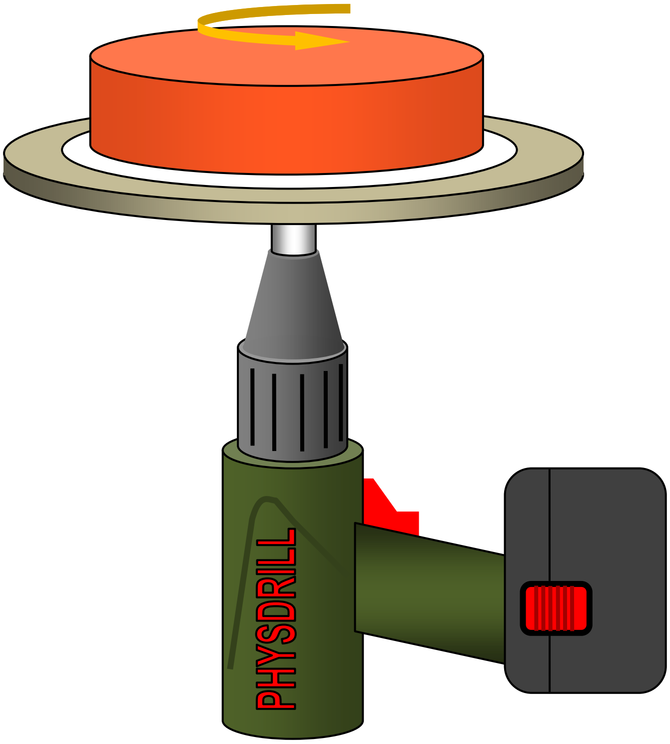
The New Resourceful Physics Teacher

Creative ideas and experiments for Physics teaching



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The New Resourceful Physics Teacher

This superb teaching resource contains over 700 fun and informative ideas and experiments for teachers and pupils in physics. Many of the ideas are unique to this book and will not be found in standard text books or teachers' guides. They mainly cover the range of physics taught to pupils age 11-18 at secondary or high school together with some material that will be appropriate to younger pupils.

These ideas, collected over forty years, will be invaluable to all those who are teaching physics whether as a separate subject or as part of a general science course.

The book is divided into topics with a complete index and relevant theory is summarised at the start of each section. Explanations and further theory are given with many of the experiments. The experiments all use standard laboratory items as well as many simple items from around the home such as a jelly and a coat hanger. This means that a particular advantage of the collection is that many of the experiments can be carried out with very simple apparatus, not requiring a traditional laboratory. The equipment needed for each experiment is listed together with tips on set-up.

The book is lavishly illustrated with over 300 full colour diagrams and photographs.
Safety precautions are highlighted where appropriate.

Some comments about the contents:

These experiments made me realise why I left industry to go into teaching

Although I've been teaching physics and general science for about 12 years I'm always looking for ideas to get the pupils motivated. Thank you for the inspiration!!

A real treasury of resources - thanks for all your hard work

I have really enjoyed using the book; as a non specialist it has been a 'godsend' on many occasions.

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INTRODUCTION

Some years ago I was attending a conference at which a professor from one of the universities in the United States was giving a lecture about demonstration experiments in Physics. I had then been teaching for about thirty years and so thought I was fairly experienced. However, I decided to go along to see if I could pick up a new experiment or two. Two and a half hours later I emerged absolutely amazed – I had not known a single experiment!

This started me thinking. If that was true for me, how many other people were unaware of these ideas? Indeed, did I have ideas that my colleagues in other schools did not know about? I decided to start collecting these together and the result is this book.

I do not claim that all the ideas are my own; indeed, many have been suggested by relatives, friends and colleagues, not to mention many of my past and present pupils who have encouraged me over the years.

I have put in some explanation and background theory where space allows to help those teachers whose basic specialisation is not in Physics. However, if any of you want to find out more please visit the www.schoolphysics.co.uk website or consult the schoolphysics Complete Edition CD.

I have tried to make it of use to all Physics teachers both new and experienced, and although many of you who read it will come across old favourites I hope that everyone will find at least something that is new and challenging. I like analogies and I have included a number of these within the text. I also hope that the ideas will go some way to popularise the subject and make people realise that there is much of fun and interest in Physics.

One particular advantage of the collection is that many of the experiments can be carried out with very simple apparatus, not requiring a traditional laboratory. This should be particularly useful not only to those of you teaching in countries without the facilities of much of the UK but also to teachers in Britain, like me, who have had to use huts with neither gas, water or proper benches. Interactive whiteboards and computers are great and I enjoy using them but you will find that they are required by virtually none of the experiments described here.

I am especially grateful to all those teachers who have allowed me to add their ideas to this collection. If you have not been individually mentioned I apologise, but without you the collection would have been the poorer.

An alternative subtitle to the book was to be 'Fun and informative experiments in Physics' and that is what it is really all about.

I imagine that very few people read introductions to a book. If you have read this, then thank you! It might have given you an idea about what I have tried to put together and why.

Enjoy the rest of the book. I hope that the ideas in it are a help to your teaching.

Keith Gibbs
Taunton 2011

SAFETY CONSIDERATIONS

By their nature, some activities in this book may be hazardous if due care is not taken. Specific hazards are identified within the text by the use of the following general warning sign:

Particular hazards identified in boxes such as this with suggested control measures.

Every effort has been made to see that the activities suggested in this book have had hazards identified and control measures put in place. However, it is the responsibility of the experimenter to take the necessary precautions, and the author of the book does not accept any responsibility for any injuries caused as a result of carrying out any piece of practical work mentioned therein.

The hazards highlighted are not necessarily exhaustive and teachers must use caution at all times when carrying out experiments. Teachers must always follow good practice, including that given in the current ASE publication 'Safeguards in the School Laboratory'.

- Unless otherwise instructed, or if it is impossible, practical work should be conducted in a properly equipped laboratory.
- Suitable eye protection should be worn whenever there is the slightest recognised risk to the pupils' or teacher's eyes. A safety screen should be placed between the teacher and the audience if there is the remotest risk of even a tiny explosion or when objects might be projected towards those watching.
- All mains electrical equipment should be properly maintained.
- A heatproof mat should be placed on the bench if any experiments involving heating are to be performed. A large tray should be placed under any apparatus where a corrosive or staining liquid might be spilled.
- Risk assessments should always be undertaken before carrying out practical work of any kind for the first time.
- Pupils should be taught safe techniques and good laboratory practice.

The summary above is intended to provide basic guidelines for safe practical work.

Although I have taken reasonable steps to identify specific hazards you should not assume that all necessary warnings and precautionary measures are contained in this book or that other additional measures are not required. However, if a zero risk policy were to be adopted we would do no practical work at all!

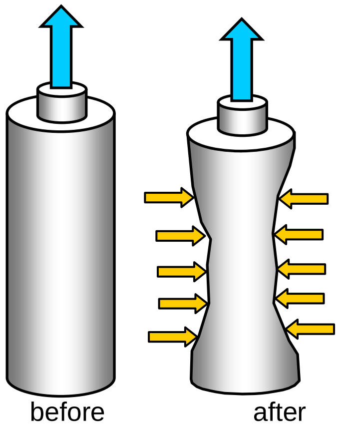
Readers requiring further guidance are referred to:

- Hazcards (CLEAPSS, 1995 or 1998, 2000 updates)
- Topics in safety, 3rd edition (ASE, 2001)
- Safeguards in the school laboratory, 11th edition (ASE, 2006)

I am most grateful to Joe Jefferies (Health and Safety Consultant) for his considerable help and advice with the identification of safety issues and for suggesting suitable control measures.

Keith Gibbs
Taunton 2011

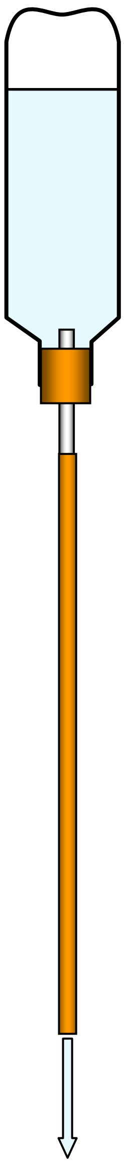
15. Collapsing can, collapsing bottle and air pressure



Both of these experiments are vivid demonstrations of the pressure of the atmosphere.

(a) Get a tin can and put a little water in it. Heat the can vigorously over a Bunsen until the water has been boiling for some time. Although there will be some liquid left, the can will be full of steam. Remove the can from the heat and quickly insert the stopper or screw on the lid.

Do not heat a closed can. Show the pupils how to deal with minor burns using running cold water.



As the can cools, the steam inside the can condenses and therefore the pressure drops. After a few moments the pressure difference between the atmosphere outside and the small amount of residual air inside is enough to crush the can flat!

I usually stand on the top of the can first before starting the experiment to demonstrate how strong it is and then get a pupil to try and straighten out the can at the end after it has cooled.

A variation of this is to use an empty drinks can. Make a small hole in one side, put a little water in it and boil the water as before. Then pick it up with a pair of tongs and rapidly invert it in a bowl of water. The steam inside the can condenses, the small hole in the can prevents water from being sucked in too rapidly and the can collapses.

(b) This next demonstration of atmospheric pressure is very simple and direct and avoids heating cans of air! Completely fill a plastic squash bottle with water - bigger bottles are more impressive. Put a bung in it with a glass tube in the centre and attach a 2 m length of rubber tubing to the tube - more if the height of your lab will allow it. Get someone to hold the end of the tube closed while you climb on a bench and upend the bottle with the rubber tube dangling vertically downwards. Now open the lower end of the tube.

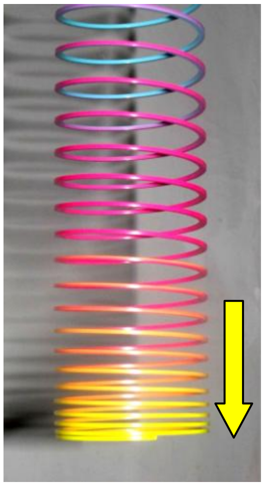
As the water runs out, the bottle will be squashed flat by the pressure of the air on the outside! The long tube gives a bigger pressure difference between the top and bottom of the water column and also prevents air leaking in.

Theory
Pressure difference between the two ends of the water column of height h = ρgh where ρ is the density of the water.

Age range: 11-13
Apparatus required:
(a) •Tin can •Bunsen •Heat proof mat •Drinks can •Tongs
(b) •Plastic bottle with rubber tube fitted to a bung in its neck •Water •Bucket

12. Falling helical spring

A variation of experiment nine is to drop an extended helical spring and observe what happens to various parts of it as it falls. You will find that during the drop the bottom coils stay where they are while the upper coils catch up with them and then the whole spring falls together. During the whole motion the centre of mass falls with an acceleration of g. The information that the spring is falling will take a certain time to travel down the spring and so initially the bottom part of the spring "thinks" it is still being held up and so remains at rest.
(Thanks to Martin for this idea)



Using a TV camera to record the fall and looking at a slow motion replay will make the results of many experiments much easier to appreciate.

Age range: 16-18
Apparatus required: •Helical spring •TV camera if possible

13. Falling bar method for g

You can use the fact that the vertical acceleration of any point on any rigid falling object is the same, no matter whether it is dropped vertically or swung or projected at an angle, in the following experiment to find g. A metre ruler is pivoted at one end and held at an angle by a thread fixed to its lower end, the thread being looped over the pivot bar and with a sufficiently heavy pendulum bob tied to the other end. Now burn through or cut the thread. The pendulum bob begins to fall and the ruler begins to swing downwards at the same moment. The position where the ball meets the bar can be used to find g. Finding this position can be made easier by putting a piece of carbon paper over a strip of white paper that is fixed to the ruler.

Theory:
Since the pendulum bob hits the ruler vertically below the pivot, the time taken for the fall will be one quarter of the period of oscillation of the ruler. The period can be found by measuring the time for ten swings of the ruler and then working out the time for one quarter of a swing.

Age range: 16-18
Apparatus required:
•Pivoted metre ruler •Retort stand and clamp •Pendulum bob •Thread •Matches •Stop clock
•Carbon paper •White paper

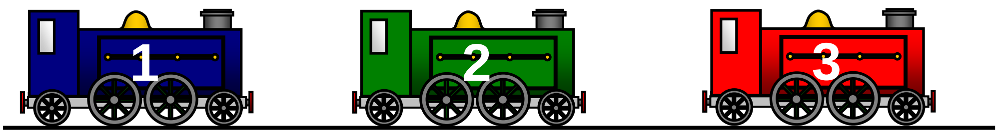
14. Monkey and hunter

A monkey hangs from a tree in a jungle and is discovered by a hunter who decides to shoot it. Pointing the rifle between the eyes of the monkey he prepares to pull the trigger. The monkey, being fairly intelligent, reasons that if he waits until the moment the bullet leaves the barrel and then drops out of the tree the bullet will pass over his head. The hunter pulls the trigger, the monkey waits until the bullet is leaving the barrel and then lets go. To his dismay the bullet hits him directly between the eyes! He was intelligent but had forgotten his Physics!

The explanation for this can be demonstrated by a classic experiment that shows the constancy of acceleration for falling bodies.

3. Train sheets

This is a set of sheets devised to teach the topics of work, force and energy. It introduces the idea of the energy stored in a spring, the resistive forces opposing motion and the resulting stopping distances. We have three trains with one, two and three units of stored energy and these are run on three different surfaces having one, two and three units of frictional resistance. If the train with one unit of stored energy travels 30 m on a surface with one unit of resistive force before stopping, then the pupils are asked to work out how far all the trains would travel on all the surfaces.



The end result is hopefully an understanding of the formula:

Work done = Energy transferred = Resistive Force (F) x Distance travelled (d).

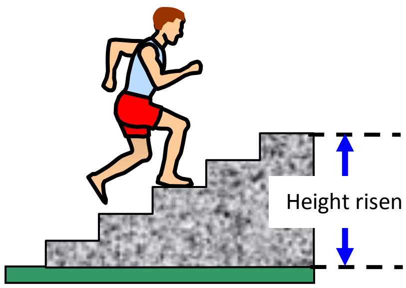
Having a clockwork train for an actual demonstration helps!

Age range: 11-13
Apparatus required: •Train sheets sample (Thanks to Pete and Phil for the idea)

Energy	Force (F)	Distance travelled (d)	Force x Distance
1	1	30	30
2	1	60	60
3	1	90	90
1	2	15	30
1	3	10	30

4. Power of a pupil running upstairs

(a) This is a simple experiment to measure a pupil's power - they carry their own mass (themselves) up a known height. The pupils run up a flight of stairs of known height and measure the time that they take to do it. They then measure their own weight and so calculate the work done and the power that they developed. Carrying a rucksack loaded with books will increase their weight.



(b) The power of their arms can be found by lifting a weight such as a bucket of sand.

Experiment (a): Only allow one pupil at a time to run up the stairs. Sensible footwear should be worn. Discourage over competitiveness which can lead to falls and injuries. Any student excused from P.E lesson is unlikely to be able to take part.

Experiment (b): No pupil should lift a weight higher than their own shoulders. Warn of back damage here.

Age range: 13-16
Apparatus required: •Bathroom scales •Flight of stairs •Stop watch •Measuring tape or ruler •Heavy mass such as a bucket of sand

VECTORS, MOMENTS AND STABILITY

General theory for this section:

The moment of a force is defined as the product of the force and the perpendicular distance from the line of action of the force to the pivot.

When an object is balanced, the sum of the clockwise moments (those trying to turn it in a clockwise direction) is equal to the sum of the anticlockwise moments (those trying to turn it the opposite way).

When an object is balanced, the vertical line from the centre of gravity passes through the point of balance and the object will topple over when this vertical line falls outside the base of the object.

1. Balancing forks and a pivot mechanism
2. Bottle top and door frame
3. Balancing a pencil and/or a snooker cue
4. Mop and back muscles
5. Action men and artists models in Physics
6. Shopping trolley
7. Balances - wooden coat hangers
8. Vectors and a rope
9. Male and female balancing
10. Mobiles to demonstrate moments
11. Arm muscles and levers
12. Centre of gravity of a pupil
13. Bear on bike
14. Moments
15. Centre of gravity and mass of a broom
16. The wooden spoon
17. Rolling up hill
18. Moving fingers on a long ruler
19. Pile of leaning blocks
20. Interesting balancing
21. The heavy bottom toy
22. Moments and a CD
23. The rolling spool

1. Balancing forks and a pivot mechanism

(a) The position of the centre of gravity of a system is vital for its stability. Fix two forks together, prongs to prongs, stick a cocktail stick through between the prongs and then balance the arrangement on the edge of a glass. (It helps to tape the prongs of the forks together). Finally set fire to the end of the cocktail stick over the glass. The wood burns, eventually going out at the edge of the glass.(It helps to tape the ends of the forks together.)

(b) A simple way of lowering the centre of gravity of a ruler when used for investigation of the law of moments is to use a rubber band to fix a ruler below a rod. The rod is then used as the pivot and is balanced on an aluminium yoke. This gets the centre of gravity below the point of suspension and makes balancing easier.

Age range: 11-14 Apparatus required: •Two forks •Cork •Glass •Ruler •Rubber band •Metal rod •Metal rod

2. Bottle top and door frame

The enormous effect of leverage can be shown by taking the cap off a bottle by holding it in the gap between the door and the frame. (Take care not to damage the door or its frame!)

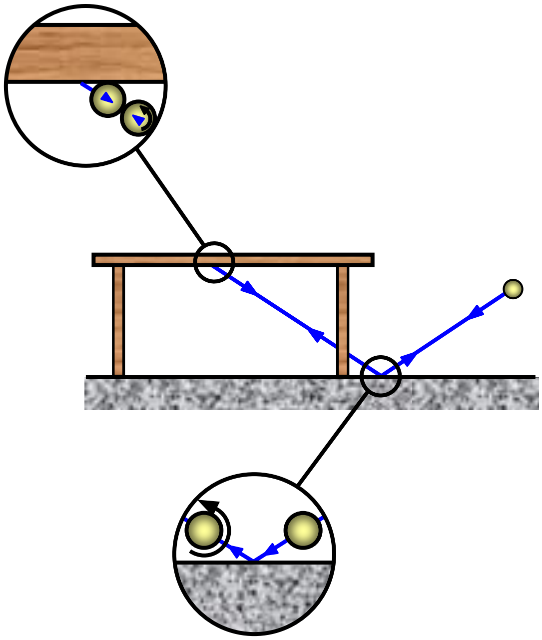
It is worth giving some warnings about long levers giving too great an effect, such as the over tightening of both car wheel nuts and spark plugs with long-handled spanners! Trying to get them undone with a short arm spanner might prove impossible.

Age range: 11-14 Apparatus required: •Bottle with removable cap •Door

46. The reflection of a power ball

Find a hard floor and a flat topped table. Throw a power ball (without spinning it) so that it hits the floor just outside the table and then bounces up under the table and hits the underneath of the table top (see diagram).

There is nothing unusual about this, but it is when the ball hits the underneath of the table top that something rather strange happens. Instead of reflecting off at the same angle the ball returns along its original path!



This can be explained by thinking about the spin of the ball. When it hits the ground at an angle the frictional force between the ball and the ground makes the ball spin (as shown in the inset). As it hits the underneath of the tabletop it is this very spin coupled with another frictional force that returns the ball along its original path.

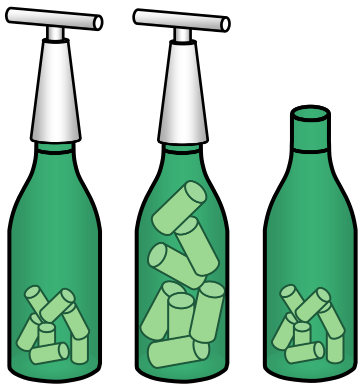
Now try wetting the ball. This lowers the friction, reduces the spin and the ball bounces out at the far end of the table!

This is a fascinating experiment on collisions. I have yet to experiment using different balls such as table tennis balls, hockey balls and tennis balls.

Age range: 16-19
Apparatus required: •Flat topped table •Power ball •Hard floor

47. Air pressure and marshmallows.

Put some cylindrical marshmallows in an empty wine bottle. Then use a 'vacuvin' and stopper to reduce the air pressure in the bottle. As you do so the marshmallows will expand because the air within them is at a greater pressure than the air in the bottle.



When air is allowed back into the bottle by taking out the stopper they will 're-inflate'. This is a good example of the change in the volume of a gas with pressure.

Age range: 11-16
Apparatus required: •Wine bottle •Vacuvin and stopper •Cylindrical marshmallows

27. Sound – a set of simple experiments

The following list is a set of simple experiments that demonstrate that sound is made by vibrating objects.

They could be done as a circus for the pupils or by the teacher demonstrating them and asking the children to come up and try for themselves.

1. Put some small pieces of paper or rice grains on a drumhead and then hit the drum with your hand or a drumstick. The paper and the rice will vibrate (jump about).

2. Strike a cymbal, and then hold it close to your ear. If you touch the cymbal with your ear you can feel the vibrations.

3. Hit a cymbal, then get hold of the edge between your finger and thumb. You can feel the vibrations stop as you grip harder, and as they do the sound also stops.

4. If you stop the cymbal vibrating by putting the edge of it against your chest the sound it makes will stop as well. Link this to the damping of sound by rooms with soft walls and the echoes made from the hard stone walls in churches.

5. Fill a shallow tray with water, and then touch the edge of the tray with a vibrating tuning fork. Waves can be seen moving across the water surface.

6. Play a comb – you can feel the vibrations through your lips as you blow through the paper.

7. Hold a ruler down on the table with your hand so that it sticks out over the edge of the table, and then twang the ruler with your other hand. You can see the ruler vibrating, and as you make the ruler shorter you can hear the sound change. The shorter the ruler, the higher the pitch.

8. Hold your hand in front of a powerful disco type speaker. You should be able to feel the vibrations in the air. If you have an old speaker with no covering lay it down with the cone facing upwards and put some small polystyrene balls in it. Now connect it to a radio or CD player and turn it on. Loud music or speech will make the balls jump around.

9. Put your hand against the body of a cello, double bass or a piano while it is being played. You can feel the vibrations in the wood.

10. Twang a rubber band – you can hear a sound and also see the band vibrating.

11. Half fill a bowl of water, and touch the surface with a vibrating tuning fork. You will see water waves spreading out from the point of contact as the water surface vibrates.

12. Take a two-litre plastic bottle full of water (or lemonade) and knock it with your knuckles about half way down. You will hear a sound but also see a lovely pattern of vibrations on the water surface.

POLARISATION

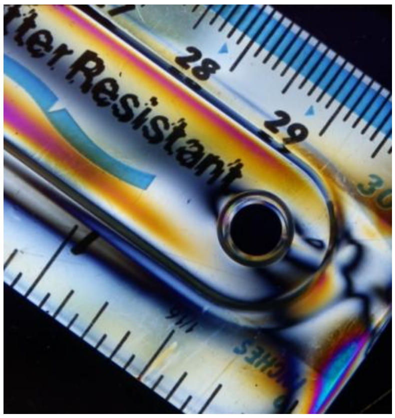
General theory for this section:
A polarised wave is one where the vibrations are in one direction only. The human eye cannot distinguish between polarised and unpolarised light.
Malus' Law: This is an equation that gives the intensity of light (I) transmitted by a piece of Polaroid:
$I = I_o \cos^2\theta$ where θ is the angle between the planes of polarisation of the polariser and analyser.
Brewster's Law: tan p = n where p is the polarising angle and n is the refractive index of the material. At this angle of incidence the reflected beam is completely plane polarised.
Polarisation is a way of distinguishing between longitudinal and transverse waves - transverse waves can be polarised while longitudinal waves cannot.

1. Polaroid and Photoelastic stress
2. Polarisation by reflection
3. Polarisation of a TV signal
4. Polarisation and a calculator
5. Rotation of the plane of polarisation
6. Sunset in milk in water

1. Polaroid and Photoelastic stress with the Overhead Projector

(a) To demonstrate the effect of polarisation two overlapping pieces of polaroid should be placed on the overhead projector. It only works using the type of projector where the light comes from underneath the transparency. Rotating one will show how the light intensity varies with angle and if this is measured with a light meter it is possible to get a verification of Malus' Law.

(b) A beautiful extension to this is to put a piece of plastic bag or a clear plastic ruler or protractor between the two crossed polaroids to shows photoelastic stress. One piece of polaroid should be placed on the glass of the projector with the plastic ruler on top of it, and with the second piece of polaroid put on top of the ruler.



The plastic rotates the plane of polarisation of the light and different wavelengths are rotated different amounts by the stressed areas of the plastic, giving beautiful coloured areas. A small cut in the plastic also shows localised stress patterns.

Age range: 16-18
Apparatus required: •Overhead projector •Two pieces of polaroid •Plastic bag
•Protractor and/or clear plastic ruler

2. Polarisation by reflection

View the glare from desks or roads through either a piece of polaroid or a pair of polaroid sunglasses. Rotation of the polaroid will cut down the glare - hence the use of the polaroid glasses for driving. Reflection from a glass-fronted cupboard also shows the effect very well. The existence of a polarising angle (p) which for glass is about 57^o is easy to show. Use a TV camera if possible to show the effect to the whole class at once.

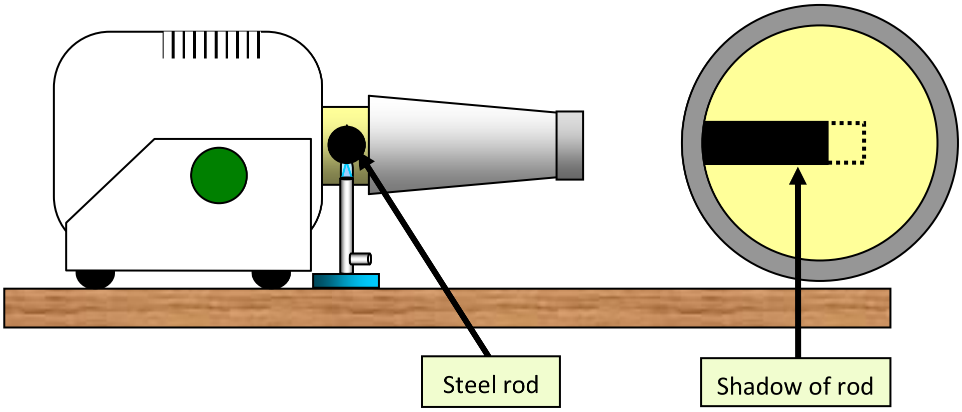
Age range: 16-18
Apparatus required: •Polaroid sheets or polaroid sunglasses •Glass fronted cupboard
•TV camera if available

3. Iron rod in projector - expansion of metals

A very simple way to demonstrate the expansion of metals is to put a steel rod in a projector beam (brass or copper will do as well, of course). A rod of about 50 cm in length and with a diameter of about 0.75 cm works well although the size is not critical. You will need the old type of projector, and the end of the rod should be placed where the slide carrier was. The projector is switched on so that it projects a magnified shadow of the rod on to a screen a few metres away. Make a mark on the screen at the end of the shadow. Heat the rod, and watch it expand by observing the movement of the end of the shadow.

Ensure that the end of the rod being heated in the Bunsen flame is to one side of the slide carrier to avoid damaging the projector body or shattering of the lenses.

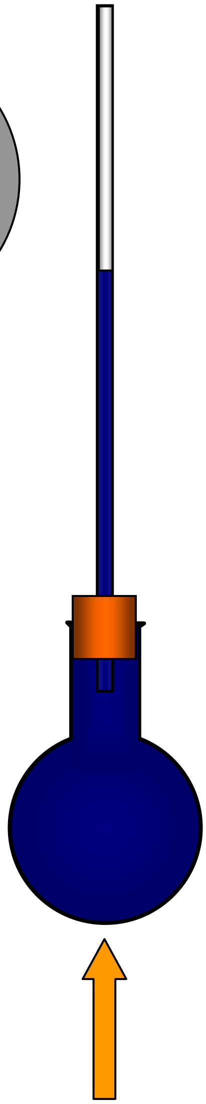
This can be used as a simple demonstration or, if more detail is needed, measurements can be made of the magnification of the projector (width of shadow/width of rod) and a guess made at the average temperature rise of the rod to give the coefficient of linear expansion of the metal. Also show that when the rod cools down it will return to its original length - make sure nobody knocks into the bench!



Theory:
Expansion of a metal bar of length L heated by θ °C = $L\alpha\theta$ where α is the coefficient of linear expansion of the metal (about 10^{-5} °C^{-1} for most metals)

Age range: 11-13 or 16 with measurements and calculations
Apparatus required: •Projector •Metal rod •Retort stand and clamp •Ruler •Bunsen

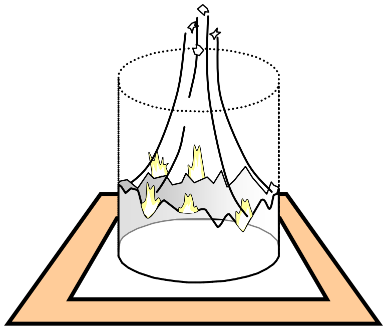
4. Expansion of a liquid



Take a round-bottomed flask and fill it to the brim with coloured water. Take a 1-2 m long piece of capillary tubing, push one end into a rubber bung and push the bung into the top of the flask. Observe the expansion of the liquid when the flask is heated. If you watch carefully it is interesting to see that initially the level of the liquid falls. The glass expands first, but since it is a bad conductor of heat it takes a while for the heat to pass through to the liquid, raise its temperature and so cause it to expand.

Age range: 11-13
Apparatus required: •Round-bottomed flask and bung with hole •Capillary tubing •Bung •Bunsen •Tripod •Retort stand, boss and clamp •Heat-resistant mat

9. Convection and a tea bag



This is a fun experiment to demonstrate convection especially if you use the £10 note!

Take a rectangular tea bag, cut off the end with the string, unfold it, and remove the tea. Shape the bag into a cylinder and stand it on a sheet of paper on the bench (a heat resistant mat underneath the paper is not really necessary but might be a good idea the first time you try this).

Set light to the top of the bag and wait.

The flame will burn downwards, sending a fine stream of ash into the air. As the flame nears the paper the tea bag continues burning, but by this time the upward convection current is sufficient to draw the last remnants of the bag upwards and they simply float away, leaving the paper untouched.

Replacing the sheet of paper with a £10 note makes the demonstration even more exciting but if you do so it is at your own risk!

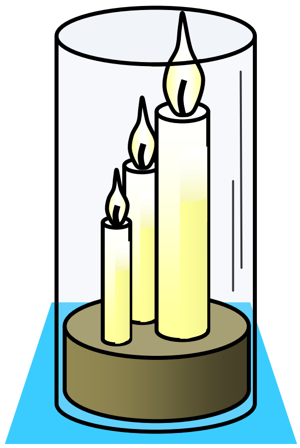
Age range: 11- Adult
Apparatus needed: •Tea bag •Matches •Heat resistant mat •Sheet of paper •£10 note – OPTIONAL!

10. A lava lamp

This is a commercial lamp. As it warms up the material in the liquid rises and falls, showing beautiful convection currents as its density changes. Thus is rather like Galileo's thermometer in some ways. (See Density, Upthrust and Archimedes, experiment 9.)

Age range: 11-14
Apparatus required: •Lava lamp

11. Three candles



Set up the three candles on a beehive shelf over water. The candles should be of significantly different lengths.

Light all three candles, cover them with a large beaker, and wait to see which goes out first.

Surprisingly, perhaps, it is the long one.

Theory
Although the emitted carbon dioxide is heavier than air when it is at the same temperature it is also hotter in this experiment and so convection currents take it to the top of the beaker so putting out the tallest candle first.

Age range: 11-14
Apparatus required: •Three candles •Beehive shelf •Dish •Large beaker •Matches

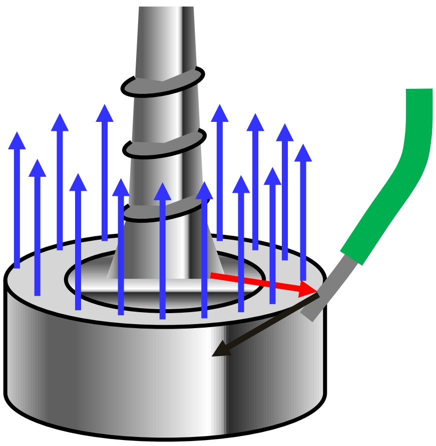
10. Simple electric motors

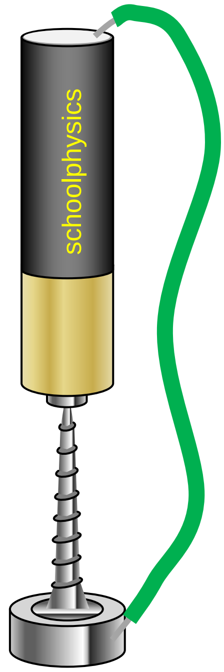
This is a very simple and yet effective way of showing the force on a current in a magnetic field and for making a simple electric 'motor'. It is vital that the pupils are shown the diagram of the field (blue arrows), current (red arrow) and motion (black arrow) so that the effect can be properly explained.

The current flows across the screw head and magnet, and a force is exerted so that the magnet and screw rotate about a vertical axis. You can check this using Fleming's left hand rule.

(I am very grateful to Ian who first showed me this experiment)

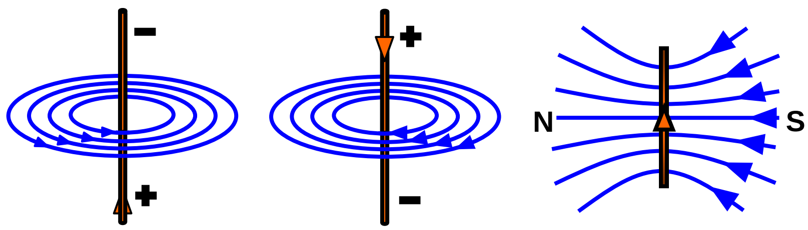
Age range: 11-16
Apparatus required:
•Cylindrical neodymium magnet
•Screw
•AA cell
•Length of insulated wire (bared at the ends)

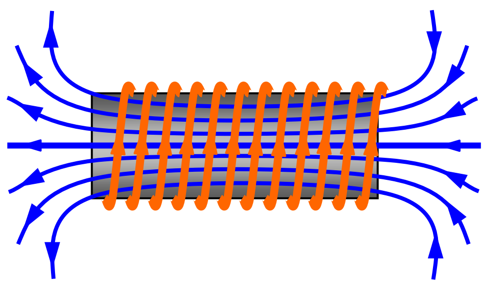




Electromagnets

A long straight coil of wire called a solenoid produces a magnetic field very much like that of a bar magnet. The shapes of some magnetic fields are shown in the diagrams below.





The core of an electromagnet is made of iron because this is easy to magnetise and demagnetise. Steel would not be suitable, because it stays magnetised for much longer, and so the electromagnet could not be switched on and off easily.

33. The Van de Graaff generator and a sheet of paper

An interesting experiment using the Van de Graaff generator is to find out the maximum weight of a sheet of paper that it can support.

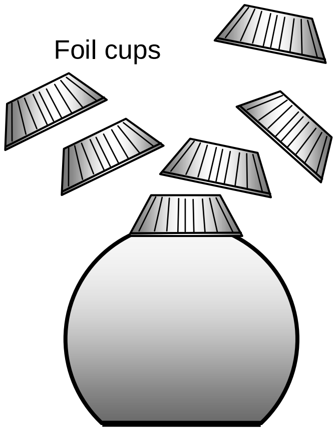
Measure the mass of a number of sheets of paper and then calculate the mass/m^2 of the paper (Δ). ('Normal' photocopy paper usually has a mass of 80 g/m^2.)

Cut a sample of known area, and place it on the Van de Graaff dome. Switch the machine on, and see if it rises. Experiment with larger and larger pieces until the sheet is just held above the dome.

The Van de Graaff generator may give unexpected electric shocks. Staff should be prepared for this.

Age range: 16-18
Apparatus required: •Van de Graaff generator •Paper •Balance

34. Metal cup cake cases and the Van de Graaff generator



This is a lovely demonstration of the repulsive force between charges of the same sign. Put a pile of metal cup cake cases upside down on top of the large dome of a Van de Graaff generator and switch the machine on. As the charge builds up the top case will drift off – the repulsion is just bigger than the weight of the case. This is then followed by the next one down and so on, giving a "rain" of cases.

Alternatively a plastic bowl holding puffed wheat can be taped to the dome. The puffed wheat flies out when the machine is turned on!

The photograph shows an interesting extension. I made a small hole in each of the holders and threaded a length of cotton through them. The lower end of the cotton was fixed to the Van de Graaff dome and the upper end to the ceiling.

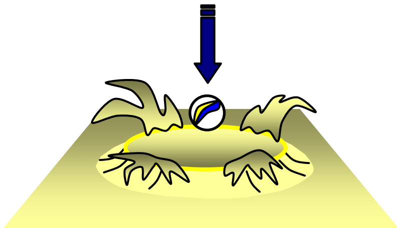
Age range: 11-18 depending on treatment
Apparatus required: • Van de Graaff generator
•About ten cup cake holders

The Van de Graaff generator may give unexpected electric shocks. Staff should be prepared for this.

6. Crater experiment

This experiment is a simulation of meteor impact forming craters on a planet. The meteors are replaced by ball bearings or wooden balls, and a tray of sand replaces the planet surface. (I have used icing sugar- both dry and mixed with water - but it is not so good.)

The projectiles are dropped from a known height into the sand and the loss of potential energy is related to the crater size. We measured the diameter, depth, wall height and general shape of the craters and also tried oblique impacts by rolling the ball bearings down a tube. Dampening the sand gives a way of investigating different types of planetary surface.



Age range: 14-16

Apparatus required: •Sand •Flour •Ball bearings •Marbles •Wooden balls •Plasticine •Ruler •Balance

7. Model lunar craters

Make a clay model of a lunar crater and use a light bulb to simulate the Sun. A light bulb can be mounted on a retort stand, and the bulb can then be raised and lowered to see the effects of the altitude of the "Sun" on the lengths of shadows on the "lunar" surface.

The photograph shows a model of the crater Clavius made by one of my sixteen-year-old students.

Age range: 11-13

Apparatus required: •Clay •Lamp (probably mains) •Ruler to measure shadow length

8. Expansion of the Universe

Here are three possible analogies of the expansion of the universe.

(a) A balloon with dots marked on it to represent the galaxies. As the balloon is blown up all the "galaxies" recede from each other.

(b) A loaf of bread with currants in it shows a 3D analogy of the recession of the galaxies. The currants represent the galaxies. As the loaf expands when it is cooked, all the "galaxies" recede from each other

(c) Thread three or four large polystyrene balls on to a length of elastic, one end of which is fixed to a hook on the wall or a secure retort stand. Now pull the free end of the elastic - all the balls separate from each other.

The point about all these analogies is that they make their own space as they expand. Similarly, before the universe began to expand there was no space! Actually there was no time either - both space and time were "created" at the start of the universe.