probes with 'cling film' to protect them. Add three different amounts of water to each, mix and record the temperature changes over the next hour.



Results



Graph shows the changing temperatures of three different water-plaster mixtures. The middle trace had the least water added. The bottom trace had the most. Open the file in your software.

Look at the results

1. Describe how the temperature in the top trace changes over time.
2. The middle trace had the least water added. The bottom trace had the most. Which do you think is the optimum (or 'best') mixture for plaster and water?
3. How does the amount of water added to the Plaster affect the temperature it reaches?
4. Would you say that the reactions get faster or slower over time?
5. Why would a reaction start off slow and speed up over time?

Extra

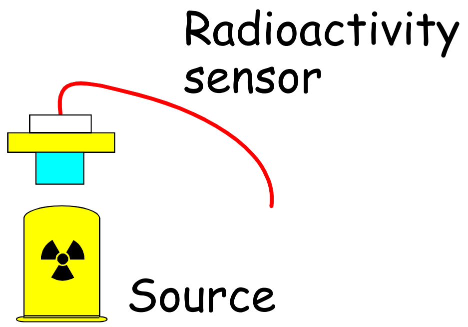
- At what times do the graphs peak? Why might this happen at different times?
- The total volume of each experiment was different. Does that spoil our results?
- Is there an optimum amount of water to use to make plaster? Try the experiment using measured amounts of water. Record the temperatures and the time the plaster took to set.

Teachers note

You might use this data handling exercise to discuss reaction rates, exothermic reaction and the stoichiometry of reactions, The reaction is auto-catalytic - heat produced helps to increase the rate of reaction. Results by Laurence Rogers, Leicester University. Questions suggested by a teacher panel in Leeds. Developed for Schools Online Science at Sheffield Hallam University - an Internet link to a similar activity is at www.rogerfrost.com

Radioactive decay – half life

Measuring radioactive decay with a data logger is one of the neater examples of how technology help us to explore science. Costs alone will dictate this is a demonstration and anyway the radioactivity sensor has just a few uses. The bigger issue is whether you can find a decaying source. There used to be a protactinium generator that contained uranyl nitrate, water and a solvent. The uranium constantly decays into protactinium. When you shake the mixture, protactinium moves into the solvent phase which you monitor over the next five or ten minutes. ***PASCO*** have an alternative decaying source - in fact without such sources the 'measuring over time' uses of a radioactivity sensor seem limited.
It is usual for the results to look noisy. You handle it by fitting a curve to the result and find the half-life from that.

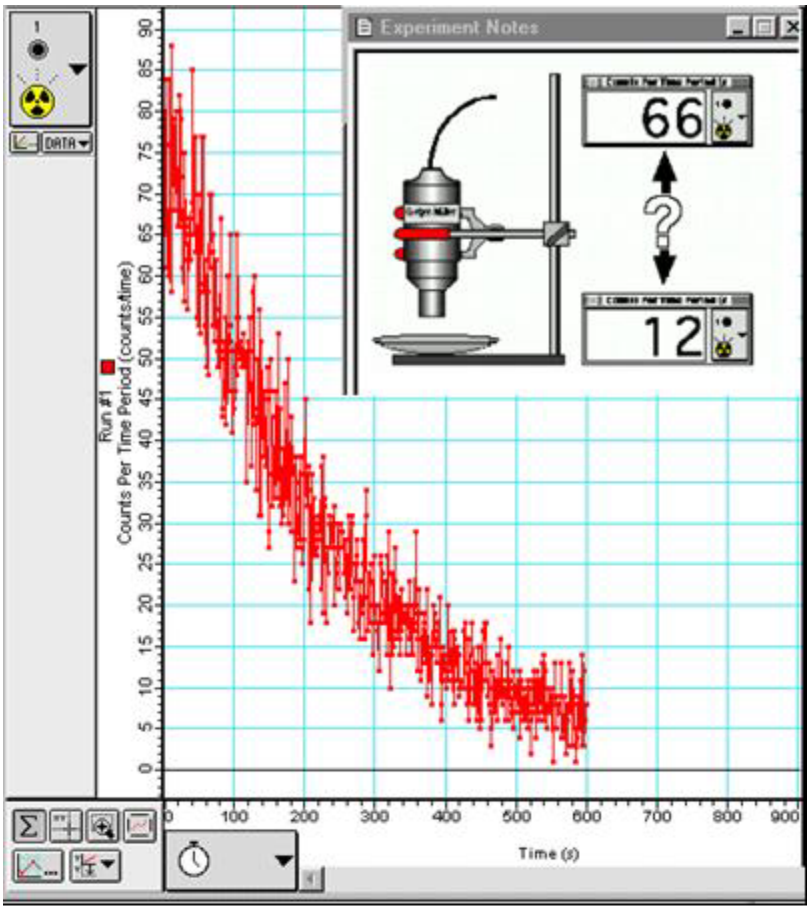


What you need

Decaying source (see text), GM tube - radioactivity sensor, clamp and stand, safety advice.

Results

Screen shot with thanks to ***PASCO's Science Workshop*** software. www.pasco.com



Rate of reaction - more methods

Rate of reaction - catalyst

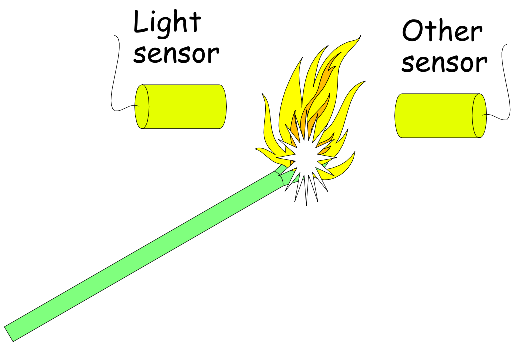
Here is a variation from the standard acid-thiosulfate reaction to use for a rate of reaction experiment. In the manual method, you mix equal volumes of sodium thiosulfate and iron (III) nitrate solution and watch a cross under a beaker disappear. In the computer method you use a light sensor to follow this change. You can add tiny amounts of different catalysts (ions of Cu, Ni, and Co) but just one drop of Fe(II) does the trick.

What you need

0.1M sodium thiosulfate solution, 0.1M iron (III) nitrate solution, 2 x 50 cm^3 measuring cylinder, beaker and a cuvette or plastic box formerly used to store pH paper, light sensor. Idea adapted from 'Classic Chemistry experiments' published by the Royal Society of Chemistry, London. See www.rsc.org.uk

Rate of reaction – lighting a match

This is a quick demonstration used as an introduction to the technology or in a rates of reactions topic. Use a light sensor to measure the light level as you strike a match. The results are worth a few minutes discussion - there's the initial reaction of the match material that is self-accelerating. This reaction subsides to lead to another reaction, the burning of wood.



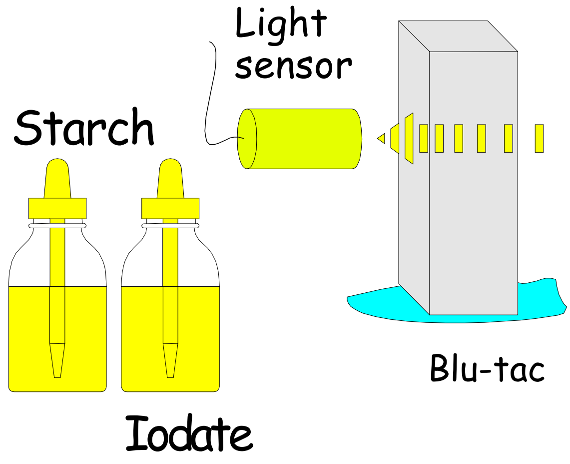
What you need

Matches, clamp and stand to hold a light sensor, plasticine or Blu-tac to hold the match.

Rate of reaction - iodate concentration

Rate of reaction - concentration

In this method, iodine is both made and used. After a while the iodine stops being used and accumulates. It then forms a blue-black colour with starch that you can monitor with a colorimeter.



What you need

Safety goggles, 2 x 250 cm³ beakers, 3 x 50 cm³ measuring cylinders, distilled water, 200 cm³ potassium iodate (4.3 g/L), 50 cm³ starch reagent (use the custard method: mix 4g starch in a little warm water then slowly add 800 cm³ boiling water. Boil for a few minutes, cool and then add 0.2 g sodium metabisulfite. Finally, add 5 cm³ 1M sulfuric acid and make up to 1000 cm³). Cuvette or a plastic box formerly used to store pH paper, light sensor. If you use a colorimeter sensor, choose a red filter and be sure to zero its reading with a cuvette of clear water.

What to do

Measure 60 cm^3 potassium iodate solution and 50 cm^3 special starch reagent.
Set up the light sensor as a colorimeter and start recording. Pour the chemicals into a beaker, mix well and tip into a cuvette.
Wait about 5 minutes for the reaction to complete
Repeat the experiment using different amounts of potassium iodate and water:

	Potassium iodate	Water
1.	60 cm^3	-
2.	50 cm^3	10 cm^3
3.	40 cm^3	20 cm^3
4.	30 cm^3	30 cm^3

Results

Use your graph to measure the reaction time.
Plot a graph of volume against reaction time.

Teachers note

For lower level work, you can omit adding water to save time.

(Method adapted from 'Classic Chemistry experiments' published by the Royal Society of Chemistry, London. See www.rsc.org.uk)

Rate of reaction - thiosulfate concentration

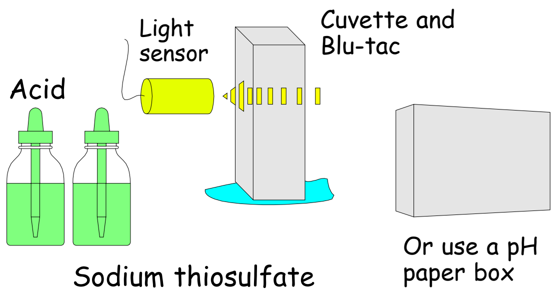
In this activity we measure how fast sodium thiosulfate and acid react when mixed in different concentrations. A light sensor will measure fast a precipitate of sulfur forms when the chemicals mix.

What you need

0.1M sodium thiosulfate, 0.1M hydrochloric acid, 2 x 50 cm^3 measuring cylinder and 5 cm^3 syringe, cuvette or a plastic box used to store pH paper, 250 cm^3 beaker, light sensor, temperature sensor, water bath at 50°C.

If you use a colorimeter sensor, choose a red filter and zero its reading with a cuvette of water. Avoid fumes from the mixed chemicals.

What to do



Connect the light sensor to the interface arranged as shown. Get the software ready to measure the light level, start recording and watch the trace on the computer screen as you cover the sensor. The trace should fall.
Measure 50 cm^3 of sodium thiosulfate into a beaker. Use a syringe to add 5 cm^3 acid to this and immediately pour some of the mixture into the cuvette. Record the falling light level for about 4 minutes as you note the change on the screen.

The experiment

You need to repeat this reaction with different mixtures, and also attend to some points:
Check that your set up will not be affected by stray light.
Decide when you will start the machine recording and be consistent about it.
Find out how to save your results between each run of the experiment.

Volume of thiosulfate	Volume of acid	Volume of water	Thio-sulfate conc.	Rate of the reaction
50 cm^3	5 cm^3	0 cm^3	E.g. '50'	
40 cm^3	5 cm^3	10 cm^3		
30 cm^3	5 cm^3	20 cm^3		
20 cm^3	5 cm^3	30 cm^3		
10 cm^3	5 cm^3	40 cm^3		

Results

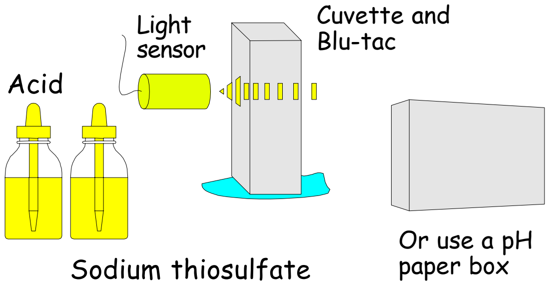
1. Use your data handling software to make a table like the one above.
2. Add the thiosulfate concentrations as explained by your teacher.
3. Find out how to measure the rate of each of the reactions and add the results to your table.
4. Plot the Rate of the reaction against the Thiosulfate concentration
5. Discuss the graph pattern in your experiment report.

Teachers note

Do a calculation or use nominal thiosulfate concentrations such as 50, 40, 30 and so on. The values will not affect the shape of the final graph.

Rate of reaction - temperature

If you were a chemical manufacturer you would be interested in finding ways to increase the rate of production.
There are ways to affect the rate of a chemical reaction. In this activity we will see how fast sodium thiosulfate and acid react when these chemicals are warmed.
These chemicals form a precipitate of sulfur - and we can use a light sensor connected to a computer to measure how fast this forms.



What you need

0.1M sodium thiosulfate, 0.1M hydrochloric acid, 2 cm^3 syringe, cuvette or a plastic box formerly used to store pH paper, felt pen to draw a fill mark on the cuvette, coffee stirrer, 50 cm^3 beaker, light sensor, thermometer or temperature sensor, water bath at 50 °C.

If you use a colorimeter sensor, choose a red filter and be sure to zero its reading with a cuvette of clear water. Avoid fumes from the mixed chemicals.

What to do

Measure the temperature of the reactants during the reaction with a temperature sensor. This helps you calculate the average temperature of the reaction mixture and record this for the experiment.
Set up the light sensor. Start recording and watch the trace on the computer screen as you cover the sensor. The trace should fall.
Pour sodium thiosulfate into a cuvette up to the fill mark. Use a syringe to add 2 cm^3 acid to this and stir the contents of the cuvette.
Record the falling light level for about 4 minutes.

The experiment

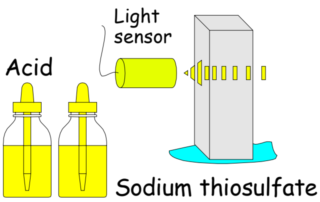
1. Repeat this reaction at four different temperatures, and also attend to some points:
2. Check that your set up gives a good response on screen and will not be affected by stray light.
3. Decide when you will start the machine recording and be consistent about it.
4. Warm up your chemicals and check their temperature as they may cool.
5. Save your results between each run of the experiment.

Handling the results

See over

Rate of reaction - temperature

In this activity you see how a higher temperature affects the rate of a reaction.
Adding hydrochloric acid to sodium thiosulfate solution turns the solution cloudy. We measure how fast this occurs by the amount of light passing through it. If the reaction works faster it will go cloudy faster. We tried the reaction at 70°C; 53°C; 43°C and 32°C.

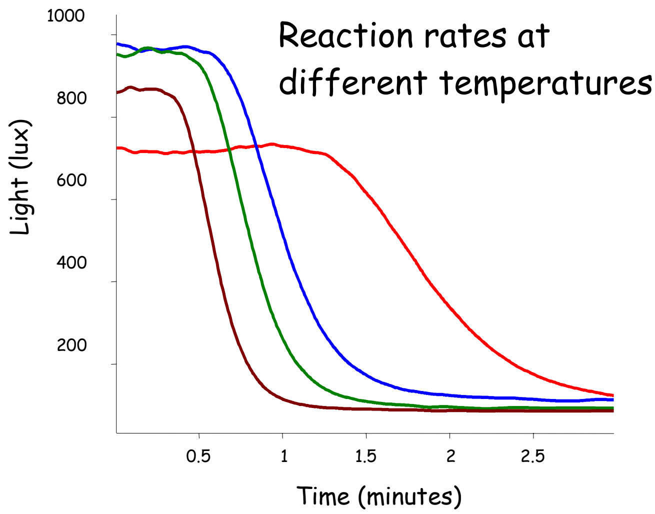


Look at the results

1. Why do the traces go *down* the screen?
2. We monitored this reaction at the four different temperatures given above. Label the graphs to show which graph line corresponds to which temperature.
3. Sketch the graph you would expect if you were to do another run at 20 °C.
4. Use the graph to find the time when each reaction stopped turning cloudy. What is the pattern between the times and the temperatures?
5. Use your spreadsheet software to plot the time readings against temperature.
6. Use this new graph to say what effect temperature has upon the time the reaction takes to stop.
7. What should a chemical manufacturer do to increase the rate of chemical production? How could this INCREASE the manufacturer's costs of production?
8. The lamp moved in one experiment. How did it affect the readings?

Teachers note

A data handling exercise - method on previous sheet. Results by Martin King, formerly of Verulam School. Results can be found at Schools Online Science at www.shu.ac.uk. Experiment from Insight 2 Teaching and Learning guide - published byLogotron



Graphs of light level against time show us how quickly a reaction occurs.

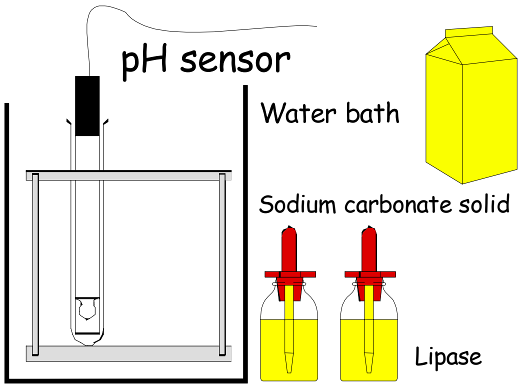
Extra

There are other ways to measure the rate of the reaction from these graphs. Here you can try and compare them:

1. Use the graph to find the time when each reaction started turning cloudy.
2. Find the steep part of the graph and measure the average rate of change for each reaction.
3. Find the steep part of the graph, fit a straight-line equation to each trace and measure the intercepts on the x-axis.
4. Find the point halfway between the starting light level and the final light level for each reaction.
5. Calculate an integral line for each trace and use this to produce a measure of each reaction rate.
6. Fit an equation to each trace and find the initial rate of each reaction.
7. Use your software to plot temperature against these different measures of the reaction rate. Compare these and discuss which ones provide 'the best' approach.
8. If your graphs appear noisy, use your software to remove the noise and leave a smooth graph line

Enzymes - lipase and emulsifier

Fats, such as the fats in milk, need to be digested by your body. They are broken down into fatty acids and glycerol by an enzyme called lipase. The body uses bile to emulsify the fat first, but how effective is this? A pH sensor can monitor the formation of fatty acids as lipase digests the fat. To make this natural process work in the laboratory, we will do the experiment at body temperature.

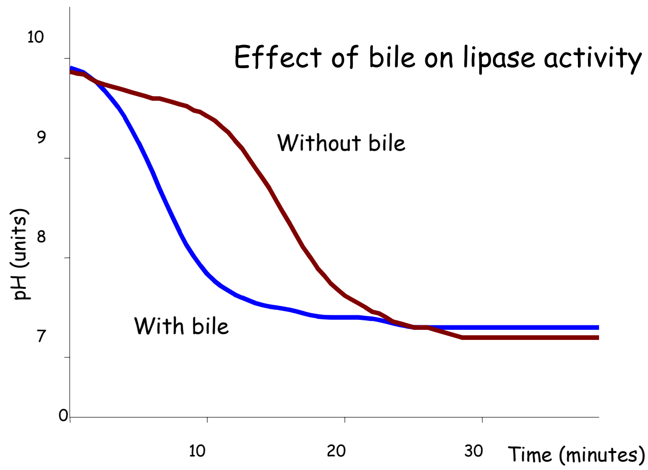


What you need

2 boiling tubes, tube rack, 2 pH probes and adapters, buffer solution to check pH probes, water bath at 30 to 40°C, fresh or UHT milk, 2% lipase in water (keeps for 24 hours in a fridge), solid sodium carbonate.
solution and green coloured detergent.

What to do

Add 5 cm^3 of milk to two boiling tubes in a water bath. Add a few drops of 'bile' to one. Check the pH with the electrode and add sodium carbonate to bring
both tubes to pH 9. This prevents it becoming acid too soon.
Start recording, add 5 cm^3 lipase solution to each tube and measure the pH for around 40 minutes.



Results

1. Predict how the graph will appear before you see your results.
2. Label the points on the graph where digestion appears to start and finish. Discuss how you could use the graph to measure the rate of the reaction.
3. How do your graphs show that one reaction is faster than the other is?
4. Why should your two graphs start and end at the same pH?

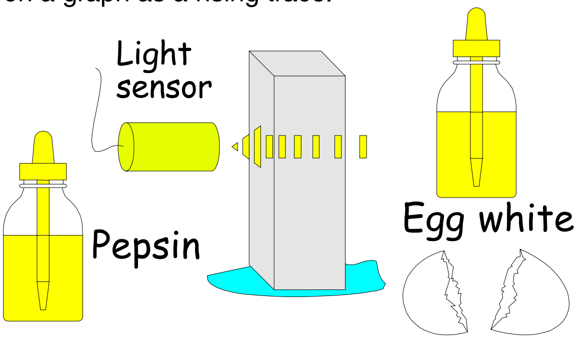
Teachers note

This demonstration may help in topics on enzymes and digestion. Set it up at the start of the lesson and look at the results at the end. Things are harder with one probe - with a long lesson you could just run through it twice. During the reaction, increasing acidity slows the reaction down so we add sodium carbonate to make the starting pH higher. Add too much sodium carbonate and it will buffer the effect of the enzyme. Keep pH electrodes wet. You can also compare the digestion of fat in homogenised and regular milk. Adapted from the 'Digestion' module of the Data Harvest publication, 'Practical Science with Microcomputers' and developed for the Wellcome Trust workshops on data logging in physiology.

Enzymes - pepsin & peroxidase activity

Enzymes - pepsin activity

The colorimeter or light sensor can trace the digestion of egg albumen by pepsin. As well as illustrating what pepsin does, this is a basic method you can experiment with to show the effects of changing enzyme concentration and temperatures. You use a light sensor or colorimeter to measure the light transmitted through a mixture. As pepsin digests protein, the mixture changes from cloudy to clear. This change will usually appear on a graph as a rising trace.

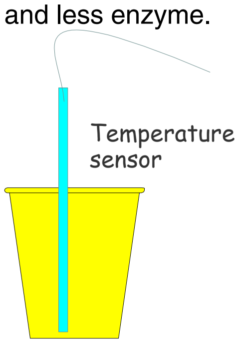


What to do

Add 1 cm^3 fresh pepsin, 5 cm^3 egg albumen to a cuvette. Connect a light sensor or colorimeter to the data logging system. Start recording. Look at the graph and label the points at which digestion appears to start and finish.

Enzymes - peroxidase activity

This is a reliable and easy demonstration of an enzyme reaction. You can use it in topics considering enzymes. Usually a temperature probe measures the heat evolved from the action. Bucket-chemistry technique works well too - for example, pour some peroxide into a flask, put a probe in the liquid and start recording. Drop a piece of catalyst, such as about 1 cm^3 of living tissue in the flask and note the change. Heat some catalyst to denature it, repeat and explain your observations. With a more refined technique, there is scope here for using this to show how different amounts of enzyme affect the rate of reaction. Either way, ask the group to sketch the graphs they would obtain by adding more and less enzyme.

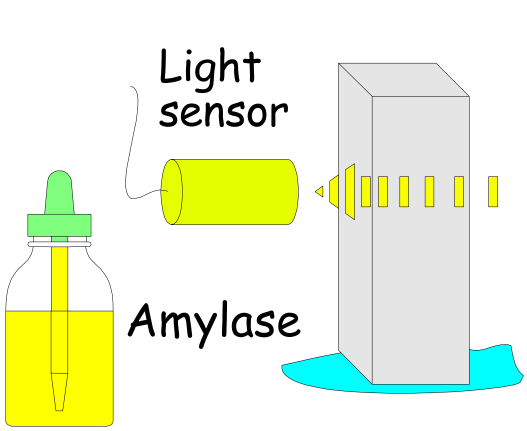


What you need

Liver (or yeast, crushed celery or potato), 20 vol. hydrogen peroxide, flask, temperature sensor. Safety goggles and gloves

Enzymes - amylase activity

Using this method, a clearer picture of an enzyme working on a substrate can be seen. A sensor measures the light transmitted through a mixture of starch, amylase and iodine solution. As the starch is digested, the mixture changes from blue-black to colourless. The sensor monitors the colour change and plots this on a graph.

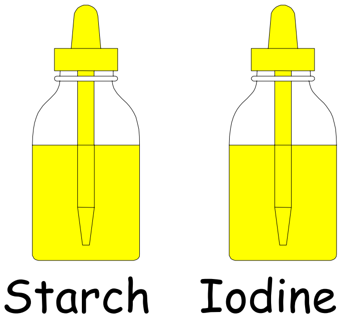


What to do

Mix 1 cm^3 fresh amylase, 5 cm^3 starch solution, and a few drops of iodine solution to a cuvette. Arrange the cuvette as shown and connect a light sensor to a data logging system. You may need to record for 15 minutes before seeing a change. Look at the graph and label the points at which starch digestion appears to start and finish. Repeat your experiment using a different temperature or starch concentration and compare your two graphs. The experiments on rates of reaction show the kind of analysis you can do with good results and an advanced group.

What you need

Today-fresh amylase, 0.1% clear starch solution, drops of iodine solution, cuvette or pH paper box, clamp and stand, 20 cm^3 measuring cylinder, 10 cm^3 measuring cylinder, light source, light sensor or colorimeter. Works better in warm conditions.



Exercise - teaching pulse and breathing

Exercise - breathing

There are devices that allow you to monitor your breathing movements. You can use a stethograph belt attached to a pressure sensor with a plastic tube. You wear the stethograph around the lower ribs and breathing movements send air puffs into the pressure sensor. Breathing movements then appear as a series of peaks - though you may just need to change and optimise the graph scale for your particular set-up. This makes for a quick and easy demonstration - perhaps to show how many breaths we take each minute. You can go on to measure your breathing after some exercise by counting the number of peaks in a minute. With luck you can sometimes note a change in the depth of the breaths but usually the belt slips slightly. Alternatively you can use a special breathing sensor which attaches round your chest as a belt. This responds to stretch which it usually then integrates into a breathing rate. This will show as a steady line on the screen as opposed to the up and down trace due to breathing movements. While in theory this is better because you no longer have to count peaks to find the breathing rate, it serves students less well in showing them a trace which is harder to learn from. On the other hand, this may suit your purposes perfectly. There are other approaches however. People have been creative and used whatever sensors they have to hand. Gas flow meters have been tried successfully. A sensitive temperature probe has been taped under the nostrils to monitor the flow of warm air. The example on the next page is the most quantitative and uses a spirometer.

Exercise - pulse

There are many electronic ways to measure your pulse. Wristwatches and school sensors do this in essentially two ways. In one, you see the pulse rate as beats per minute on a meter and a graph display. Do some exercise and the trace moves up the screen. Rest and you can measure how fast you recover and how fit you are. Done efficiently, this makes a good teacher demonstration after which others in the class can try during the lesson - though unless you run a tight schedule, it will take ages for everyone to have a go. The resulting graph could be annotated to describe what happened and what can be learned from this. Most sports science measures of fitness use a simple pulse rate before and after, whereas the software analysis tools are more powerful than you need. For instance, they can show the rate of change of pulse and much more. How this relates to fitness is a point for discussion. One idea I've seen tried but cannot recommend in print is to see how your pulse changes as you hold your breath. As I said, it's not recommended.

The other way that pulse is displayed is as a series of waves where each wave represents a beat of the heat. To arrive at the pulse rate you have to count the peaks - whereas in the previous arrangement the electronics did this counting for you. While this is not what you asked for, it does give a better feel for what a heart beat is. You may also see a notch in each wave that normally arises from the closing of the aortic valve. One practical tip: record the pulse wave over no more than 20 seconds if you want to be able to see the waves as they occur.

Pulse measuring systems work on several principles - some sense the warmth (as infrared) of the blood as it pulses through the ear or finger, some pick up electrical current through the chest. The least expensive pulse device is an ordinary sound sensor pressed close to your heart against your clothing and this is highly recommended for a tryout. Never mind how they work, the distinguishing feature is whether you can record the pulse while the subject exercises. It is very useful if you can. Also to be found are electrocardiogram (ECG or EKG) sensors which in addition to showing the heart rate, also show the PQRST features of the heart action potentials. It does seem useful to be able to show this - as one's own ECG is more interesting than any example in a textbook. If your supplier does not make this sensor, you should be able to find an inexpensive one in retail outlets. Be reassured that the equipment is a rough tool and certainly not good enough for making a diagnosis. It is simply a gadget for mixing fun and learning.

How do your lungs and heart respond to exercise?

How do your lungs and heart respond to exercise?

What you need

Exercise bicycle, heart sensor and breathing sensor - see opposite.

What to do

Exercise for a few minutes, rest for at least as long and note the changes in your pulse and breathing.

Results

1. Look at the graph of breathing over time. Label the graph to say what happened.
2. How many breaths were taken each minute?
3. Look at the graph of pulse rate over time. Label the graph to say what happened.
4. Measure the graph to see how long it took for the pulse to drop to their lowest point.
5. Why does the pulse change?
6. Compare the graphs from two people: measure their pulse average or area to find whose graph has kept the lowest overall.
7. Look at the pulse wave: what is the graph showing?
8. You may see a 'notch' on the peaks, what do you think this is?

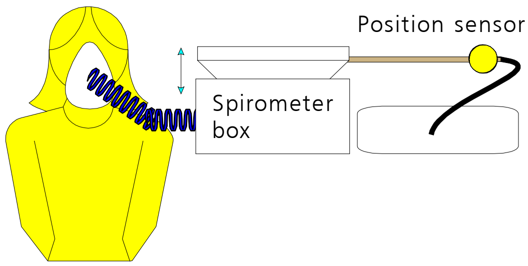
Teachers note

Using sensors provides a graphic picture of heart rates and breathing movements. It is both enjoyable and memorable. This is a jump start to an activity for topics in physiology and sports science. It may be part of a circus of activities. See previous page for more about pulse and breathing.

Using a spirometer

What you need

Position, angle, or potentiometer sensor, spirometer box, tubing and disinfectant.



What to do

Find a 'calibrate' feature in your software to match box volume to the sensor reading.
To prevent the breathing peaks bunching up record for 20 seconds at a time. Change the y-axis scale too if it improves the appearance.

Results

Label the graph and use it to work out your breathing rate at rest and after exercise.
The graph shows volume on the y-axis. What is your normal tidal volume? Does this change when you exercise?
The area under your graph is a measure of how much air you breathe. How much more air do you take in when you exercise?

Teachers note

The position sensor replaces the kymograph / smoked drum with an on-screen display. You can measure tidal volumes, maximum expiratory volume and total volume per minute. (For further information, see a related activity in the Insight 2 software Teaching and Learning guide published by Logotron.)

Exercise - skin temperature

How does your body temperature change as you exercise? What causes this change and do some parts of the body get warmer than others do? Tape temperature probes to body places such as the ear, chest, leg foot and forehead. Predict how you expect the temperature to change. Exercise for a few minutes, rest for at least as long and see how the skin temperature rises and falls.

Wire up a human volunteer with temperature probes - one under the tongue and one between the thumb and forefinger. Use a third probe to monitor the air temperature. Allow some minutes for the temperatures to equilibrate, and then subject the person to a 'cold challenge' for ten or more minutes. Following this, continue to monitor the three temperatures for a further 100 minutes. Take note of changes in the skin.

A sausage with a probe inside makes for an unusual control. The sausage represents flesh without a circulation. Afterwards subtract the sausage readings from the human skin readings and you may see the warming action of the circulation.

After exposure to cold, the skin turns pale, 'goose bumps' appear and the subject starts to shiver. The skin temperature falls steadily during the exposure, the mouth temperature falls too - though only slightly. After the cold stress, the skin temperature starts to rise. The skin still appears pale - hinting that the peripheral circulation is still lowered. The mouth temperature soon returns to normal. Over the next 100 minutes of recovery, the fingers regain their colour and become warmer than room temperature. At the same time, the mouth temperature also rises slightly.

The cold challenge causes a rapid shut down of the peripheral circulation to help maintain the body's core temperature. This is maintained for at least as long as the core temperature takes to return to normal. At this point, the blood flow to the skin returns. (All credit for the method and temperature regulation results to former student teacher Bob Tateson, Stronsay School. Reported by Paul R Mills of Northern College in their Biology Newsletter No.61. The college is on the Internet at www.norcol.ac.uk)

What you need

Three small (i.e. responsive) temperature probes, two hours, a data logger with good batteries and a willing subject.

Who can make their hands the warmest

If it's true that starting data logging has got to be easy, then this demo or class activity is the first thing you do. It requires no chemicals or science equipment so has every chance of working anywhere, including an IT room. Furthermore, it works with any age group because you can analyse the data at a variety of levels. You can run through the exercise once as a demonstration, and then if you have equipment, let the class do it. The aim of the activity could be to introduce ideas about homeostasis, friction, measuring temperature, the temperature scale, interpreting graphs or data analysis.

Who can make their hands the warmest?

What you need

Two temperature probes.

What to do

Explain that you want to find out who can use their hands to put the most energy into a temperature probe. Explain further that we do not wish to know who can destroy a valuable sensor and point out the weak points of the probe (e.g. it can bend, the tip can break, its cable can break internally and does not like the heat from a flame). Set up the screen with a time graph, a bar gauge and / or a digital meter display. Ask the group what they expect the graph from this 'race' to look like.
Select a couple of pupils, start recording the 'race' over the next minute or so. Ask them how they will know who is the winner? Afterwards, talk through the graph looking for ideas on what happened

Results

1. Label the graph to say which trace is which, what happened when and why it happened
2. Was it a fair race i.e. did both traces start at the same point?
3. If not, use the software to show which person achieved the largest temperature change
4. If yes, try any of the following
   Calculate who achieved the largest rise in any period of 15 seconds.
   Calculate who achieved the highest average temperature.
   Or show who achieved the fastest rise (e.g. rate of change) in temperature.
   Or calculate the area under the graph to show which trace stayed the highest overall.

Do some of us get hotter than others when we exercise?

What to do

Use a remote data logger and measure the hand temperatures of two pupils as they do a brisk walk up and down the stairs. For a better comparison, they should use the same data logger and thus keep together when they exercise. Continue recording a while as the pupils recover. Upload the results to the computer and set about using the language of graphs to compare them

Results

1. Whose temperature stayed highest overall?
2. Whose temperature rose fastest?
3. What measures of the graph help you show this?
4. What in the graph tells you that your body tries to keep your temperature steady?
5. Why would we cover an athlete with a blanket after a race?

Hands and friction - thanks to Brett Laniosh and S Gilbert of Dudley LEA, UK in Measurement & Data logging at Key Stage 3 & 4 - A practical guide.

Temperature regulation

How hot do we get by exercising with extra clothing?

What to do

1. Sketch the graph you would obtain if you walked the stairs wearing your coat or sweater.
2. Wear a coat, walk the stairs and measure your temperature as in the previous exercise
3. Explain any difference between your prediction and your results.
4. Measure any difference between your exercises with and without extra clothing.
5. Does your body manage to keep your temperature steady?

Hands and friction - thanks to Brett Laniosh and S Gilbert of Dudley LEA, UK in Measurement & Data logging at Key Stage 3 & 4 - A practical guide.

How does your hand respond to hot and cold?

What you need

Hand hot water, ice water, two temperature probes.

What to do

Hold a temperature probe and place your hand in fairly hot water. Start recording. Hang a second probe in the water. Remove your hand and both probes but continue to hold the first probe. Continue recording until your hand temperature returns to normal.

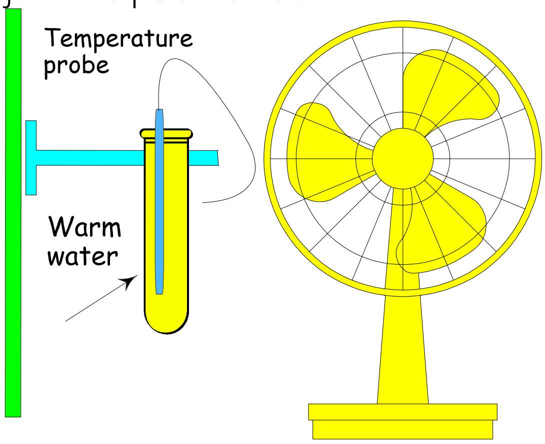
Results

1. How does the graph describe your hand's response to heat?
2. The second probe is our control. What do we learn from it?
3. Try this: subtract the readings of the second probe from the first. This will subtract the temperature of the water and show how your skin responds. Does this tell us anything new?
4. Repeat using cold water.

Homeostasis - perspiration

Introduction

When you are hot, you perspire. You produce a liquid on your skin and this helps you to cool. You cool because whenever liquids evaporate or dry up, they take heat from around them.
You can see this happening in this experiment. You will make a layer of water (perspiration) on a flask and see if the temperature drops. The temperature change is very small, so you will use temperature sensors to see the change. Many people use a desk fan in the warmer weather. Some say it helps because it blows cold air. Some say that the fan makes your skin feel cold because it dries up your sweat'. You can use your temperature probes to test a fan and explore this idea.



What you need

Test tube or flask with water at skin temperature, cotton wool to swab it, desk fan, temperature sensors.

What to do

Connect the temperature sensor to the data logger and the computer.
Set up the apparatus and fill the tube with water at skin temperature.
Start the data logger recording, start the fan and see if it cools the container.
Swab the outside of one of the tubes with water and record the temperature for a few minutes.

Questions

1. Label your graph to show the points where the fan was switched on, and where the flask was swabbed with water.
2. How did the liquid affect the temperature of the probe during the experiment?
3. How much did the temperature drop when the flask was wet.
4. How does this make you cool?

Explain these observations:

5. On a hot day, dogs salivate and pant vigorously.
6. On a windy day, getting out of the swimming pool is a chilly business.
7. After-shave and perfume feel cool on your skin.
8. If you are hot, people say not to wipe the sweat from your head.
9. Athletes pour water over their heads.
10. And a tricky one: athletes drink salty, hypotonic drinks.

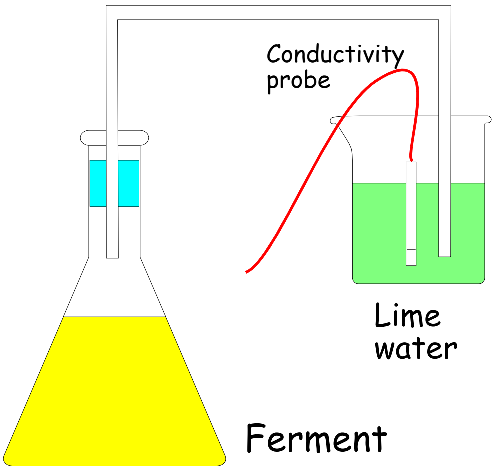
Teachers note

This 'class experiment' uses a more convincing method than usual. Add some 'colour' with one of the evaporation ideas at page 94. With thanks to Liz Singleton, science adviser, Leeds LEA

Fermentation - methods

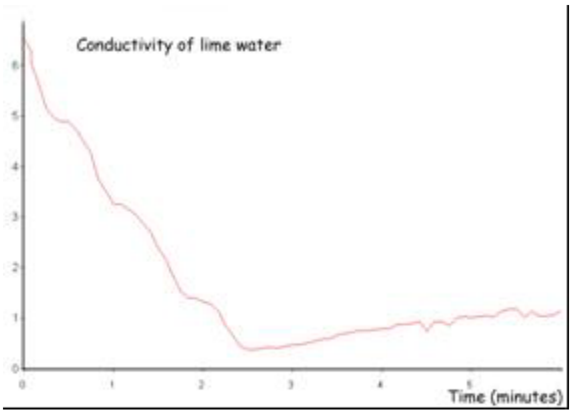
Fermentation - methods

Fermentation produces carbon dioxide that bubbles into lime water. A conductivity sensor monitors the lime water.



What to do

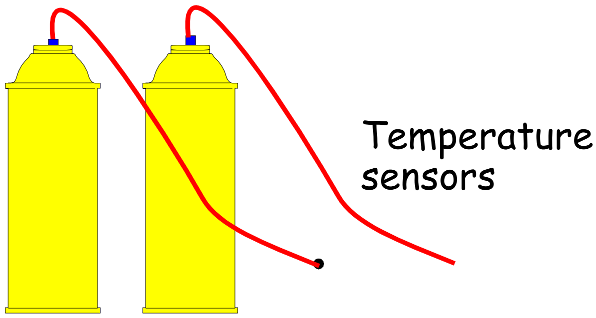
Mix a sachet of dried yeast, 10g sugar and 100 cm^3 warm water in a flask, run a delivery tube into 150 cm^3 lime water. Fix a conductivity probe in the lime water. Let the flasks sit in a water bath to maintain their temperature. Record for an hour as the conductivity of the lime water decreases. Note: there may be a time lag before any change due to the dead space of air in the system.



Reference: Magnet - the Magnificent Network, Australia. Visit the science areas of Magnet and Magpie on the web at Monash University. Results by John Gipps using Tain equipment and software www.tain.com.au

Fermentation - grass cuttings

Recording the temperature of grass cuttings or moist leaves with a probe is many times better than any manual method. As the related data handling exercise on the next page shows, the graph where temperature is displayed over time gives a good picture of what has been happening. You can of course do this activity in vitro too - placing grass cuttings in a vacuum flask and leaving the machine to take readings. Microbial activity in a pile of grass can generate a considerable amount of heat. You can explore how long this lasts for and when it reaches its peak. Get a data logger and place two or three temperature sensors into a heap of composting material. One can be placed deep inside and one can monitor the environmental temperature. If you run this for several days, also record the light level or the ambient temperature level. The light sensor makes a useful indicator of when it's day or night. The ambient temperature is the control.



What you need

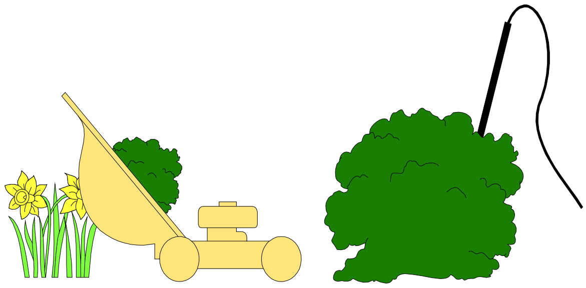
One or two vacuum flasks, two handfuls of grass cuttings - one sterilised, two temperature probes, light sensor.

Fermentation - is cut grass dead?

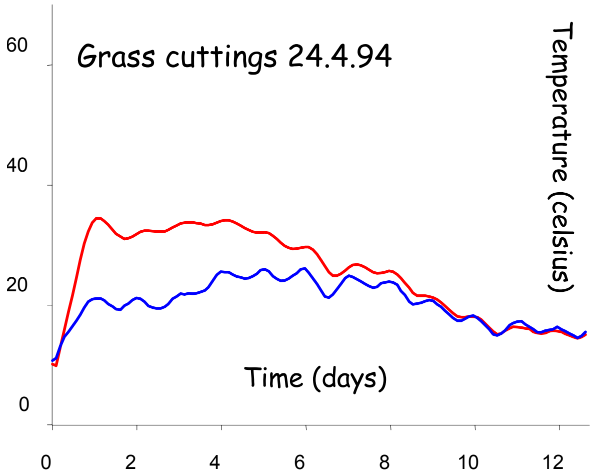
When you cut the grass you remove its source of vital materials. The cut leaf 'dies'. But leave a pile of grass in the garden and it seems to be warm and alive. What's happening? Indeed, when does it die?

What you can do

My colleague, Laurence Rogers cut his lawn and put the cuttings in a heap. He placed two temperature sensors in the pile of grass - one was deep in the middle, the other rested near the surface. Finally, he left the computer to record how the temperature changed.



The results



The graph shows the changing temperature of a pile of cut grass. Open the results file in your software and try the following questions

Look at the results

1. One grass trace came from the probe deep in the middle, the other came from near the surface. Which trace do you think is which?
2. What is the highest temperature recorded by each probe?
3. Why is one temperature more than the other?
4. Why are the temperatures gently fluctuating? Measure the time interval between the small peaks on the traces for a clue.
5. Why do the temperatures finally drop to the same level?

Extra

- We forgot to do a control experiment! What could we have done?
- The surface temperature is the control experiment. Use your software to subtract its readings from the middle temperature. You should have a new trace.
- Use the new trace to say when life in the pile of grass finally ceased.

What you can do

Would a pile of rotting vegetables behave in this way? See if your pile shows a similar temperature peak and fall. Don't forget to do a control experiment this time.
Use your sensors to find how hot a pile of grass can get. (Care - fire risk!)

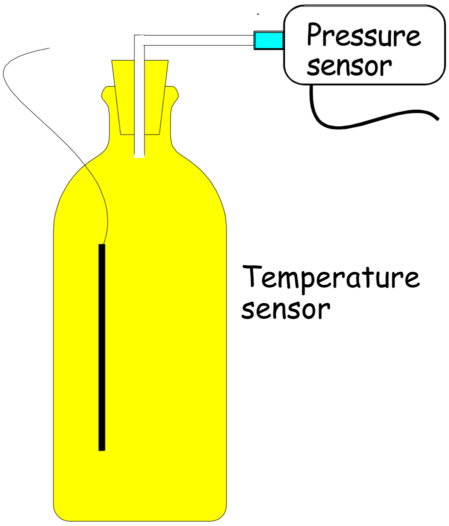
Teachers note:

This is a data handling exercise. Results with thanks to Laurence Rogers. Uses Insight 2 Software published byLogotron. Activity developed for Schools Online Science at Sheffield Hallam University www.shu.ac.uk. Find a version of this activity on the Internet - the link is at www.rogerfrost.com

Fermentation - more methods

Fermentation - different sugars

This is a demonstration to set up and leave. Yeast will ferment sugars and produce carbon dioxide gas. It will set to work on one sugar before another. It's partly to do with the cell permeases and why a brewer might add invert sugar to a ferment to speed things along. You can test one or two sugars using a technique where you mix yeast, water and sugar and record the pressure change over a few days.



What you need

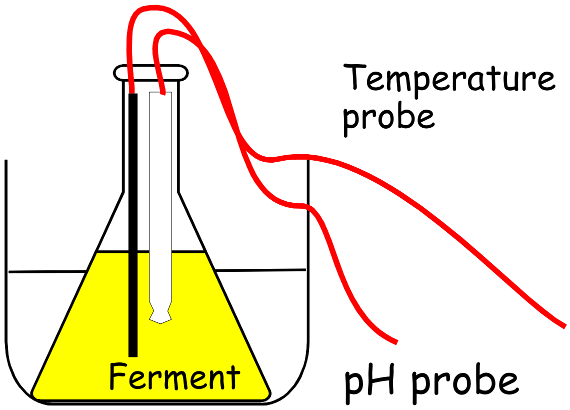
Pressure sensors, temperature sensor, 2 bottles with a screw cap and delivery tube (e.g. glue a syringe barrel to the drilled bottle cap), yeast, balance, choice of sugars such as glucose, sucrose, invert sugar, lactose - about 5% in water.

What to do

Mix a sachet of dried yeast, 10g sugar and 100 cm^3 warm water in a bottle, connect a pressure sensor using plastic tubing. Let the bottle sit in a bowl of water to maintain its temperature. Expect to see a lag period in which the yeast gears up its enzyme systems. To take this further, add a temperature sensor to the set-up and repeat at different temperatures. The yeast may produce a foam and need a trap to stop it coming over into the sensor. Take care: the sensors have a maximum pressure limit so fix the tubing loosely. (***Method by Rod Taylor, from Data logging a basic guide for teachers by DCP Microdevelopments and The City Technology College, Kingshurst, UK. Also a CDROM, The Science of Brewing looks at this industry in depth and lists many brewing related projects and experiments. Published by B3 Media, PO Box 1017, Cooks Lane, Kingshurst, Birmingham, B37 6NZ, UK. Tel 0121 770 8923, Fax 0121 770 0879. http://www.kingshurst.ac.uk/b3media***

Fermentation - general

Fermentation features in the making of milk products as well as baking, brewing and composting. Despite the universality of the term, it brings additional relevance to topics about enzymes, catalysts and chemical reactions. You can apply the basic technique to many such reactions.
The temperature, pH or oxygen level of a ferment change over time and sensors provide a graphical picture of this. Discuss the results and use them as a homework exercise. If it works well you have a result to use for all time.

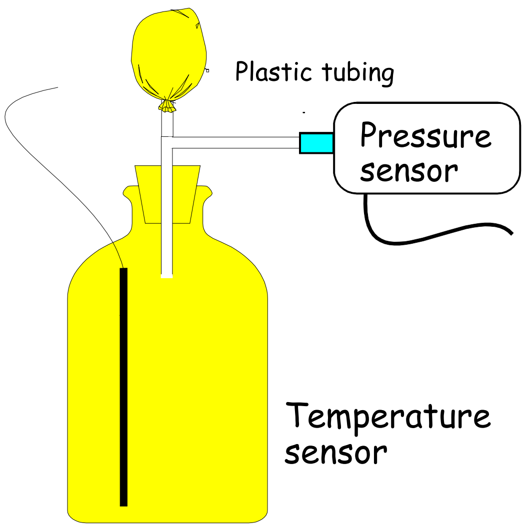


What you need

Ferments such as souring milk, yoghurt mixed with milk, yeast and sugar, beer or wine kits. Also a flask, cotton wool plug, water bath and a safe place where this can be left undisturbed. Use a selection of temperature, pH or oxygen sensors. Try to suspend the probe in the ferment as this prevents damage to the tip. Agitate the liquid to improve the response of the oxygen probe. Note that in some systems you can't use pH and oxygen probes together - they interfere with each other.

Fermentation - effect of temperature

You can show how temperature affects a biological system, such as growing yeast. The following set-up works fast enough at warm temperatures. You need a pressure sensor to monitor the production of carbon dioxide at a series of temperatures. At room or cool temperatures it takes 45 minutes per run, so the full experiment best suits a project.



What to do

Pour 100 cm^3 glucose solution into the flask and warm to 35°C. Mix in the yeast, fix a pressure probe to the delivery tube and record for 40 minutes. Repeat at other temperatures, e.g. a selection of 35°, 40°, 45°, 50°, 55°C. The balloon valve help prevent damage to the sensor.

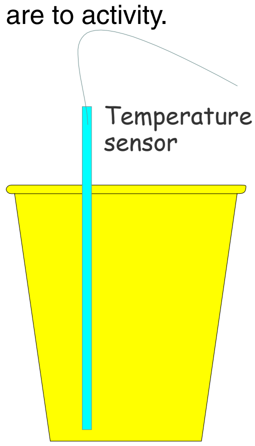
What you need

As shown, or alternatively a side-arm flask with a delivery tube and temperature sensor in a bung, balloon as a pressure valve, pressure sensor, 600 cm^3 10% glucose solution, 6 x yeast sachets, water bath.

(Method by Peter Adams - more at Tain Electronics www.tain.com.au.)

Fermentation - temperature change

It would save lots of time if we could get bread dough to rise faster. Maybe adding extra sugar would help the yeast to work faster? Maybe as some claim, adding vitamin C improves things further? In this method you simply use temperature as a measure of yeast activity. Make dough using fresh yeast, warm water and flour and split it into three parts. Add sugar to two parts and then add ascorbic acid to one of these. Place a temperature probe within each lump. Record the temperature for a couple of hours. Look at the graphs for a measure of the activity of yeast over time. An extra temperature probe will allow you to monitor the surrounding temperature at the same time. Afterwards, subtract the room temperature from the three dough mixtures. Find out how important sugar and vitamin C are to activity.



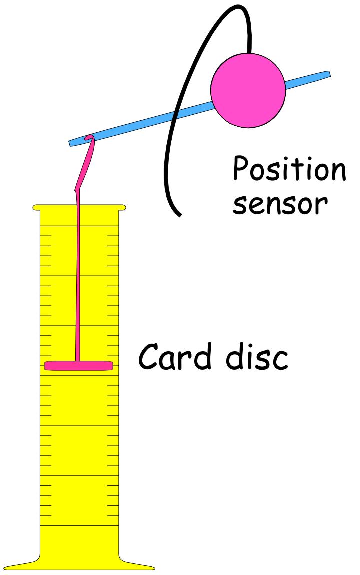
What you need

Temperature sensors, insulated beakers, flour, water, yeast, sugar, and ascorbic acid.

Fermentation - rise of bread dough

Fermentation - rise of bread dough

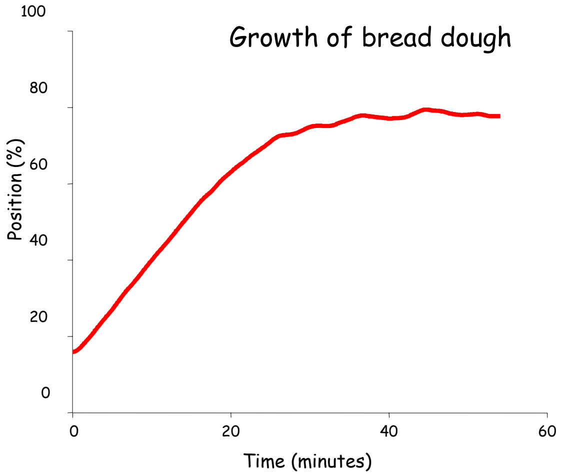
The rise of bread dough is an example of how an enzyme system gets up to speed. Typically there are three phases to graphs showing fermentation and these are worth discussion. You can talk about the period before things start working and suggest reasons for the exponential activity and the slow down. You can demonstrate and complete this in a double session. That aside, the method offers scope for a project to find the optimal conditions for bread making - how, for examples would adding sugars or shifting the pH give the dough a boost.



What you need

As shown or a slack syringe with cap to seal, position or angle sensor with a lever arm, clamps, bread mix (e.g. fill a 250 cm³ beaker to the 50 cm³ mark with flour, use a tongue depressor to stir in water and knead, add a spoonful each of sugar and yeast and knead further).

Results



(Results by Laurence Rogers, Leicester University. Developed for Schools Online Science at Sheffield Hallam University - find this on the Internet. Software used was Insight 2 published by Logotron)

What to do

Place a yeast dough mix in a syringe, hold it in a clamp and seal the Luer end fitting. Use the same clamp stand to rest the lever arm of a position sensor.

Field study notes

Field study - general

You can measure the air humidity, light level, soil and air temperature and find a cyclical pattern over a few days. Neat as this is, it does need to be related to something biological. Doing the same measurements in two distinct habitats might yield some useful explanations for the plant life in each. You could also measure the soil temperatures at different depths.

More likely, field study work will involve taking measurements not so much over time but in different places. For this you need a device with a display to tell you say, the light, temperature and air humidity in each place. You could walk a line from sheltered woodland to open grassland and take readings at regular distances. But even though the technology can take readings for you, there remains an issue about getting back to base with a set of readings matched to where they were taken. One suggestion, bizarre as it seems, is to add the readings to a table on your clipboard, or to the spreadsheet on a palmtop computer.

Field study - microclimate

The local church (well a cathedral in fact) wanted to be allowed to display some precious icons in their crypt. However, the church authorities were concerned that the conditions in the crypt might not be suitable. The nearby school got to hear and offered their services to monitor the crypt temperature, humidity and light level. If I recall rightly, there was a happy ending and the cathedral was given the go ahead to store the icons. The results taken over a few weeks, were intriguing - for example there was a superb inverse relationship of temperature to humidity. In other words, as the temperature rises, the humidity falls. The light sensor, as in most such work, serves as the handy marker of day and night. (Thanks to John Quill and Wells School, UK)

At a field study centre they showed a similar pattern between temperature and humidity in the microclimate of a plantation. They compared the climate in this woodland habitat with that in an open grassland setting. They plotted the temperature against the humidity level, and used a correlation coefficient to assert its significance. ***(Thanks to Nigel Dykes, Cranedale Centre, Yorkshire. Reported in Northern College Biology Newsletter No.61. The college is on the Internet at www.norcol.ac.uk)***

What you need

Data logger, light sensor, temperature sensors, sound sensor, humidity sensor.

Photosynthesis - field study

Taking your data logger to the pond and measuring a number of parameters over a few days is a fairly manageable field study activity. It tends to show a daily cyclical pattern that is worthy of a discussion. For example, you should see almost matching peaks in the pH, oxygen and light levels. The extent to which they do not is another issue for discussion - here you can draw out the facts that light levels influence oxygen production. A data handling activity for this follows.

Equally you can discuss why the pH level increases - recall that carbon dioxide is used by photosynthesis. Beyond doing this, I have heard little.

(Thanks again to Nigel Dykes - details above).

What you need

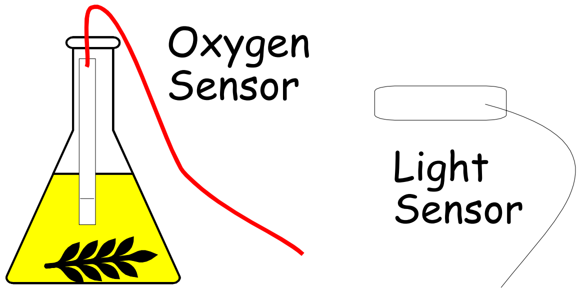
Data logger with good batteries, a few days, plastic carrier bag as protection, sensors and probes for pH, temperature, humidity, oxygen and light levels. Note that the pH and oxygen probes need to be kept physically apart as they influence each other when connected to the same data logger.

Photosynthesis - experiment notes

Photosynthesis - in vitro

Monitoring photosynthesis is a key need in teaching biology. It is especially interesting to see the pattern between light levels and oxygen levels in an aquarium. It is worth demonstrating its setting up, and worth having some model data in reserve just in case. On a following page you will find a data handling exercise to use. Here are some notes on setting up the experiments.

Oxygen measurement



Set up a flask with Elodea pond weed and add a pinch of sodium hydrogen carbonate for good luck. Clamp a light sensor nearby. Add the oxygen probe and leave it till it produces a steady response. If this doesn't ever happen, check the probe membrane for physical damage, or change it anyway. Run the experiment for a few nights and days – this will allow you to discuss both the light and the dark reactions of photosynthesis. Stirring the flask is supposed to helps steady the response of the electrode but as it allows the oxygen to equilibrate with the air we usually leave it unstirred.
Alternatively you can use an aquarium.
Ask the pupils to think about how the light level will change during the experiment. Ask to sketch a graph that shows this. Next, get them to a sketch a graph of how the oxygen level will change. Compare the predictions with the results. See page 132 for a worked example.

What you need

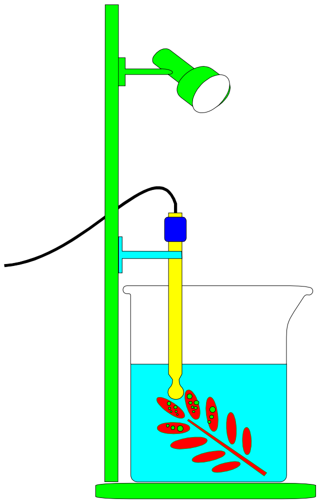
Flask with Elodea, sodium hydrogen carbonate, light sensor, oxygen sensor and electrode.

Photosynthesis - 'carbon dioxide' measurement

Carbon dioxide measurement

Carbon dioxide uptake can be also monitored using a pH electrode. A data logger can collect the readings automatically over a few days. Carbon dioxide sensors do exist, but tend to be expensive. Place a pH electrode in a flask with sodium hydrogen carbonate solution and fresh Elodea. Clamp the electrode close to the plant where it will monitor small changes in pH due to the use of CO_2 by the plant. Place a light sensor nearby and connect the sensors to a data logging system. Leave for a day or so to obtain a graph like the one below. This graph shows how the pH around a plant changes over a day. Note how small but evidently significant the pH change actually is. I would not balk at or try to smooth the noise in the graph - it adds a very real imprint. (Results with thanks to Dr Gary Skinner, Bedales School, UK)

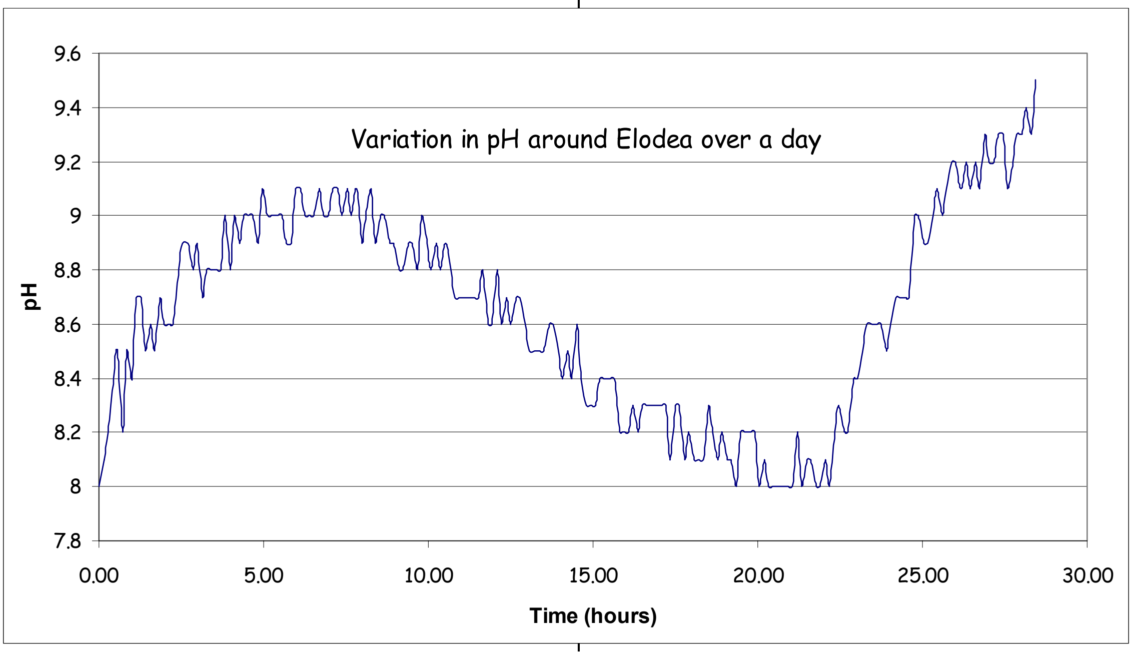
A variation on this - to show the effect of light level in the space of a lesson - replaces natural light with a strong light source. This causes a temperature change of a few degrees and not only affects the plant's activity but also the response of the probe. To avert this, place the flask in a water bath to dissipate the heat from the source or place a glass tank between the light and the flask.



You can now investigate the effect of light level on carbon dioxide uptake. Cover the flask with foil until you are ready to begin. Start recording and continue for about thirty minutes. For the first ten minutes cover the flask with foil, for the next ten remove the foil and for the final ten switch on a second bright light source.

On many logging systems you can't reliably use a pH probe and an oxygen probe in the same liquid.

A related experiment can be found at ***Enhancing Science with IT Classroom activities*** available at the UK Virtual Teacher's Centre on the Internet.



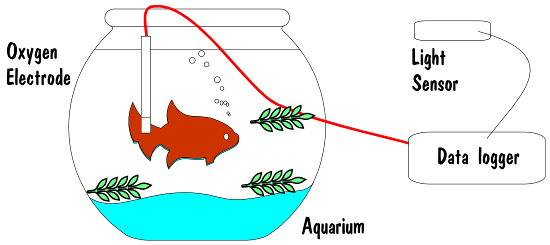
Photosynthesis - aquarium

There's some pond weed and some green algae in the aquarium. If they are living, and they are, they must be doing something - why would the pet shop say that the plants were good for the fish, and yet they do not eat them.

In fact, the plants are producing oxygen but that is hard to see. An oxygen sensor helps us 'see' when the oxygen level changes on a computer screen.

Plants need light so you might expect that day and night affects them. A light sensor will help us check when it is day time.

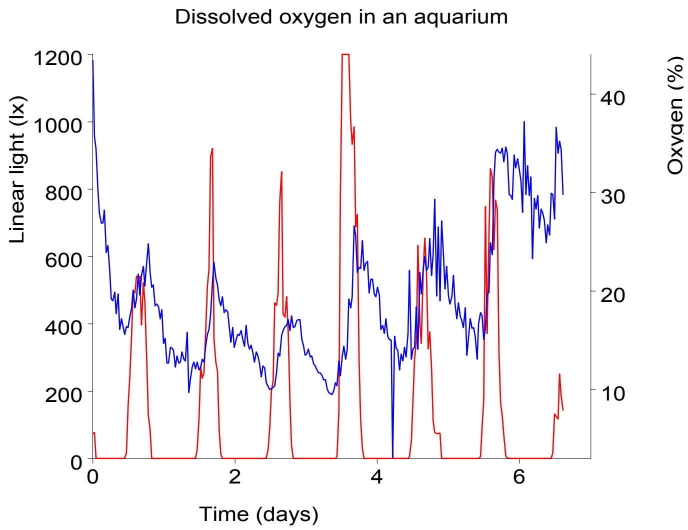
What to do



Place an oxygen sensor in an aquarium and set up a light sensor nearby. Connect to a data logger and let it measure undisturbed for several days. Data loggers automatically take readings from sensors over long periods of time.

Look at the results

1. Find the results file and open it in your data handling software. Look at the light level graph: How many days did this experiment run for?
2. How many troughs are there in the graph?
3. What do the troughs correspond to?
4. What is the time interval between each peak on the graph?
5. What time of day do the peaks in the graph correspond to?
6. Why are the light peaks at different heights?
7. Although the oxygen graph is noisy, how many peaks does it have?



8. How do the oxygen peaks match with the light level peaks?
9. Why might the oxygen level reach a peak after the light level does?
10. At what time of day do the plants produce the most oxygen? At what time of day do the plants produce the least oxygen? What does this tell us?
11. What are the plants doing in the aquarium? How is this good for the fish?
12. How can the fish breathe at night-time?

Extra:

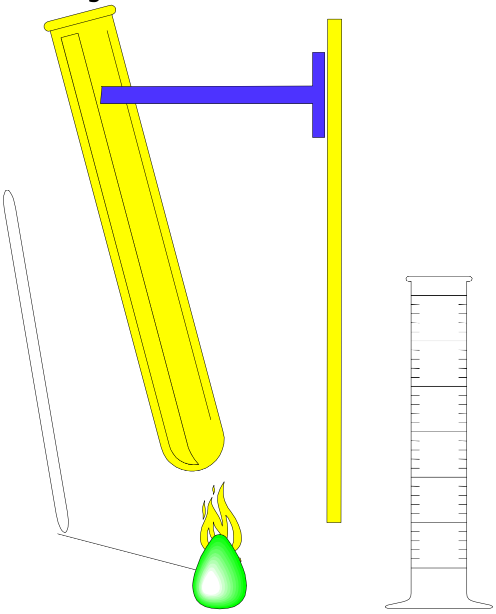
- Why do you think the graph is 'noisy'? Get your software to smooth the graph. Does this still give a fair picture of the experiment?
- Does this cyclical pattern work the same in a running stream?
- What happens to the oxygen levels and the light levels when plants overgrow in a river?

Teachers note

Use this exercise after you have set up this experiment. (Results file by Laurence Rogers, University of Leicester. Activity developed for Schools Online Science at Sheffield Hallam University. Find the worksheet on the Internet at www.shu.ac.uk)

Food - measuring energy

In this activity you measure the heat produced by an amount of burning food. A temperature probe will help take the readings.



What you need

Samples of food, balance, boiling tube, clamp and stand, temperature probe, 25 cm^3 measuring cylinder, mounted needle, Bunsen burner. Safety precautions.

What to do:

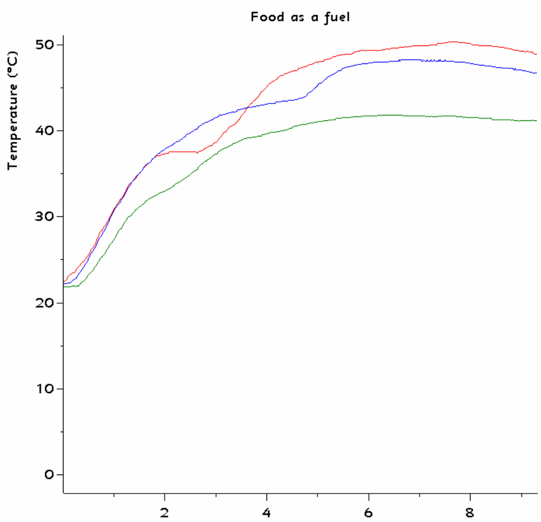
- Weigh your food sample. Clamp a tube with 25 cm^3 water and a temperature probe above a clamped mounted needle with the food attached.
- Start recording and light the food in a Bunsen flame. Let the food burn to a cinder as it heats the tube effectively. If the flame extinguishes re-light the food and continue without delay. Save your results.

Results

- Take readings from the graph to record the temperature change produced by the burning food.
- Describe the sources of error in this experiment.
- If you suffered a drop in temperature, perhaps due to the food extinguishing, use your graph to add the temperature drop to the overall rise.
- Why is it useful to weigh the food?
- You need to work out how much heat was produced per gram of food. This calculation that allows you to compare the foods
- Temperature change produced per gram food = temperature rise / mass of food used

Teachers note

Use this as a way to get to grips with using sensors. Compared to the standard approach, this method is good at reducing measuring errors.
Teacher Reshma Syed used small oil lamps to compare different vegetable oils. Results from Data Harvest www.data-harvest.co.uk



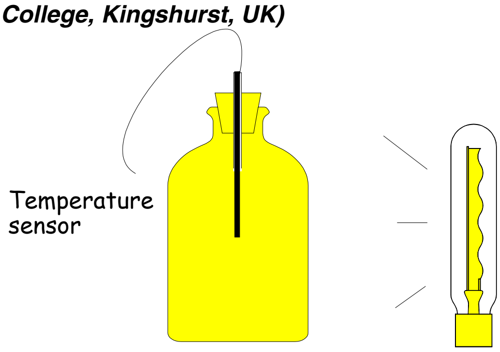
The greenhouse effect

Greenhouse effect

Teaching care for the environment inevitably leads to the issue of global warming, never mind the other issue of trying to illustrate this effect. With the help of temperature probes, taking readings over time, you can do this quite effectively. Furthermore, a graph on screen can show a more convincing change.
A couple of approaches have been reported which show different aspects to the phenomenon. One deals with the idea of radiation passing through a material and heat becoming trapped inside. The other looks at the property of carbon dioxide in forming an insulating blanket around the world. A third is hearsay: fill an aquarium with carbon dioxide gas either from a cylinder or by pouring some acid in the tank and adding soda. Place a temperature probe into the tank and switch on a lamp to see how the contents warm up. (To make the point that the tank has a heavy gas inside, blow bubbles and watch them settle on the carbon dioxide). For comparison, repeat this with a tank filled with air.

Carbon dioxide leads to warming

Put small amount of water into two drink bottles. Place temperature probes into bungs to fit the bottles. Arrange them around a switched off lamp. Start recording, drop an Alka-Seltzer into one bottle and replace the bung. When both temperatures are equal and steady, switch on the lamp and continue to record for at least 30 minutes. Use the software to calculate the rate of heating of each container. Suggest what might happen to the temperatures in a day / night cycle. At the end of the lesson, place the bottles beside a sunny window and continue recording. ***(Method by Rod Taylor from Data logging a basic guide for teachers produced by DCP Microdevelopments and The City Technology College, Kingshurst, UK)***

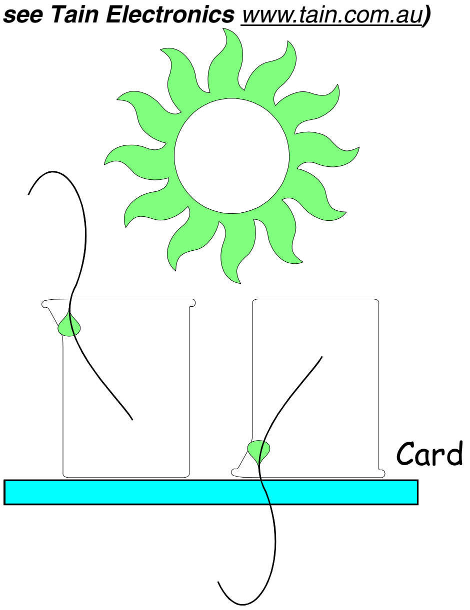


What you need

Two large fizzy drink bottles, two temperature probes pushed through a bottle-sized bung, citric acid/baking powder mix or Alka-Seltzer, desk lamp as a source of sun

The space behind glass tends to warm up

Set up two beakers, one upside down and one normal. Fix the temperature probes inside them and start recording. When both temperatures are equal and steady, switch on the lamp and continue to record for at least 30 minutes. The air will warm faster in the inverted beaker. ***(Method from Peter Adams - see Tain Electronics*** www.tain.com.au***)***



What you need

Two temperature probes, heat source, 2 x large beakers, a means of fixing the probes at the centre of each beaker.

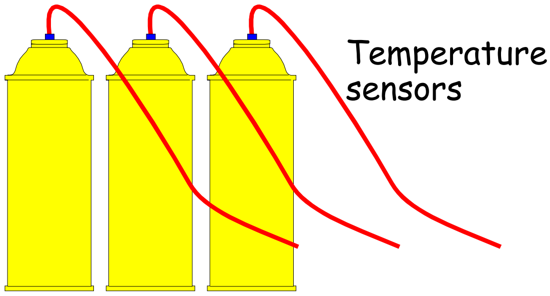
Microbiology - phases of growth

As microbes grow within a culture, there is a lag phase where the organism gears up its systems, as well as exponential and plateau phases. The number of microbes is related to a change in turbidity that can be monitored with a light sensor. Finding a bug and a culture medium is the first hurdle. People report success with yeast, E Coli - K12 strain and Micrococcus lutea (do check the regulations). You also want the culture to start off fairly clear as you will not know whether the growth has genuinely plateaued or if the culture has become too turbid to read. Students may be happy enough to note the growth phases. Appreciate that turbidimetry is a rough science: the density of the culture increases with increasing numbers of microbes but half the light reading doesn't necessarily mean twice the number. It is worth trying, but do see the alternatives around page 126 first as the method here merits discussion.

What you need

Inoculating loop, Bunsen burner, colorimeter sensor, cuvette, nutrient broth, suitable culture.

Respiration or Germination - energy release



Set up three vacuum flasks with a temperature sensor in each flask. Add live or killed material. Start recording and continue to record for a day or more.

Results

- Sketch the graphs you would obtain and compare these with your results.
- Add your comments to the graphs and print them.

Respiration - oxygen in exhaled air

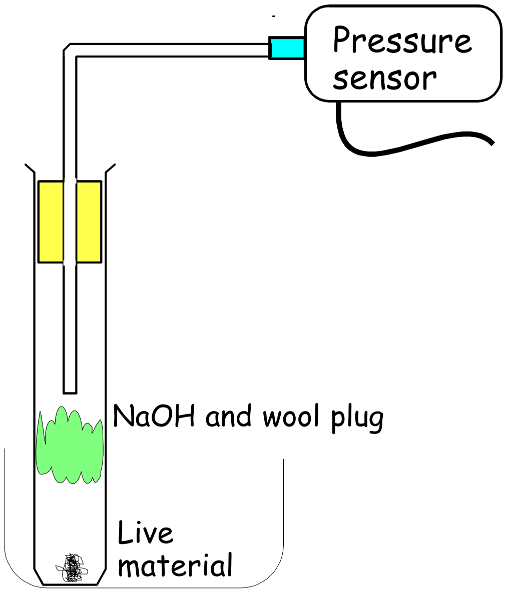
We don't actually use all the oxygen in the air we breathe in. For one thing, if we did there'd be little point in mouth-to-mouth resuscitation - but there is another way to make this point clear. It needs just a few moments effort for an effective illustration of the idea that we remove oxygen from the air. If you have lost confidence in oxygen probes, see the sensors section, page 35 for some tips. Ahead of time, place an oxygen sensor into a polythene bag and start recording the oxygen level. When you have a steady reading, point this out, sit down and re-breathe the air inside the bag. The trace should fall. We also wanted to show that the bag still contained oxygen - so we ran carbon dioxide into it and watched the oxygen level plummet. You can also put the probe in a) a just-opened crisp bag - they use nitrogen to keep them fresh or b) tubes of carbon dioxide, nitrogen and oxygen.

What you need

Polythene bag, carbon dioxide cylinder, oxygen sensor and probe

Respiration - use of oxygen

You can monitor the use of oxygen by live material with a pressure sensor. As an organism respires, the carbon dioxide gas produced can be removed with sodium hydroxide. The set-up described here can be used to show how respiration is affected by temperature. The results should show a pressure drop over time. The live material will be unable to remove all the oxygen from the tube, so there will be a point where no further change occurs. Changes will be slight and take from 10 to 20 hours.

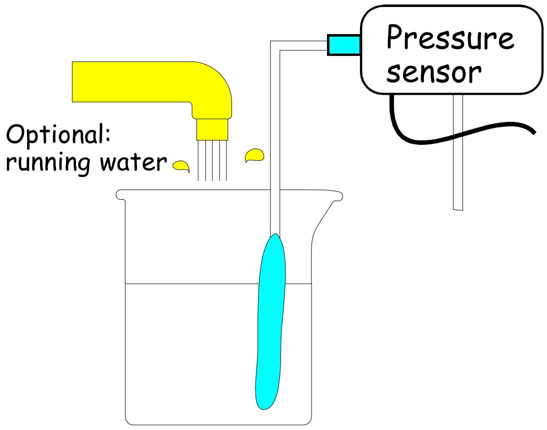


What you need

Air-tight boiling tube, bung, delivery tube and pressure sensor, 10M sodium hydroxide solution, glass wool plug and a temperature sensor to monitor changes in temperature. Live material such as apple, mealworms, liver or germinating seeds. Take care that the live part of the tube is not contaminated with the alkali. If the room temperature varies, run this in a water bath as the pressure change from temperature variation is significant. Alternatively run it a second time as a control without the live material.

Osmotic pressure

Osmotic pressure depends on the concentration of a solution. You can show its progress using a pressure sensor.



What you need

Visking tubing sealed one end, filled with 1M sucrose and connected to a pressure sensor, immerse in a large beaker of water.

What to do

Start recording and check that your graph trace on screen deflects when you push the sac. Continue to record for an hour or two.

Results

1. The graph trace should show a flat line at first, but it will change direction. Why is this?
2. Sketch the graph you would expect. Your graph should have a flat line, a pressure rise and no change section. How does this explain what happens during osmosis?
3. Why does the pressure change over time?
4. Suppose the beaker was replaced with running water. How would this affect the graph?
5. Look at your results and label a) the point of equilibrium and b) the point where water flows into the sac.
6. You could try this experiment with a more concentrated sucrose solution. Sketch how this graph would look.

Extra

- Is there a relationship between pressure and concentration? Repeat the experiment with half and quarter strength sucrose solution to see if it is linear. Use a gradient or rate of change feature in your software to measure the rate of change of pressure.

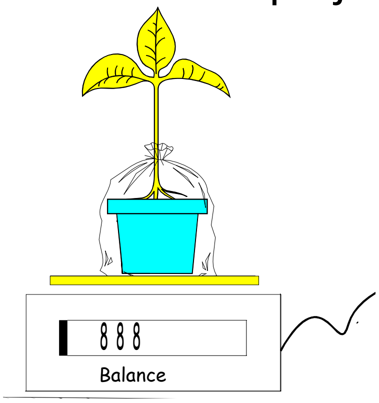
Teachers note

You can measure the rate of osmosis at other concentrations. The rate will be different but the relationship between rate and concentration is not that linear by this method. The causes are many and discussed by John Gipps. He reports that aside from leaks, the sucrose concentration changes throughout the experiment and sucrose also leaks out of the tubing. Furthermore, a lack of agitation means that a layer of sugar continuously surrounds the Visking bag. His alternative is to place the Visking bag in a porous metal sieve and record the pressure as water flows continuously over the bag. The sieve corsets the bag, occasionally bursts but tends to result in higher pressures. (Thanks to John Gipps c/o Tain Electronics www.tain.com.au)

Transpiration

What to do

Place a small well-watered coleus plant in a plastic bag. Tie a band around the stalk to ensure that water does not evaporate from the pot and soil. Place on an electronic balance and press the 'tare' button to zero the mass. Leave near a window during warm weather. Record the mass over a couple of days.



What you need

Computer linked balance, coleus plant in a light plastic plot. Also consider using light, temperature and humidity sensors

Results

Your graph, like the example here, shows the mass lost by the plant.

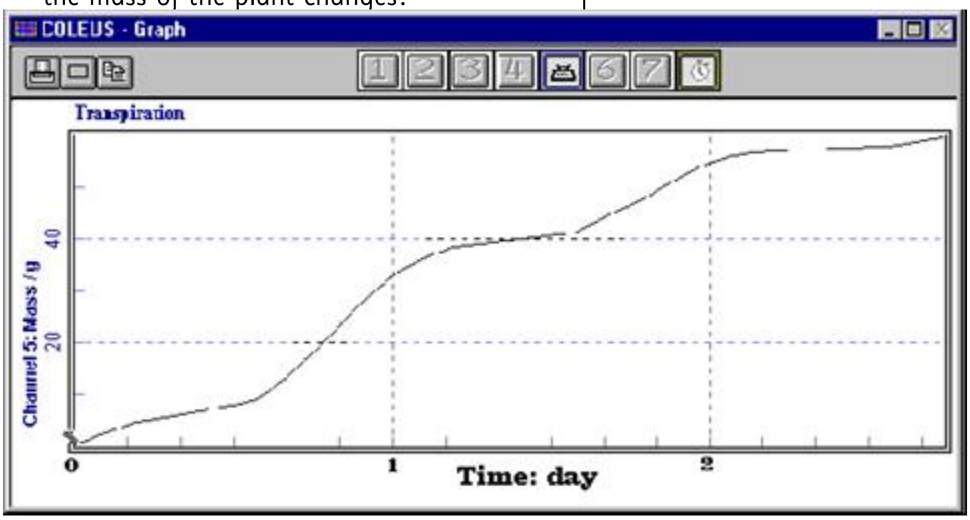
1. How long did we record for?
2. Your graph of mass lost rises up the screen. Why is the trace rising?
3. What is happening to the mass when the trace is nearly flat?
4. What does the graph tell you about how the mass of the plant changes?
5. This experiment was started at 4 pm. When do the three plateaux occur?
6. Suppose we had measured the light level at the same time, sketch how a light level trace would look on this graph.
7. Take gradients from the graph to see whether the mass loss is faster during the day or the night.
8. How many times faster or slower is the rate of transpiration during the day?

Extra

- Use your software to calculate the differential of the mass trace. This gives you the rate of transpiration. Plot how this changes over time.
- Suggest why the rate of transpiration dropped throughout the experiment.
- Your system may allow you to record the light, temperature and humidity in the room at the same time as the mass. Try this.
- Which of these three parameters do you think the transpiration rate is most linked to?
- Look for a pattern between the differential plot of the temperature and the mass.

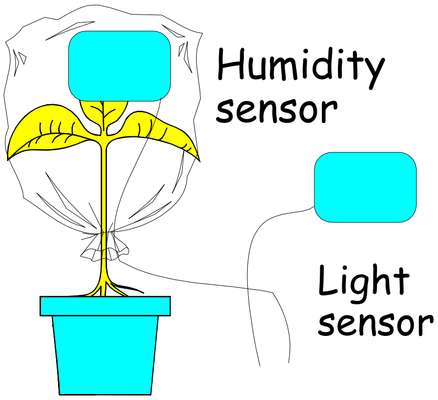
Teachers note

Graph made with Datadisc and Datamass software and using a Philip Harris system. On this occasion 'mass lost' was recorded hence the rising trace. While we chose to present this as it happened, it is easy to change to a display you prefer. From the Datadisc web site at www.datadisc.co.uk The recording took place over a weekend in June. With thanks to Philip Harris, Rob Dickinson, John & David Crellin.



Transpiration - teachers note

Transpiration - humidity



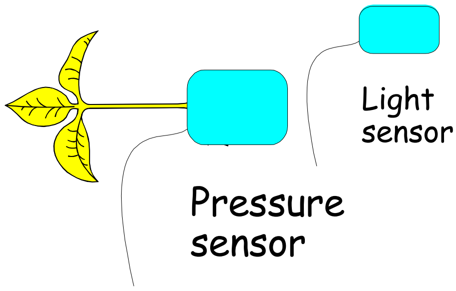
Here follow some approaches to monitoring transpiration. They should suit a demonstration or student project. Perhaps the simplest is to place a leaf in a polythene bag with a humidity sensor. Knot the opening of the bag, leave it for about 20 minutes and note the rise in humidity. This is a reasonably quick and reliable demonstration to do at the start of a lesson. You might ask for suggestions for a control experiment. One suggestion is to compare the humidity of a leaf attached to a plant with the same leaf cut off the stem. Another is to compare a cut leaf with a leaf smeared with petroleum jelly.

What you need

Plant, polythene bag, humidity sensor

Transpiration - pressure

You can also measure the rate of plant transpiration by attaching the stem of a plant cutting to the tube of a pressure sensor. The pressure sensor measures the suction effect at the cut end of the stem. With an experiment run-time of five to ten minutes, the set-up offers an opportunity to see the effect of the wind by switching on a desk fan as well as the basic effect. See what happens when you remove half the plant's leaves. Credits to equipment suppliers ***PASCO*** at www.pasco.com / ***Texas Instruments*** at www.ti.com / ***Vernier Software*** at www.vernier.com

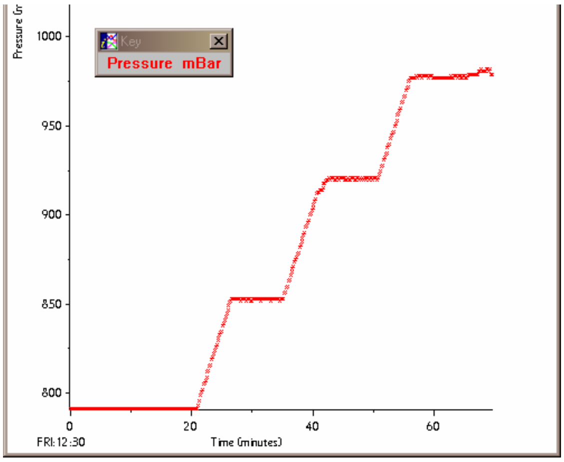


What you need

Plant cutting with leaves, pressure sensor, desk fan, plastic tubing and a cable tie to seal the junction. Several suppliers offer a special, narrow-range (e.g. 0-10 kPa) biology gas pressure sensor to use in place of the normal full range (e.g. 0-700 kPa) pressure sensor. A typical transpiration experiment will give a change of 2-4 kPa so if you have a full range device you can only hope for a blip on the screen. This also serves to highlight the importance of a tight seal between the plant and the tubing. You can use a cable tie to improve the seal but take care not to damage the stem.

Data loggers - the scientist's camera!

There is a rich world of data waiting to be collected out there. Take an accelerometer with you on a theme park roller coaster or if that's too sad, take one into a lift instead. Take a pressure and radioactivity sensor on a plane trip and note how the cabin pressure drops during take off, stabilises at a low level, and is restored during landing. The radioactivity count rate increases during take off, stays high throughout the flight and falls back on landing. Take pressure and temperature sensors on a hot air balloon ride and see how their readings decrease as the balloon rises.



The last hour of a long haul flight: graph showing the pressure change. Thanks to www.data-harvest.co.uk

You can shoot a model rocket, see the thrust peak during the initial burn, and then level out as the engine burns out. For this you can use a force sensor - one of a few sensors to take on your next bungee jump. You could run a data logger as a thunder storm looms - you may catch a drop in temperature as a cold front comes over, you may even catch lightening followed by thunder. And just because you are on holiday is no reason to stop learning - no ski holiday would be complete without packing a data logger and sensors to measure temperature, humidity, light level and pressure. Of course, I jest but the more we can relate to the experience, the more students can get a perch on how things work.

Take one final example: on his way to give a talk, colleague John Wardle collected data during his 200-mile winter car journey. The temperature of the car rose, stabilised and dropped briefly as he stopped at a filling station. Likewise, the light level, initially dark, rose steadily throughout the journey. The sound level was high at the beginning and end of his journey, low through most of it and dropped lower during his petrol stop. The start and end of the journey were noisy because they were in town and involved plenty of accelerating.

If one of the key skills we're trying to engender in pupils is the ability to predict and use graphs, then these ordinary situations are a means to achieve that. (Sources: PASCO, USA ; John Wardle, Sheffield Hallam University)

Other titles in Roger Frost's series for teaching science and available from many of the suppliers listed overleaf

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