Contents

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Worksheet P0 [side 1]
Planning and doing investigations

You will do experiments throughout your work in Physics. Often these are planned so that you can gain the right experience or understanding of an idea. Sometimes, you will have to work out your own experiments. You will do this when given a problem which you have not been told exactly how to solve. Such problems are called *investigations*.

This worksheet is designed to help you plan and do investigations. Your teacher will tell you when you need to use a **Planning sheet** for your work.

Planning your investigation

- Make sure you have read **all** the instructions you have been given.
- Decide what it is you are being asked to do.
- Think of an experiment you can do that may help you solve the problem.
- Think about what observations and measurements you should make.
- Decide what equipment you need in order to carry out your experiment.
- Decide how you are going to present your results:

  i You may need to describe what you see happen.
  ii If you make some measurements, are you going to write them down in a table?
  iii Will it be best to plot a graph as well?
- The **Planning sheet** will help you to remember to plan all these things.

Doing your investigation

- Collect together the equipment you need and set up your experiment.
- Before making accurate measurements, make sure your experiment works as you intend. Often you may have to make some changes.
- Once it seems to be working, make and record any observations or measurements you intend to take.
- Think whether you can improve the experiment. Do the results you have obtained help you to find an answer to the problem?
- Are there now some different experiments you could try?
- Remember, even if an experiment does not give the results you expected, it is never a failure. You will always have learnt something about the problem you are investigating that you did not know beforehand.
- Finally, write a report on your investigation, whatever the outcome.

Writing your report

- Prepare a report about what you have done. In your report you should say:

  i what the purpose of the investigation was.
  ii what you planned to do.
  iii what the results of your tests were.
  iv what conclusions you reached from your evidence.
  v how you could improve the investigation if you did it again.

CONTINUED

Worksheet P0 [side 2]
Planning and doing investigations

Planning sheet

Name: ____________________

Date: ____________________

The title of my investigation is:

____

The problem I intend to solve is:

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This is what I plan to do:

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Diagram:

These are the measurements I intend to make:

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This is the equipment I shall need:

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This is how I intend to present the results of my experiments:

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Worksheet **P1A**
Building a model bridge

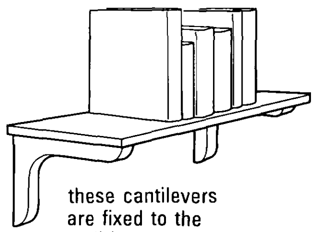
● Design and build a model bridge using only the materials provided. Your bridge must satisfy the following conditions:

i The bridge may rest on piers made from blocks, but it must not be attached to them.
ii The bridge must be a single span, crossing a gap of at least 30 cm.
iii The total mass of the bridge must not exceed 30 g.
iv The bridge must be able to support a load of 20 N.

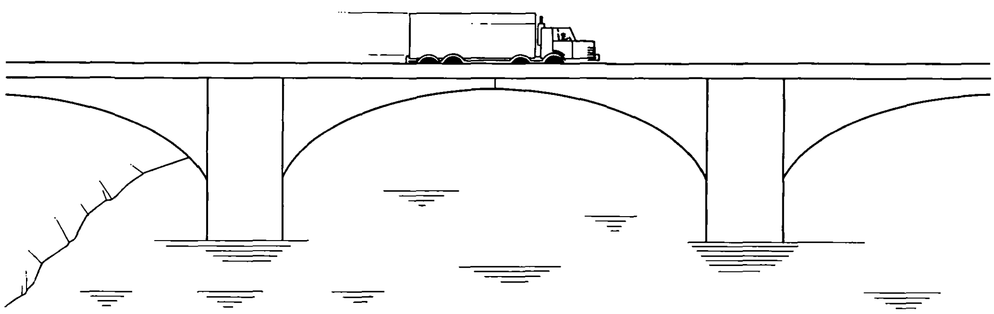
The bridge will be tested by hanging a 20 N load from the middle of it.

Worksheet **P1B**
Cantilevers

Cantilever is the name given to any beam or girder which is fixed at one end. Many bookshelf supports are cantilevers.

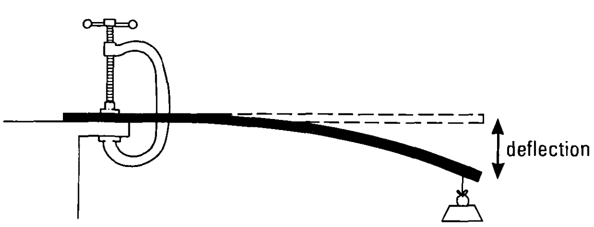


A cantilever bridge consists of a pair of cantilevers, one attached to each pier, meeting at the centre. A load at the centre of the bridge will tend to bend the cantilevers downwards.



Investigation

You will need:
a piece of wood about 1 m long to act as a cantilever (a metre rule would do)
a G-clamp to fix one end of the cantilever to the bench
masses to act as loads on the end of the cantilever
a metre rule to measure the deflection of the end of the cantilever



a ● Plan and carry out an investigation to find:
i the relationship between the deflection of the end of a cantilever and the force acting at its end.
ii the relationship between the deflection of the end of a cantilever and the length of the cantilever.
● To do this you will need to make measurements of force and deflection, and display your results as a graph.

b ● Write a report on your investigation. Describe what you did, and what your results show.

Worksheet P1C
Looking at bridges

a ● Plan and carry out a survey of the many different sorts of bridge that there are. If you are lucky enough you may be able to use local bridges. Otherwise you will have to use photographs.

● Try to see how the construction of each bridge depends on:

i what the bridge is used for.
ii the materials the bridge is made from.
iii when the bridge was built.

b ● Decide how you are going to record the information you collect. A table like this might be a good way:

bridge no.	where it is	what type of bridge it is	what it is made of	what goes over it	what goes under it	date it was built	notes
1							

For each bridge in your survey, try to explain how its structure depends on the materials used, the job it has to do, and the date when it was built.

c ● Write a short report on your findings.

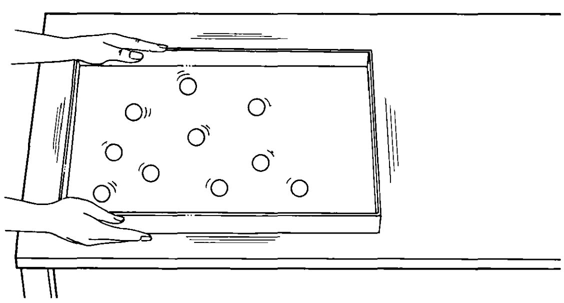
The rail and road bridges over the River Forth.

Worksheet **P2A** [side 1]
Marbles in a tray

These experiments enable you to see how, in some ways, moving particles can behave like solids, liquids and gases. They also show you how matter can change from one state to another.

You will need:
a tray
a ruler that fits in the tray
a large marble
25 small marbles (one of which is a different colour from the rest)

Experiment 1 : Gases



a ● Put about ten marbles in a tray to represent air molecules in a room.
● Shake the tray by sliding it about on the table with a rapid irregular motion; this represents the warm walls of the room.
● Observe what happens as you shake the tray.

1 Describe in as much detail as you can the motion of the marbles as you shake the tray.

2 What behaviour of the marbles corresponds to the *gas pressure?*

3 How can you show a gas at a higher temperature?

b ● You can represent the atmosphere, with its particles thinning out higher up, by giving the tray a **very slight** tilt and then keeping it tilted while you shake it.

c ● You can represent a compressed gas by adding more marbles and shaking the tray.
● You can also represent a compressed gas by using a ruler to crowd all the marbles into half the tray. Continue shaking the tray and watch the 'gas' expand when you remove the ruler.

d ● Add a marble whose colour is quite different from the rest. Watch what happens to this marble as you shake the tray.
● Now add a large marble and watch what happens to it.

4 How does the large marble's motion differ from that of the smaller marbles?

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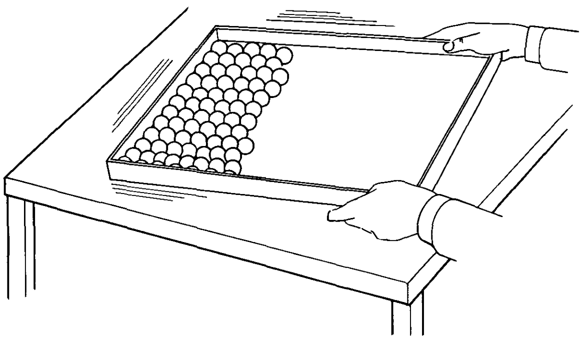
Worksheet P2A [side 2]
Marbles in a tray

Experiment 2: Liquids and solids



a ● Put enough marbles in your tray to fill it at least a quarter full.
● Keep the tray slightly tilted so that all the marbles run down to one end, without running on top of each other.

b ● Shake the tray gently with its lower edge on the table top.
● Watch how with gentle motion the marbles shake down into a regular pattern – like a solid.

c ● Shake a little harder so that the marbles start to move around each other.

1 What does this process represent?

d ● Put a differently coloured marble in with the rest and watch its motion amongst the other marbles.

2 Find the name of the process this represents.

Experiment 3: Evaporating and boiling

a ● Shake a tray of marbles gently and watch what happens to the marbles at the top of the 'liquid'. You should see some marbles escape into the empty space at the top of the tray.

1 What is this process called in a real liquid?

b ● Shake the tray a little harder.

2 What happens to the number of marbles escaping into the space at the top of the tray?

3 What could you do to a liquid that would correspond to shaking a tray of marbles harder?

c ● Shake the tray harder and watch what happens eventually.

4 What does this process represent?

Worksheet **P3A**
What people say about radioactivity

Here are some statements about radioactivity. For each one say whether you think the statement is true or false, or that you just don't know. Give your reasons for thinking that the statements are true or false. For some you will have an immediate answer. Others may mean nothing to you at the moment.

While you are working on radioactivity, turn back to this worksheet when you think you have found out something that makes you able to give an answer.

1 'Radioactive substances make everything near them radioactive.'

2 'All radioactive substances are man-made.'

3 'Once something has become radioactive there is nothing you can do about it.'

4 'We would be better off without radioactivity.'

5 'Some radioactive substances are more dangerous than others.'

6 'Radioactive means giving off radio waves.'

7 'Waste from nuclear power stations is very radioactive.'

8 'Saying that radioactive iodine has a half-life of three days means any produced now will be gone in six days' time.'

Worksheet **P3B** [side 1]
Using radioactivity

Why is radioactivity so useful?

Several properties of the radiations emitted by radioactive materials make them useful.

● Radiation is easy to detect, even in tiny amounts. This makes it easy to locate the radioisotopes that are giving out the radiation.
● Radiation can be very penetrating. It can be used to look inside solid objects, in the same way that X-rays are used.
● Radiation can destroy living cells. This makes it dangerous, but also useful for sterilizing things by killing micro-organisms, and for the treatment of cancer.

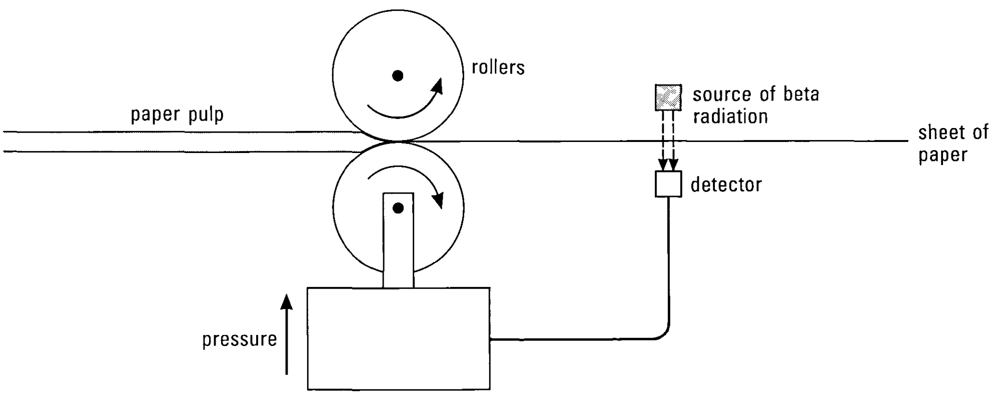
Some examples of uses of radioactivity are given in the following sections. After you have studied them, you will be given some real-life problems to try to solve using radioactivity.

Using radioactivity in industry

Radioactivity has many uses in industry. Here are a few examples.

Measuring thickness

When paper is being manufactured, it is important to get the thickness right. Beta radiation is passed through the paper, and detected the other side. The thicker the sheet, the weaker the beta radiation will be after passing through. This can control the rollers which decide the thickness of the paper. The source of beta radiation is often strontium-90 (^{90}Sr), half-life 28 years.



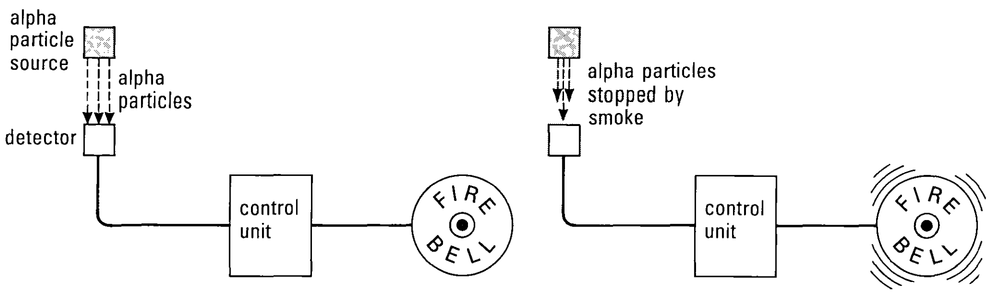
1 Why is beta radiation used and not alpha or gamma radiation?

CONTINUED

Worksheet P3B [side 2]
Using radioactivity

Detecting smoke

Alpha particles are easily stopped, and this makes them useful in smoke detectors. Americium-241, with a half-life of 433 years, is often used as the source of alpha particles.

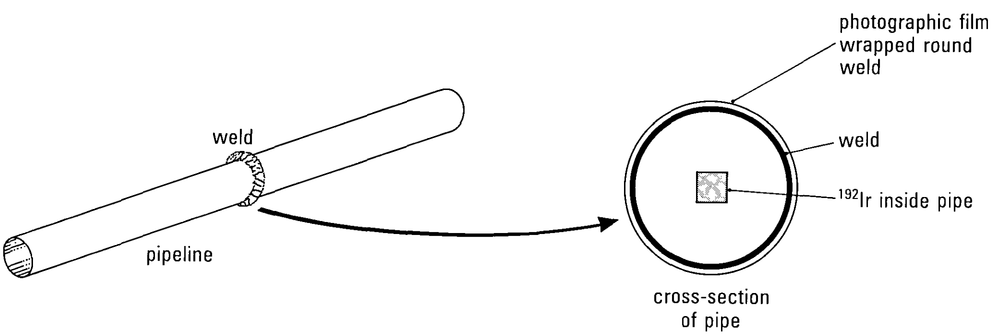


2 Why is alpha radiation used in this case, and not beta or gamma radiation?

3 Why is a radioisotope with a long half-life needed?

Looking at the insides of structures

Gamma radiation can be used like X-rays to get pictures of the insides of solid objects. For example, when underground pipelines are laid the sections of pipe are welded together. It is important to check that the welds do not have any faults inside. This is done using gamma ray photography. Iridium-192(^{192}Ir), half-life 74 days, is often used as the source of gamma rays.



Any faults in the weld show up when the film is developed.

4 Why is gamma radiation used in this case, and not alpha or beta radiation?

Tracing movements

It is often important in industry to know where liquids and gases are travelling. For example, iridium-192 can be added to power station cooling water in tiny quantities. By looking for gamma radiation, scientists can tell where, and how fast, the cooling water has travelled through the many pipes in the power station.

5 Why is gamma radiation used in this case, and not alpha or beta radiation?

CONTINUED

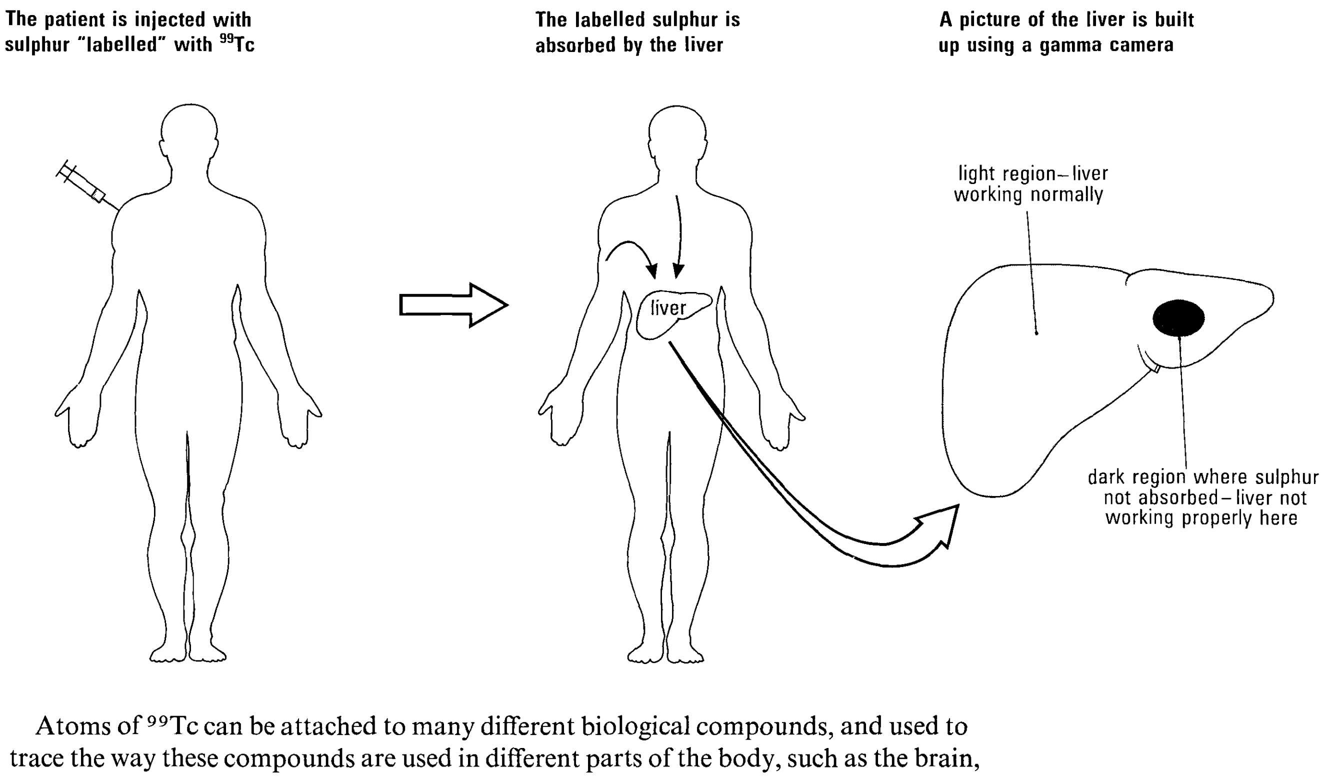
Worksheet P3B [side 3]
Using radioactivity

Using radioactivity in medicine

Medical investigations

Radioisotopes are very useful for investigating the insides of people's bodies without having to cut them open. The radioisotope most commonly used is technetium-99 (^{99}Tc). This gives out gamma rays and has a half-life of about 6 hours.

The diagram below summarizes the way ^{99}Tc might be used to investigate a person's liver. One of the liver's many jobs is to remove unwanted substances from the blood. If a person is injected with small amounts of sulphur, the liver will remove the sulphur by absorbing it. If a small amount of ^{99}Tc is attached to the sulphur, it becomes slightly radioactive and gives out gamma radiation. The ^{99}Tc is a kind of radioactive 'label' on the sulphur. When the radioactive sulphur is absorbed by the liver, it can be detected using a gamma camera.



Atoms of ^{99}Tc can be attached to many different biological compounds, and used to trace the way these compounds are used in different parts of the body, such as the brain, kidneys, lungs and bones.

6 Why is gamma radiation most suitable for this application?

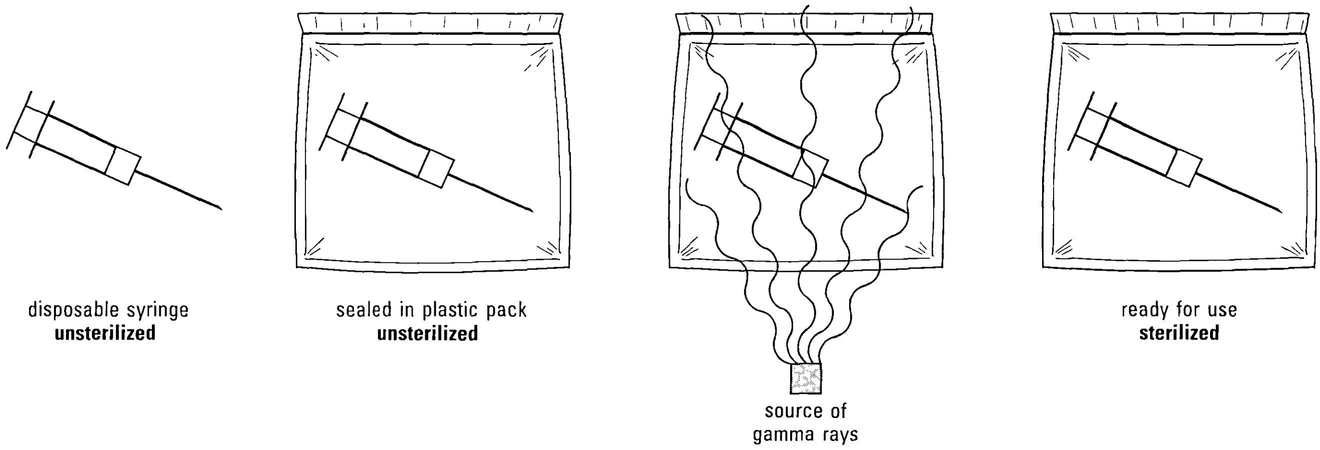
7 Why is it important that the ^{99}Tc has a fairly short half-life of 6 hours?

CONTINUED

Worksheet P3B [side 4]
Using radioactivity

Sterilizing

To avoid infecting patients, many medical items have to be sterilized to kill bacteria and other micro-organisms on them. They are sterilized using gamma rays. This diagram illustrates the method.



Treating cancer

Cancer cells are more easily killed by radiation than normal cells. By aiming gamma rays very accurately at cancerous growths, doctors can try to destroy the cancer cells without affecting the rest of the body. Gamma radiation from cobalt-60 (^{60}Co), half-life 5 years, is often used.

Using radioactivity safely

Radiation is dangerous because it can kill living cells. Careful safety precautions must be taken when using radioisotopes. Strong sources of radiation are put behind lead or concrete screens. People who work with radioisotopes are checked each day to make sure they have not received too much radiation.

However, the amount of radiation we get from artificial radioisotopes is small compared to the natural radiation that comes from the rocks around us, from the Sun and from space.

CONTINUED

Worksheet P3B [side 5]
Using radioactivity

Solving problems using radioactivity

This section includes a list of problems that have been solved using radioactivity. Each problem can be solved using a radioisotope from this table:

Radioisotopes

Isotope	**Solid, liquid or gas**	**Type of radiation**	**Half-life**
polonium-210	solid	alpha	138 days
hydrogen-3	gas	beta	12 years
strontium-90	solid	beta	28 years
cobalt-60	solid	gamma	5 years
iridium-192	solid	gamma	74 days
xenon-133	gas	gamma	5 days

For each problem say

a how you would use radioactivity to solve the problem (draw diagrams if possible)

b which radioisotope you would use, and why.

The first problems are the easiest.

Problem 1: Polythene sheeting

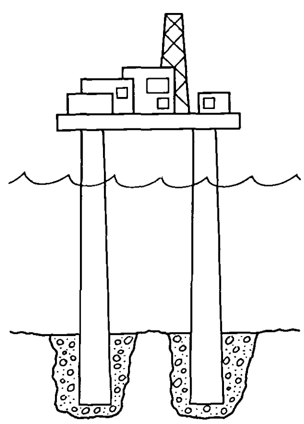
Your company makes polythene sheeting by passing thick sheets of polythene through rollers. How will you make sure the sheeting is of even thickness?

Problem 2: Petri dishes

Your company manufactures plastic Petri dishes. They are used for growing bacteria in laboratories, so it is important that they are sterile when delivered to the customer. They cannot be sterilized by heating because the plastic would soften. What will you do?

Problem 3: Lungs

You are a hospital consultant specializing in treating breathing problems. You suspect that one of your patients has a blockage in an air passage in one of her lungs. How can you check?



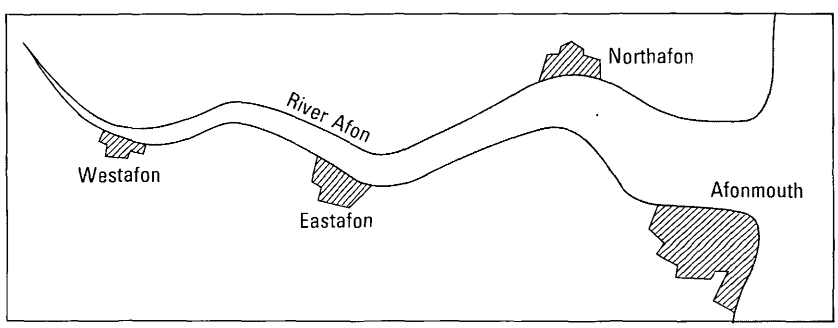
Problem 4: North Sea oil rig

You work for an engineering company that builds North Sea oil rigs. The legs of the rigs are set into the sea bed with concrete. It is essential that the concrete contains no faults or air pockets, otherwise the rig may blow over in a storm. How can you check?

Problem 5: Shifting sands

You work for the Afon River Authority.

You have a problem because the river is getting blocked by silt (fine sand) near Afonmouth. How can you find out where the silt is being carried from?



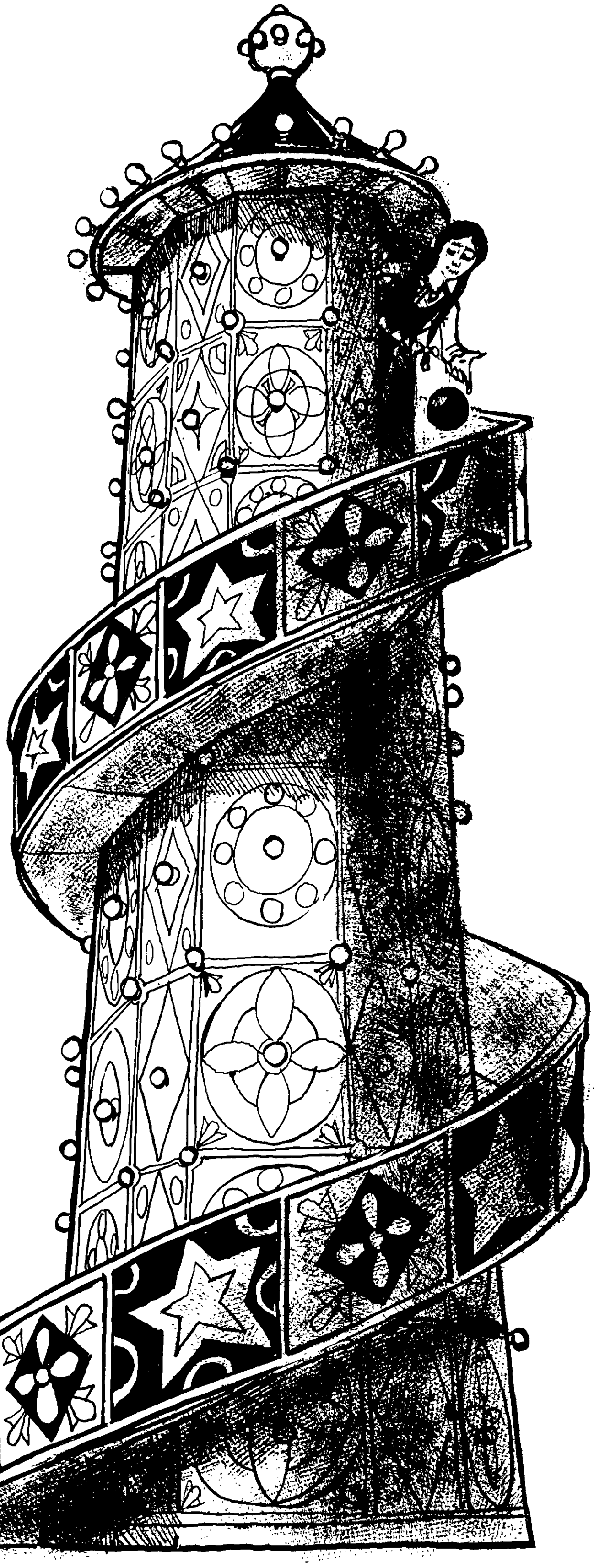
Worksheet **P4A**
Inventing a timing device

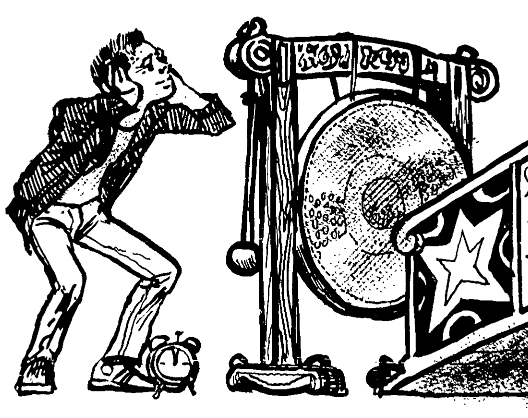
Scientists often need good measuring instruments in order to do experiments. This worksheet asks you to invent your own timing device. Your timing device must make a noise two minutes after it has been started. Your aim must be to make it do this as precisely and reliably as possible.

a
- Design and construct a timing device that will make a noise two minutes after it has been started.
- Plan what you will do carefully before you start. Think about what equipment and materials you will need before you begin constructing your timing device.

b
- Perform all your initial tests as carefully as you can. Remember: to make your timer make a noise after exactly two minutes you will have to be very precise.

c
- Write a report on what you have done. In your report you should:
  - **i** describe how you planned the construction of your timing device.
  - **ii** describe how you decided what equipment and materials to use.
  - **iii** describe how you tested your timing device.
  - **iv** describe what results your tests produced, and any improvements you made to your design as a result of these tests.
  - **v** include a drawing or photograph of your invention.





Worksheet P4B [side 1]
Measuring time intervals

Measuring speeds in the laboratory often depends on being able to measure small time intervals. The following experiments will give you experience of measuring small time intervals using a variety of devices.

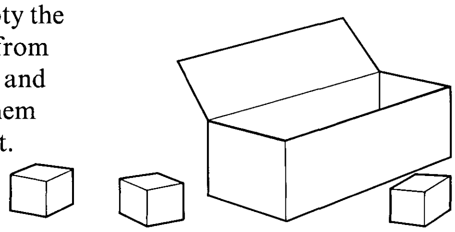
Experiment 1: Using a stop-watch

You will need:
a stop-watch (use your own watch if it has a stop-watch button)
a box with a set of blocks to put in it

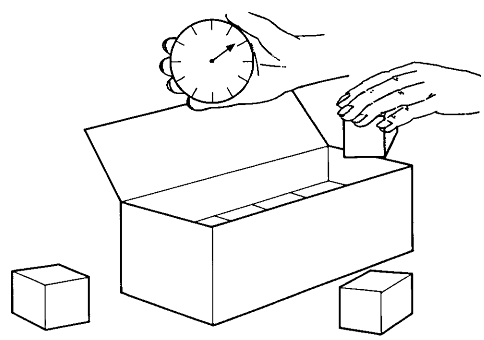
Imagine you are a 'time and motion' expert who has been called in to find out how fast a person can pack a box with blocks.

Make sure that you can start and reset your stop-watch. The pictures show an analogue display:  Your stop-watch may have a digital display: 00.05

a ● Empty the blocks from the box and place them beside it.

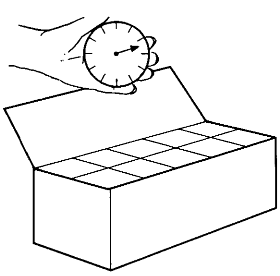


b ● Time how long your partner takes to fill the empty box with blocks.
● Tell your partner when to start packing the box, and start the stop-watch at the same time.



c ● As soon as the box is full, stop the stop-watch.

1 How long did your partner take?
2 In a real time and motion study you would repeat this experiment several times and find an **average time** for your partner. Why would you do this?



d ● Change places with your partner. See if you can beat your partner's time.

3 Why do you think time and motion studies are used in industry?

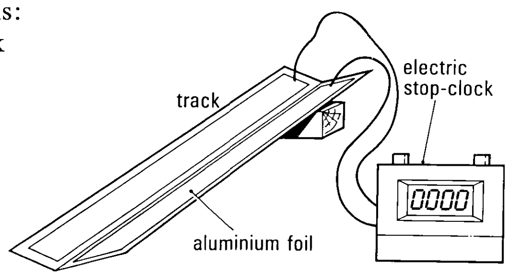
CONTINUED

Worksheet P4B [side 2]
Measuring time intervals

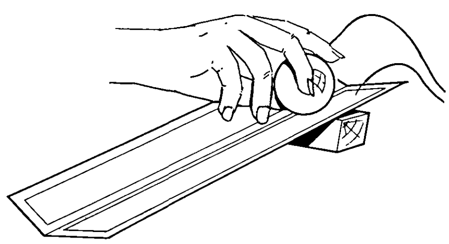
Experiment 2: Using an electric stop-clock

You will need:
an electric stop-clock
connecting wires
a grooved track that has a 20 cm long piece of aluminium foil along each edge
a block to support one end of the track
a metal ball (large ball bearing)

a ● Set up your apparatus like this:
● Make sure that the stop-clock is reading zero, and that its power supply is switched on.



b ● Check that the apparatus is working by placing the ball bearing on the two strips of aluminium foil. This completes the electric circuit, and the stop-clock should start working.
● As soon as the stop-clock starts working, take the ball off the track and reset the clock.



c ● When the clock has been reset, carefully place the ball at the top of the track and allow it to roll down the groove.

The clock will start as soon as the ball touches the aluminium foil strips, and will stop when the ball reaches the end of the foil.

● Record how long it took the ball to roll 20 cm.

d ● Take some more results by repeating step **c** several times. Each time alter the slope of the track.

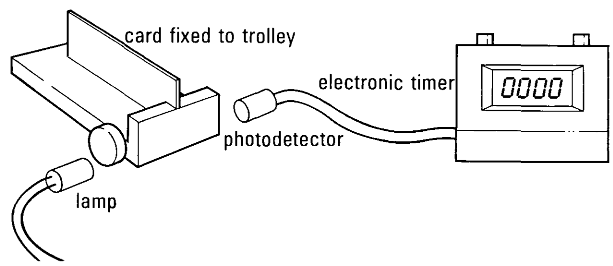
CONTINUED

Worksheet P4B [side 3]
Measuring time intervals

Experiment 3: Using an electronic timer

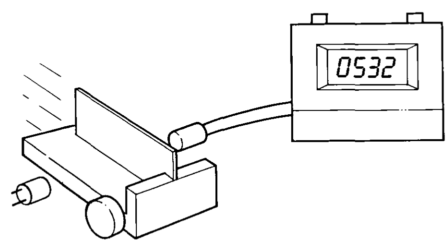
You will need:
an electronic timer
a lamp
a photodetector
a dynamics trolley
a piece of card 20 cm by 8 cm

a
- Set up the apparatus like this:
- Make sure that the electronic timer's power supply is switched on.
- Point the lamp's beam onto the photodetector.
- Switch on the timer. It should only operate when you put an object between the lamp and the photodetector.



b
- Make sure that the timer is reading zero.
- Roll the trolley between the photodetector and the lamp. The timer will work while the card is interrupting the light beam.

The electronic timer shows how long the card took to pass through the beam.



c
- Now try rolling the trolley through the beam at several different speeds. Record your measurements each time.

Calculating speeds

Do not do this part until you have reached section **P4.2** in your Physics book.

In Experiment 2 on this worksheet you measured the time it took a ball bearing to run down a slope over a distance of 20 cm. In Experiment 3 you measured the time it took a 20 cm long card mounted on a trolley to pass through a light beam. You can now work out the speeds of the ball bearing and the trolley, using the measurements you recorded. Here is one example:

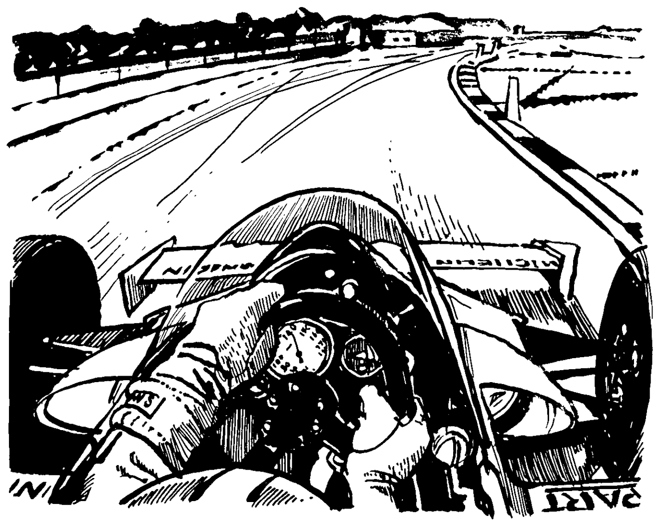
Suppose you found the card on the trolley took 0.5 s to cross the light beam. The length of the card was 20 cm. You can find the average speed of the card like this:

$$\text{average speed} = \frac{\text{length of card}}{\text{time card took to cross beam}}$$

So in this case the average speed is: $\frac{20\text{ cm}}{0.5\text{ s}} = 40\text{ cm/s}$.

Now calculate some speeds from your own measurements from Experiments 2 and 3.

Worksheet **P4C** [side 1]
Plotting a distance–time graph



Being able to plot and read graphs accurately is an important skill in science. This worksheet shows you how to plot a distance–time graph and use it to find the speed of a moving object.

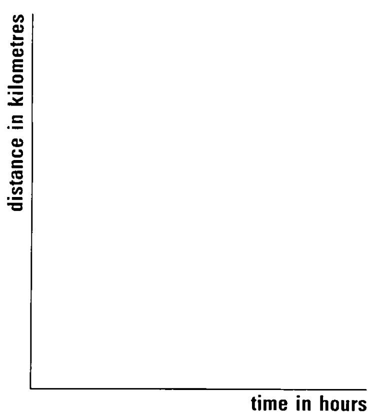
The data in the table below shows how the distance travelled by a racing car changed with time during a long distance race. The distance travelled was recorded every half-hour for three hours.

Time in hours	**Total distance travelled in kilometres**
0	0
0.5	60
1.0	140
1.5	240
2.0	340
2.5	420
3.0	480

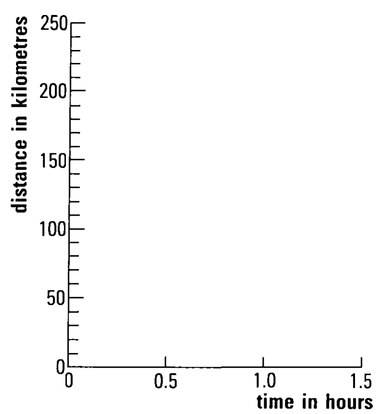
After 0.5 hours the car had travelled 60 kilometres altogether.

Follow the steps below to plot a distance–time graph of the data.

a
- Draw two axes on your paper, one vertical and the other horizontal.
- Mark the vertical axis '**distance in kilometres**' and the horizontal axis '**time in hours**'.



b
- Pick a suitable unit to represent the time on the time-axis; one unit per half-hour would be suitable. Mark in the half-hours: 0, 0.5, 1.0, 1.5, and so on.
- Now do the same with the distance-axis; one unit per 50 km would be suitable here. Mark in the distance: 0, 50, 100, 150, and so on.



These choices of units are called scales. Remember to write the scales on your axes, to help anyone else who may want to get information from your graph at a later date.

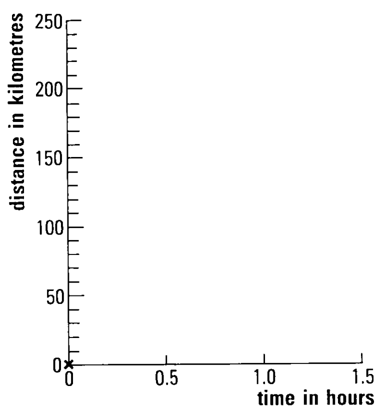
CONTINUED

Worksheet P4C [side 2]
Plotting a distance–time graph

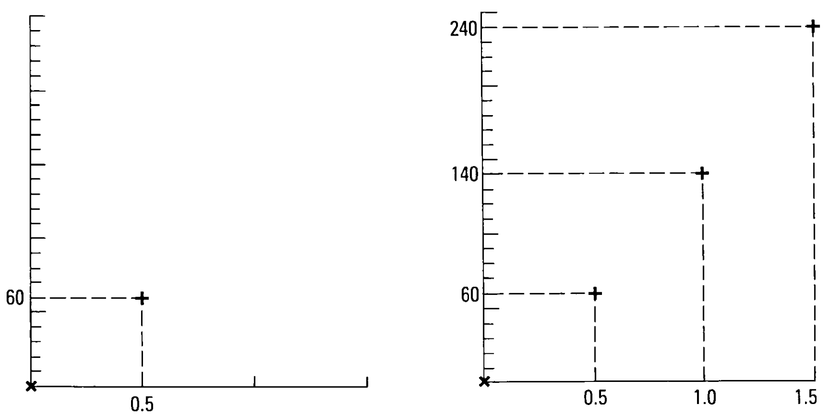
c

● Now start plotting the points. The first point is (0 h, 0 km), so place a mark where both the hours and kilometres are zero.

● The next point is (0.5 h, 60 km). Find the place on the time-axis which is marked 0.5 h and imagine a line going vertically from this point. Now find the 60 km mark on the distance-axis and imagine another line going horizontally from this point. Where these two imaginary lines cross is the next point.



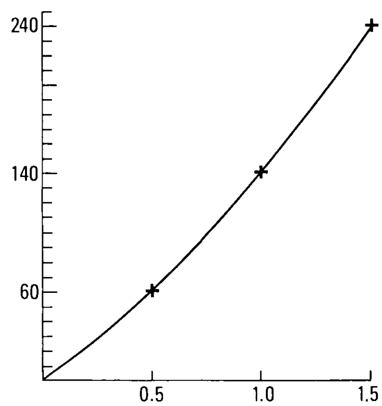
● Use the same method to plot all the other points.



d

● Now join up the points.

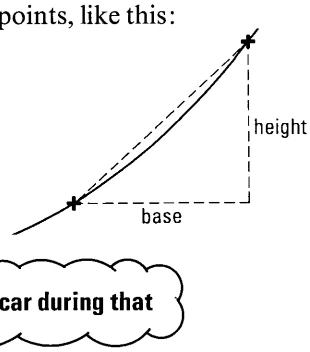
If the car has travelled at a steady speed during each of the half-hour intervals, you could join up the points with straight lines. However, this is very unlikely to be the case, so it is best to draw a smooth curve through the points.

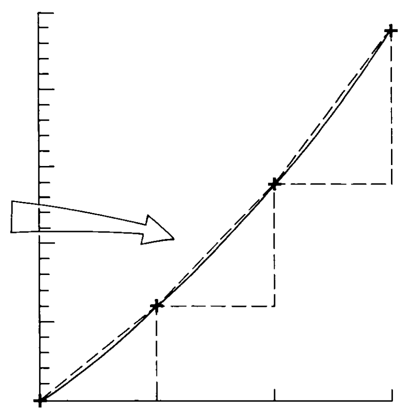


e

● To find the average speed for each time period you should draw right-angled triangles between each of the points, like this:

● Take each triangle in turn and measure its base and its height in scale units. Divide the height by the base to get the slope of that part of the graph.





This slope is the average speed of the racing car during that period of time.

Here is a question to think about:

How would you calculate the racing car's average speed for the complete three hours ? Question **11** in Section **P4.2** of your Physics book should help you to do this.

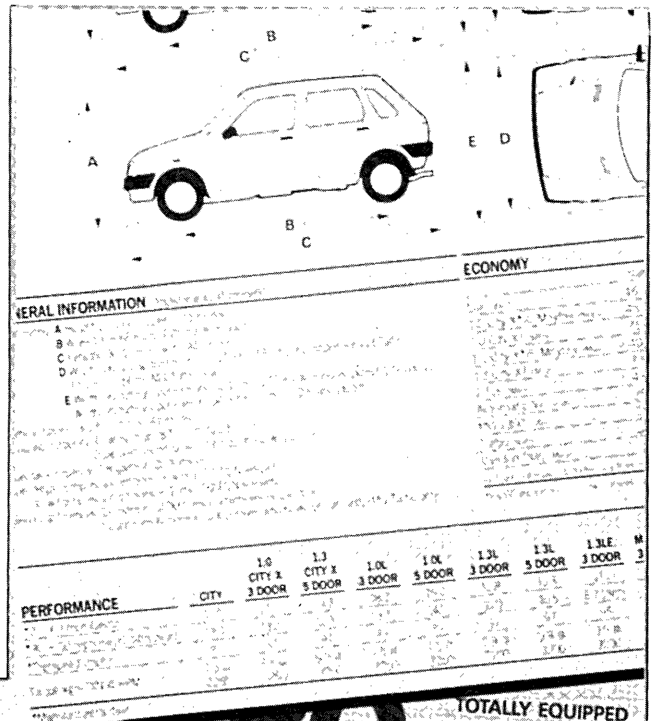
Worksheet **P4D**
Car performances

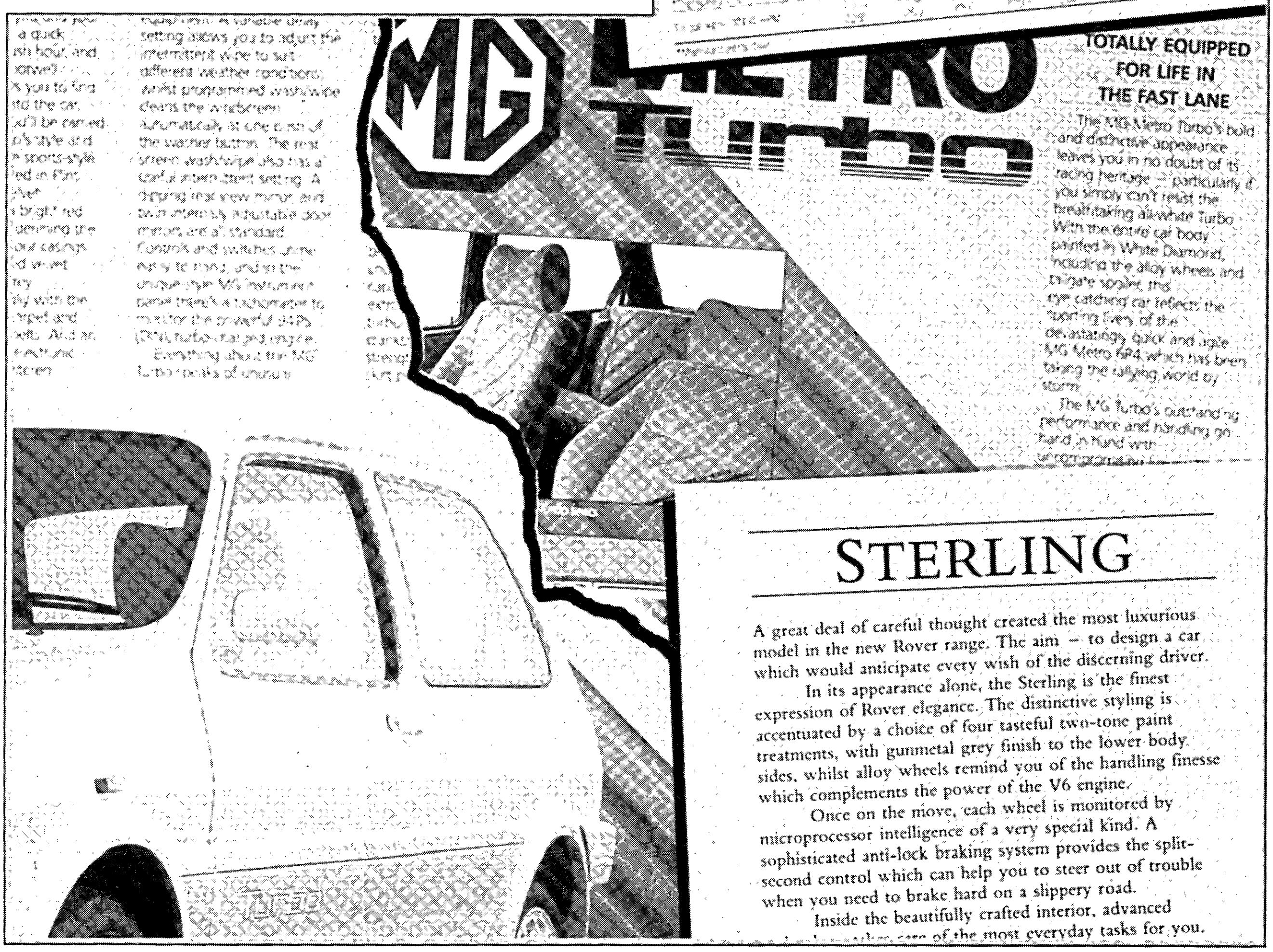
Many car manufacturers try to help sell their cars by telling you how long they take to accelerate to a given speed from a standing start. For example, a car might be able to reach 60 miles/hour in 12 seconds.

1 What is the average acceleration of such a car, in metres per second every second? (Remember that 5 miles is very nearly 8 kilometres, so 60 miles/hour is about 96 kilometres/hour.)

2 Some people think that cars which can accelerate quickly are dangerous. Other people say that it is safest to have a car which can accelerate quickly. Give any arguments you can think of for and against cars which can accelerate quickly.

3a Collect as much information as you can about the times different cars take to reach a speed of 60 miles/hour from a standing start. (Motoring magazines and brochures from car showrooms may help.)
b Display the information in the form of a chart so that it is easy to see which cars have the greatest acceleration.



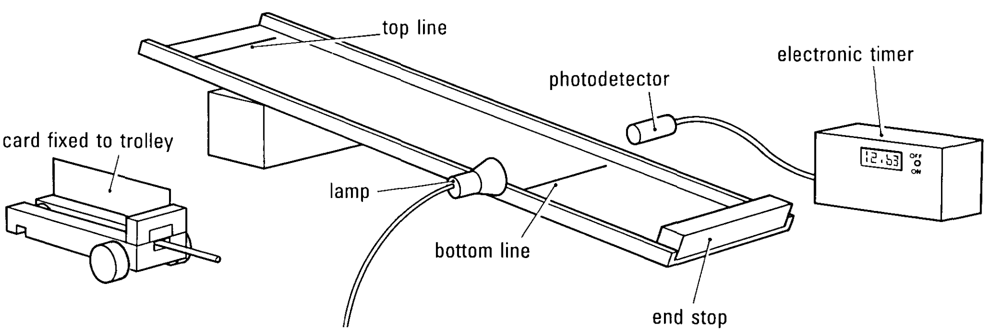


Worksheet **P4E** [side 1]
Measuring acceleration

This experiment shows you how to measure the acceleration of a trolley running down a ramp. If you have time you can extend the experiment by investigating how the acceleration of the trolley changes with the slope of the ramp.

You will need:
a dynamics trolley
a piece of card 20 cm by 8 cm
a trolley runway
an end stop
a block to support the trolley runway
an electronic timer
a photodetector and lamp
a stop-watch

Experiment



a ● Set up the apparatus like this:
● Place the photodetector and lamp on either side of the bottom line on the trolley runway. The beam from the lamp must shine on the photodetector.

b ● Copy this table:

This is the time on the electronic timer. (→ B)

This means you can find the final speed by dividing measurement A by measurement B. (→ C)

This is the time on the stop-watch. (→ F)

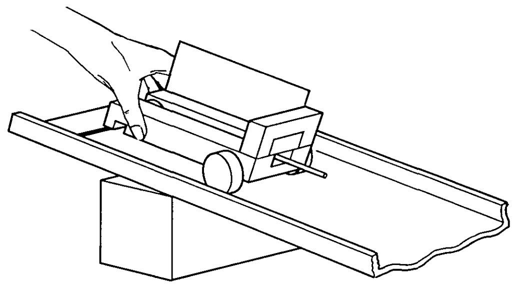
A. Length of card in metres		
B. Time it took card to pass through light beam in seconds		
C. Final speed of trolley in metres/second (A/B)		
D. Initial speed of trolley in metres/second		
E. Change in speed of trolley in metres/second (C – D)		
F. Time it took trolley to change speed, in seconds		
G. Acceleration of trolley in metres per second/second (F/E)		

c ● Switch on the electronic timer and make sure that it is reading zero.
● Set the stop-watch to zero.

CONTINUED

Worksheet P4E [side 2]
Measuring acceleration

d • Hold the trolley at the top of the trolley runway. The back edge of the card should be exactly over the top line on the trolley runway.



• Let go of the trolley and start the stop-watch at the same time.
• Stop the stop-watch as soon as the card has passed through the light beam.
• Record the times on the stop-watch and electronic timer in your table.

e • Try getting some different results by altering the slope of the trolley runway. Each time record your measurements in your table.

f • Find the acceleration of the trolley for each set of measurements you recorded. You can do this by completing your table. The letters in brackets in the table show you how.
• Here are some points to remember:

i You can find the acceleration like this:

$$\text{acceleration} = \frac{\text{change in speed}}{\text{time taken for change}}.$$

ii The starting speed of the trolley is zero, as it is held still at the top of the trolley runway.

iii The final speed of the trolley as it passes through the light beam can be found like this:

$$\text{final speed} = \frac{\text{length of card}}{\text{time on electronic timer}}.$$

iv The change in the speed of the trolley can be found from:

change in speed = final speed − starting speed.

v The time it takes the trolley to change its speed is given by the reading on the stop-watch.

Extension (hard)

Try to find a relationship between the acceleration of the trolley and the slope of the trolley runway.

Using a microprocessor

If your school has a VELA (Versatile Laboratory Aid) or a similar device, you can use it to measure time intervals and speeds. Use the handbook that goes with the equipment to find out how to measure time intervals by connecting the equipment to a lamp and a photodetector.

Alternatively, your school may have a special attachment for a computer (such as the BBC microcomputer) which you can use to measure both times and speeds.

Worksheet P5A
What keeps things moving?

Section P5.1 in your Physics book has given you two theories about motion:

Theory 1
To keep a thing moving it has to be pushed or pulled. Without force there is no motion.

Theory 2
Once a thing is moving it will stay that way. All forces do is change its motion.

You are going to do some experiments to investigate which theory seems to be the better one.

What keeps this trolley moving?

Investigation

> *You can use:*
> a trolley runway to move things
> an end stop
> wooden blocks
> masses
> a force meter to measure forces
> an electronic timer to measure speeds
> a photodetector and lamp
> a piece of card 20 cm by 8 cm
>
> *You do not have to use any of these things if you do not want to!*

a ● Plan and carry out an investigation to find out which theory is best.

b ● Here are some questions you can think about which may help you plan your investigation:

> *Theory 1*
> **i** If a force is needed to keep things moving, is it always the same force?
>
> **ii** What do you have to do to change the speed at which something is moving? What happens if you increase its mass?
>
> *Theory 2*
> **iii** If no force is needed to keep things moving, why do they come to rest if you stop pushing?
>
> **iv** If you give something a push, does it always take the same time or the same distance to stop moving? Can you change how far it travels before it stops?

c ● Write a brief report on your findings. If you have time, present your report to the rest of the class and discuss what other people have found.

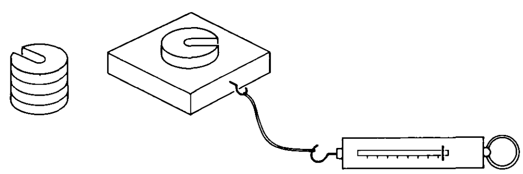
Worksheet P5B
Investigating friction

In order to understand why a force is needed to keep something moving, it is important to understand something about the force of friction. You are going to investigate the force of friction between a block and your work surface.

You will need:
a block with a hook in one edge — a 0–10 N force meter
a piece of thread — a set of 100 g masses

Investigation

a ● Set up your apparatus like this, with a 100 g mass on the block.



b ● Make a copy of this table:

mass on block in kilograms	Force needed to pull block steadily, in newtons

c ● Now gently pull on the force meter until the block is moving at a steady speed.
● While this happens, take a reading on the force meter and record it in your table.

d ● Repeat step **c** several times; each time add another mass to the pile on your block.
● Record all your readings in your table.

When the block is moving steadily the pulling force is equal but opposite to the force of friction between the block and the work surface.

1 What relationship, if any, is there between the mass on the block and the force of friction between the block and the work surface?

Continuing the investigation

e ● You can now continue your investigation into friction by doing some experiments to answer the following questions.

2 Does the area of contact between the block and your work surface affect the force of friction?
3 Try using a block of a different material. Does this affect your results?
4 Try putting a little furniture polish between the block and your work surface. How does this affect your results?

f ● Write a report on your investigation. Try to explain anything you have discovered.

Worksheet **P5C**
Investigating frictionless motion

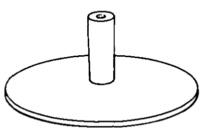
What happens to a moving object if no friction forces act on it? In the following two experiments you are going to investigate motion in the absence of friction.

Experiment 1 : A model hovercraft

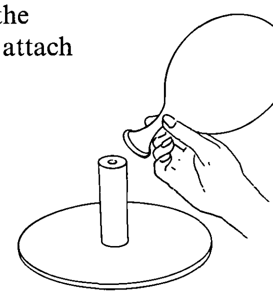
You will need:
a balloon
a piece of dowel with a hole drilled down its centre
a hardboard disc with a hole in its centre

Make sure the dowel fits the hole in the hardboard disc.

a ● Glue the piece of dowel into the hole in the hardboard disc and leave it to dry.



b ● Blow up the balloon and attach it to your 'hovercraft'.



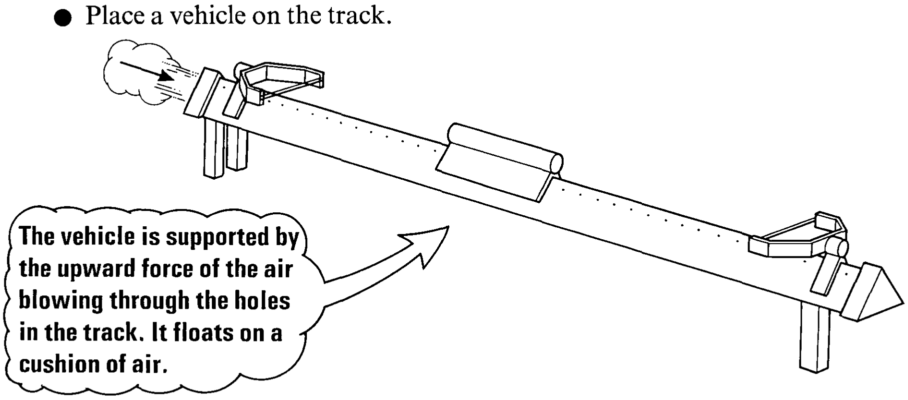
c ● Give your hovercraft a gentle push and watch how it moves.

1 Describe the way your hovercraft moves. For example, does it move steadily in a straight line?
2 Explain why your hovercraft moves in this way.

Experiment 2: An air track

You will need:
an air track and accessories

a ● Switch on the blower connected to the air track.
● Place a vehicle on the track.



b ● Give the vehicle a gentle push so that it makes a soft collision with the elastic band at the end of the track.
● Observe how the vehicle moves.

1 Describe the way your vehicle moves.
2 Which theory describes this type of motion?

Worksheet P5D
Unbalanced forces

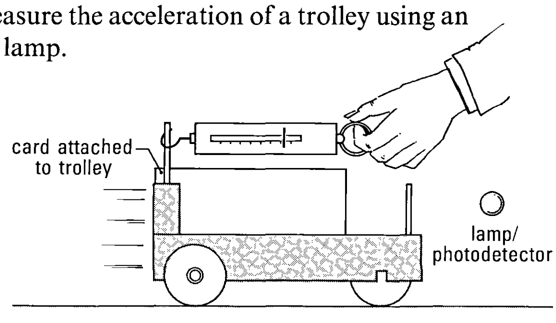
When unbalanced forces act on an object, its motion changes. You are going to investigate the way the motion of a trolley changes when an unbalanced force acts on it.

Investigation 1: The effect of the force on acceleration

You will need:
a dynamics trolley
a trolley runway
an electronic timer
a photodetector and lamp
a stop-clock
a piece of card 20 cm by 8 cm
a force meter to pull the trolley along

Worksheet P4E showed you how to measure the acceleration of a trolley using an electronic timer, a photodetector and a lamp.

● Plan and carry out an investigation to find out what happens to the acceleration of a trolley when it is pulled by an unbalanced force.
● The details of the investigation are left to you, but here are two questions you may like to answer:



1 Does a constant force produce a constant acceleration?
2 In what way does the size of the acceleration depend on the size of the unbalanced force?

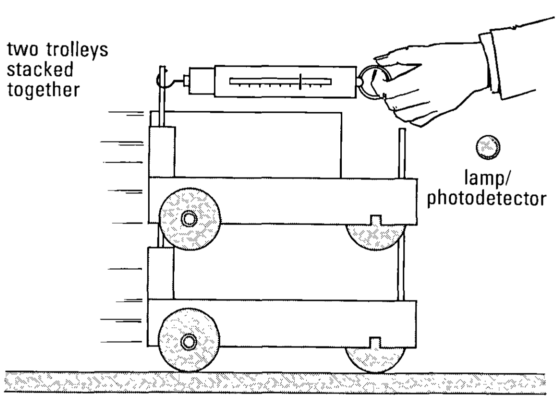
Investigation 2: The effect of mass on acceleration

You will need:
the equipment you used for Investigation 1
a method of increasing the trolley's mass

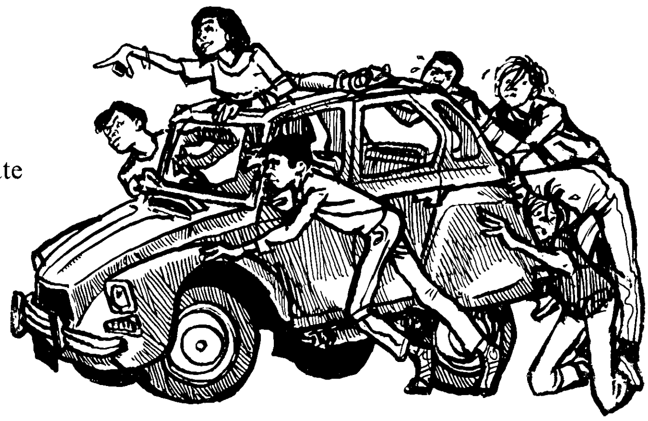
● Plan and carry out an investigation to find out whether the acceleration of a trolley is affected by the mass of the trolley.

Hint: Keep the unbalanced force on the trolley constant.

● The details of the investigation are left to you.



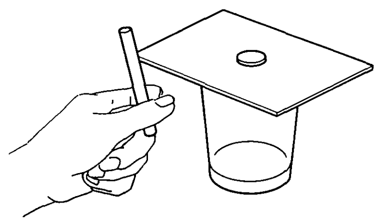
Worksheet **P5E** [side 1]
Inertia



In the following experiments you are going to investigate how difficult it is to start and stop moving objects.

Experiment 1

You will need:
a piece of card
a beaker or glass tumbler
a coin
a small piece of dowel rod



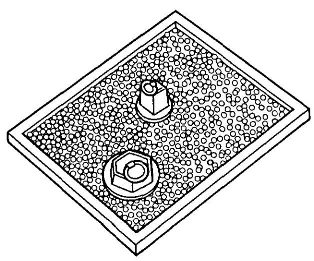
a ● Set up the beaker, card and coin like this:

b ● Give the card a sharp tap with the rod.

1 What happened to the coin?
2 Explain why this happened.

Experiment 2

You will need:
a tray of beads
two hardboard discs
a large mass
a small mass



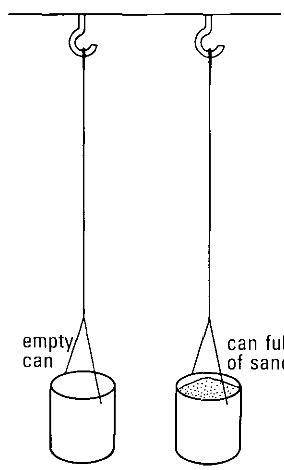
a ● Set up the apparatus like this:

b ● Compare the amount of force that is required to start each mass moving.

1 Which mass was it harder to move?
2 Explain why a greater force was needed to move this mass.

Experiment 3

You will need:
two identical cans
sand
string



a ● Suspend the cans like this:

b ● Push each can and feel the force needed to move it.

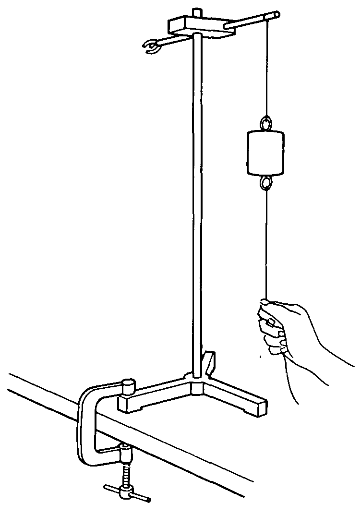
1 One of the cans is empty, the other is filled with sand. Which is it more difficult to start or stop?
2 Explain why a greater force was needed to move this can.

CONTINUED

Worksheet P5E [side 2]
Inertia

Experiment 4

You will need:
a large mass
two pieces of thread
a retort stand, boss and clamp
a G-clamp



a ● Set up the apparatus like this:
● Slowly increase the pull on the bottom thread.

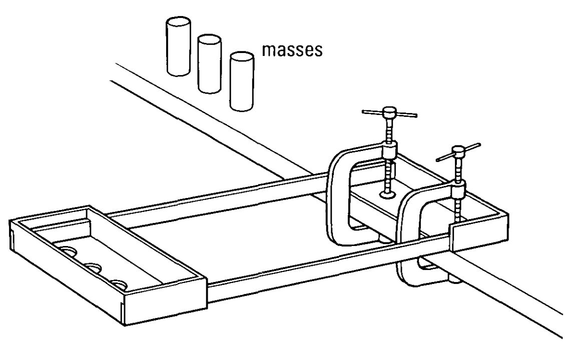
1a Which thread breaks?
b Explain why.

b ● Now set up the apparatus again.
● This time give the bottom thread a sudden tug.

2a Which thread breaks now?
b Explain why.

Experiment 5

You will need:
an inertia balance
two G-clamps
three masses



a ● Set up the inertia balance like this:

b ● Gently pull the inertia balance to one side and release it.

1 What happens?

c ● Put a mass in the balance and repeat step **b.**

2 What happens now?

d ● Repeat step **b** with two masses in the balance, and then three.

3 What connection, if any, can you find between the time the balance takes to move 'to and fro' and the mass in the balance?

Worksheet P6A [side 1]
Kinetic energy

Energy has to be transferred to a body to set it in motion. The energy stored by a moving body in this way is called kinetic energy.

Experiments 1, 2 and 3 involve transferring energy to a trolley when setting it in motion.

Experiment 1

You will need:
a dynamics trolley
a trolley runway

a • Place the trolley on a level surface.

b • Give the trolley a sharp push.

1 What happens to the trolley?

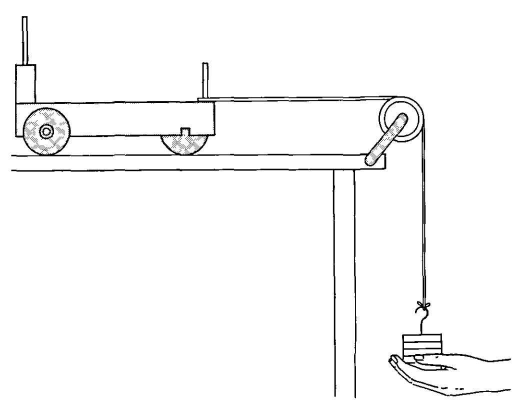
2 Where was the energy transferred from to set the trolley in motion?

3 Where has the energy been transferred to when the trolley comes to rest?

Experiment 2

You will need:
a dynamics trolley
a pulley on a clamp
string
slotted masses on a holder

a • Set up the apparatus like this:



b • Release the masses so they fall to the floor.

1 What happens to the trolley:
a while the masses are falling?
b once the masses have reached the floor?

2 What is the effect on the trolley of:
a letting the masses fall a greater distance to the floor?
b increasing the size of the falling mass?

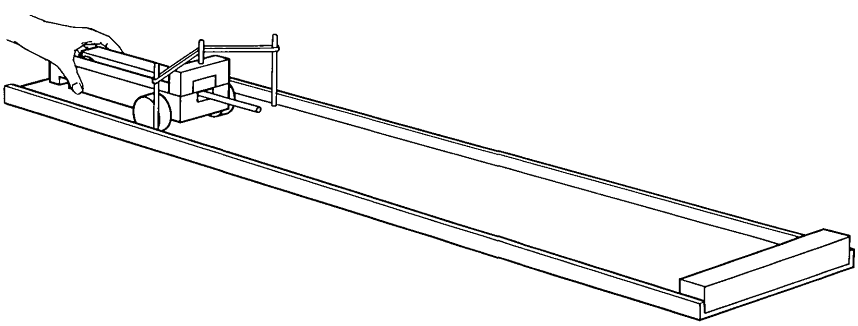
CONTINUED

Worksheet P6A [side 2]
Kinetic energy

Experiment 3

You will need:
two dynamics trolleys
an elastic catapult
a trolley runway
an end stop

a • Set up the apparatus like this:



• Give the trolley runway a small slope so that the pull of the Earth just balances the force of friction on the trolley.

b • Catapult the trolley down the trolley runway.

1 What happens to the trolley?
2 From where is the energy transferred?

c • Try using two elastics to catapult the trolley, but stretch the catapult back the same distance as before.

3 Does this transfer the same or more energy to the trolley? Explain your answer.
4 Does the trolley move faster, or at the same speed as before?

d • Now use the same catapult, stretched back the same distance, to catapult **two** trolleys down the trolley runway.

5 How has the speed of the trolleys changed?
6 How has the energy transferred to the trolleys changed?

Experiments 4 and 5 show you how the kinetic energy of an object is related to its mass and speed. It is not essential to do these experiments. Your teacher will tell you whether you should do them or not.

If a trolley is pushed with a steady force, its speed will increase. The energy transferred to the trolley is equal to the work done by the force. With more knowledge of the way forces can increase speed it is possible to work out how the kinetic energy gained by a trolley is related to its mass and speed. Such calculations show that the kinetic energy of a moving body is given by the equation:

kinetic energy $= \frac{1}{2}m v^2$.

A **Help sheet** will show you how this equation is derived.

CONTINUED

Worksheet P6A [side 3]
Kinetic energy

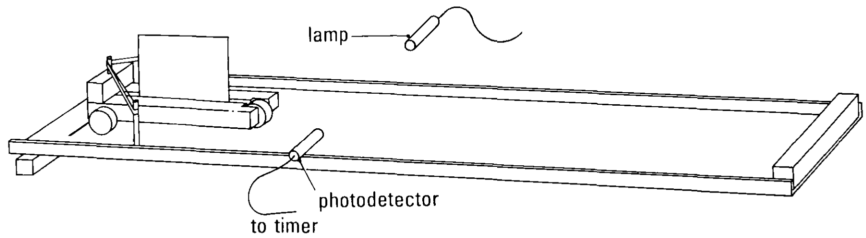
If you do Experiments 4 and 5 you will need:

two dynamics trolleys	an electronic timer
a trolley runway	a photodetector and lamp to control the timer
an end stop	a piece of card 20 cm by 8 cm
an elastic catapult	

Experiment 4: Changing the mass

a ● Set up this apparatus:

The timer is used to measure the time it takes the card to pass through the light beam.



● Give the trolley runway a small slope so that the pull of the Earth just balances the force of friction on the trolley.

b ● Mark a line on the trolley runway so that you can always pull the catapult back the same distance.
● Catapult the trolley along the trolley runway and measure its speed just as it leaves the catapult. (Why is it necessary to measure its speed at this point rather than further down the runway?)
● Repeat this several times and find an average speed.

c ● Now double the mass of the trolley. (Pile one trolley on top of another.)

How much energy has to be transferred to the trolleys now to make them leave the catapult at the same speed as before?
The answer is that the energy will have to be doubled.

d ● You can double the energy given to the trolleys by putting two elastics across the catapult instead of one. (The second elastic must be identical to the first elastic.)
● Check whether the trolleys do leave the catapult at the same speed as before.

Experiment 5: Changing the speed

How much energy would have to be transferred to a single trolley in order for it to leave the catapult at double the speed?

The answer is that the energy would have to be increased to four times the original amount. (Ask for help if you cannot see why this is so.)

a ● Increase the energy given to the trolley to four times the original amount by putting four elastics on the catapult. (All elastics must be the same as the first one.)

b ● Check to see if this prediction is correct. ▶

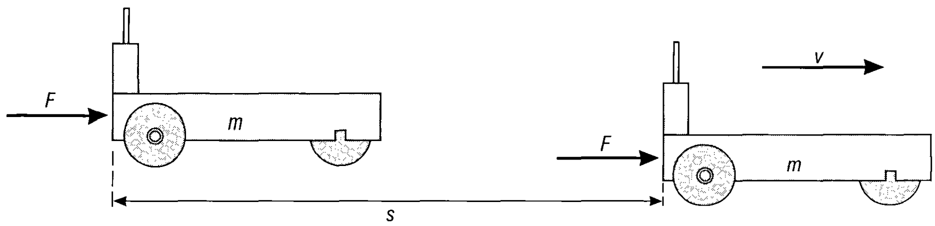
A trolley catapulted off four elastics should leave the catapult at twice the speed a trolley leaves a one-elastic catapult.

Worksheet P6A
Kinetic energy
Help sheet

Finding an equation for kinetic energy

The trolley, of mass m, starts from rest.

Pushed by the steady force, F the trolley reaches a speed v in a distance s.



The energy transferred to the trolley in giving it speed v is Fs.

▼

Using Newton's second law

The force F pushing a trolley of mass m gives it an acceleration a.

The force F, the mass of the trolley m, and the acceleration a, are linked by the equation:

$$F = m\,a.$$

Substituting $m\,a$ for F in the equation for the energy transferred to the trolley gives:

$$\text{energy transferred} = (m\,a)\,s.$$

Finding the acceleration of the trolley

The trolley accelerates to a speed v.

The average speed of the trolley is $v/2$.

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}.$$

$$\text{So: time taken} = \frac{\text{distance travelled}}{\text{average speed}}$$

$$= \frac{s}{(v/2)} = \frac{2s}{v},$$

and:

$$\text{acceleration} = \frac{\text{gain in speed}}{\text{time taken}}$$

$$= \frac{v}{2s/v} = \frac{v^2}{2s}$$

▼ ▼

We can now use the equation for the acceleration to find an equation for the kinetic energy of the trolley:

$$\text{kinetic energy} = \text{energy transferred to trolley}$$

$$= (m\,a)\,s$$

$$= m\frac{v^2}{2s}s$$

$$\boxed{= \tfrac{1}{2}m\,v^2}$$

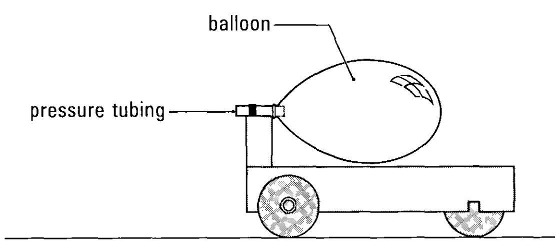
Worksheet P6B [side 1]
Recoil

Recoil is the name we give to the moving apart of two objects that push against each other. These experiments investigate some patterns in the motion of objects when they recoil.

Experiment 1

You will need:
a dynamics trolley
a balloon
50 mm of pressure tubing to fit firmly into the neck of the balloon
sticky tape
100 g slotted masses to place on trolley
a trolley runway
an end stop

a ● Attach the balloon to the pressure tubing and inflate the balloon.
● Attach the inflated balloon and tubing to the trolley.
● Release the trolley.



1 What happens?

b ● Try blowing the balloon up harder.

2 What effect does this have on the motion of the trolley?

c ● Now try changing the mass of the trolley.

Try to inflate the balloon by the same amount each time you do this experiment.

3 What effect does changing the mass have on the trolley's motion?

Where is the recoil in this picture?

CONTINUED

Worksheet P6B [side 2]
Recoil

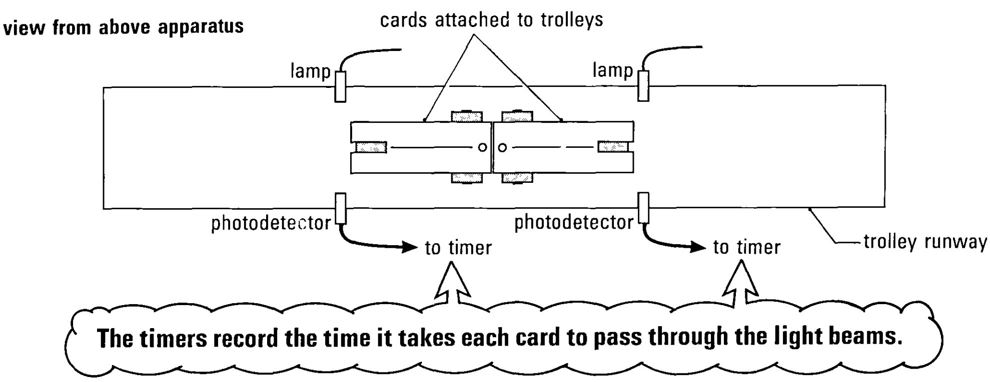
Experiment 2

You will need:

a piece of wood	two lamps
four trolleys	two timers
a trolley runway	two 20 cm by 8 cm pieces of card
two photodetectors	

For this experiment use trolleys which can be made to 'explode' apart from each other when held together and then released. This may be done by a spring-loaded plunger which can be released by giving a peg a sharp tap with a piece of wood. Another way is to have two strong magnets fixed on the trolleys with similar poles opposite each other.

a ● Arrange two trolleys, the light gates, timers, cards and trolley board like this:



b ● Make a copy of this table:

LEFT-HAND TROLLEY				RIGHT-HAND TROLLEY			
mass of trolley	time for card to pass through light beam	speed of trolley	mass x speed	mass of trolley	time for card to pass through light beam	speed of trolley	mass x speed

c ● Release the trolleys so that they 'explode' apart.
● Note down in your table the time it takes each card to pass through the light beams.
● Fill in the rest of the columns in your table.

d ● Now repeat your experiment using two trolleys on the left-hand side and one trolley on the right-hand side.

e ● Do the experiment with as many other combinations of trolleys as you can.

f ● Look carefully at your table of results. Write down a summary of what your experiments show.

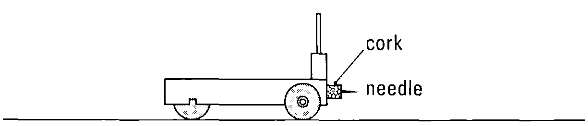
Worksheet P6C [side 1]
Collisions

The experiments in this worksheet look at how useful the idea of momentum may be in collisions between moving objects. In Experiment 1 a moving trolley collides with a stationary trolley and sticks to it. The momentum of the moving trolley is compared with the momentum of the combined trolleys after the collision.

You will need:
- a trolley runway
- a block to support the runway
- an end stop
- four dynamics trolleys
- two photodetectors
- two lamps
- two electronic timers
- two 20 cm by 8 cm pieces of card
- two corks to fix to the trolleys
- a needle
- a spring

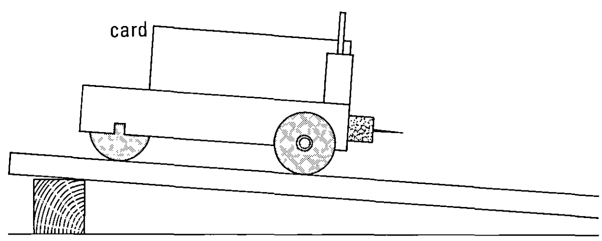
Experiment 1 : Inelastic collisions

a ● Put the needle in one of the corks so that only its sharp end sticks out. Attach the cork to a trolley like this:



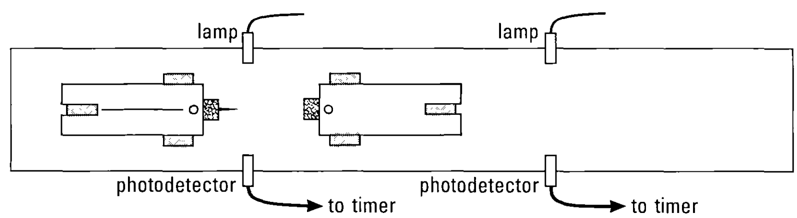
● Attach the other cork to another trolley.
● Check that when the trolleys collide the needle on one trolley sticks into the cork on the other trolley. After the collision, both trolleys should move off together.

b ● Fix the card to the trolley carrying the needle.
● Arrange the trolley runway on a slight slope so that the trolleys will run down it at a steady speed if given a small push:



c ● Now arrange the photodetectors and lamps as shown in the diagram opposite.
● Place the trolley without the needle between the two light beams.
● Set both timers to zero.

view from above apparatus



d ● Make a copy of this table.

BEFORE THE COLLISION				AFTER THE COLLISION			
mass of trolley	time for card to pass through light beam	speed of trolley	momentum (mass x speed)	mass of trolleys	time for card to pass through light beam	speed of trolleys	momentum (mass x speed)

CONTINUED

Worksheet P6C [side 2]
Collisions

e ● Give the trolley carrying the needle a sharp push so that it passes through the first light beam and collides with the other trolley. **The two trolleys should move on together. The second timer records the time it takes the combined trolleys to pass through the second light beam.** ● Complete all the columns in your table.	**f** ● Now repeat the experiment using one and then two trolleys stacked on top of the trolley carrying the needle. ● Record your results in your table. **g** ● Look at the two columns headed 'momentum'. These show the momentum before and after the collision. What general conclusion can you draw from your experiment?

Experiment 2: Elastic collisions

Collisions in which one trolley collides with, and sticks to, another trolley are called *inelastic collisions*. In inelastic collisions, some of the original kinetic energy is transferred to the surroundings, warming them up.

Elastic collisions are collisions in which none of the original kinetic energy is transferred to the surroundings. The total kinetic energy after the collision is the same as that before the collision.

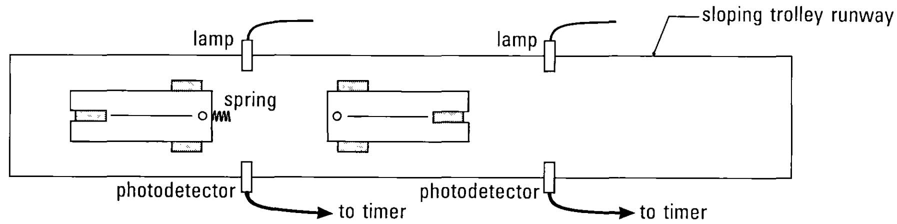
You can make an elastic collision between two trolleys by fixing a spring to one of the trolleys. When the trolleys collide, the spring first compresses and then expands again.

Elastic collisions can be produced with air-track vehicles by placing magnets on the ends of the vehicles. The magnets must be arranged so that they repel each other.

a ● Use the apparatus shown below to make an elastic collision between two trolleys.

At the start, one trolley should be stationary between the light beams, as in Experiment 1. Both trolleys will need to carry pieces of card to cut through the light beams.

view from above apparatus



b ● Do your results fit in with the pattern you found for the inelastic collisions in Experiment 1?

Worksheet P7A
Free fall

When something falls to the ground its motion changes. This experiment will enable you to find out how the motion of an object changes as it falls to the ground. First you need to know how a ticker-timer works.

How a ticker-timer works

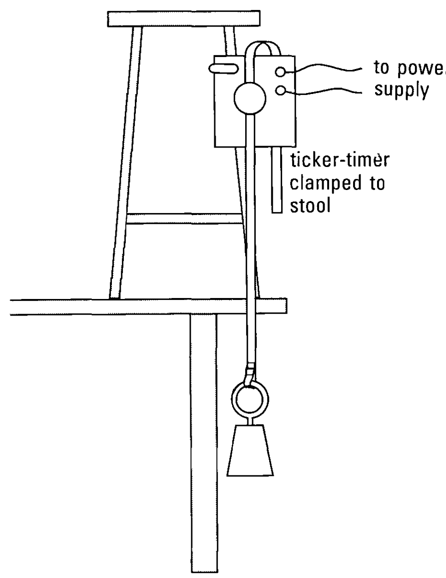
The ticker-timer will make 50 dots per second on the paper tape. If you have not used one before, try this:

Thread a piece of paper tape under the vibrator, then switch the vibrator on and pull the tape along underneath it.

Look at the dots on the tape. The space between each dot and the next dot is the distance you pulled the tape in the time between the two dots. The time between the dots is $\frac{1}{50}$th of a second (0.02 s).

Experiment

You will need:	
a ticker-timer	paper tape
several masses, ranging from 0.5 kg to 2 kg	sticky tape
a power supply (battery or power pack)	a clamp

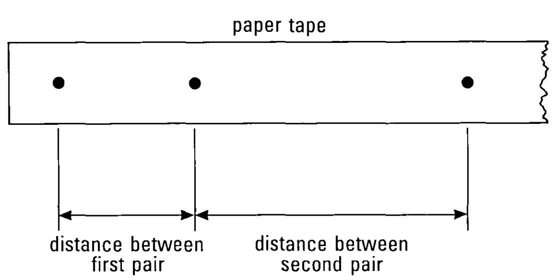


a ● Set up your apparatus like this:
● Attach two or three metres of paper tape to a 0.5 kg mass and thread the tape under the vibrator.
● Put something soft on the floor for the masses to fall onto.

b ● Hold the mass close to the vibrator and pull up the slack tape. Make sure the tape can run freely under the vibrator.

c ● Switch on the power supply and release the mass.

Analysing the tape



1 Look at the pattern of dots on your tape. What can you say about the motion of the falling mass?

2 Select a pair of dots as close to the beginning as you can.
a Measure the space between the dots. This is the distance the mass fell in $\frac{1}{50}$th of a second.
b Multiply this distance by 50 to find the average speed of the mass during this $\frac{1}{50}$th of a second.
c Repeat the measurements for the remaining dots.

3a Plot a graph to show the way the speed of the mass is increasing with time.
b What conclusions can you draw from your graph?

d ● Repeat the experiment for some other masses.

4 Compare all your results. What pattern can you see?

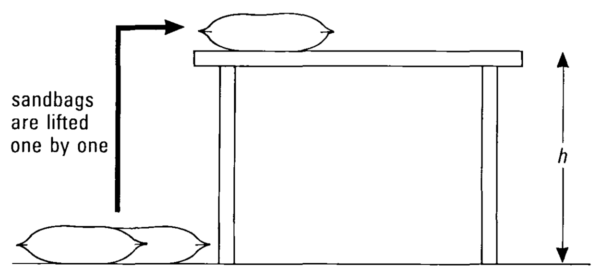
Worksheet **P8A** [side 1]
Power

These experiments are an investigation into your own output power. Your power output depends on the job you are doing. So each of these experiments uses the human engine in a different way.

Experiment 1

In this experiment you are to find your output power by lifting sandbags from the ground onto a table for 30 seconds. As there will certainly not be enough bags for you to lift in 30 s, one of your partners should push a bag off the table onto the floor every time you lift one up.

You will need:
sandbags
a stop-clock, or watch
a metre rule
a personal weighing machine



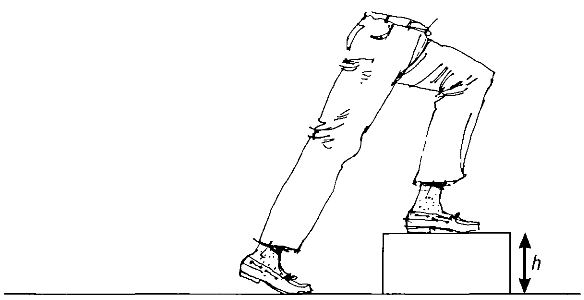
a ● Lift as many sandbags as you can from the ground to a table in 30 s.
● Record the number of sandbags you lifted in 30 s.

b ● Work out the energy transferred to each sandbag in lifting it from the ground to the table.
● Work out the total energy transferred to the sandbags in 30 s.
● Work out your output power.

Experiment 2

This experiment measures the power you can develop through your legs in lifting yourself. 'Step-ups' are something you may have done in PE or as 'circuit training'. Start with both feet on the ground. Put one foot on the step, then the other. One 'step-up' is complete when both feet are on the step. Then both feet must return to the ground before the next step.

You will need:
a 'step' about 30 cm high
a stop-clock, or watch
a metre rule
a personal weighing machine



a ● Do as many 'step-ups' as you can in 30 s.
● Record the number of step-ups you did in 30 s.

b ● Work out the energy you transfer in lifting yourself the height of the step.
● Work out the total energy you transferred in lifting yourself for 30 s.
● Work out your output power.

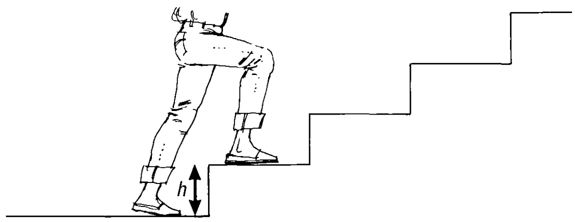
CONTINUED

Worksheet P8A [side 2]
Power

Experiment 3

This experiment is similar to Experiment 2, only this time you will run up a flight of stairs and one of your partners will measure how long it takes you. To work out the total energy transferred you will need to measure the height, *h*, of each step and count the number of steps, *n*, in the complete flight. The total vertical height through which you have lifted yourself is $n \times h$.

You will need:
a flight of stairs!
a stop-clock, or watch
a metre rule
a personal weighing machine



a
- Run up the stairs as quickly as you can. **Take care not to slip.**
- Record the time it takes you to run up the stairs.

b
- Work out the energy you transferred in lifting yourself up the flight of stairs.
- Work out your output power.

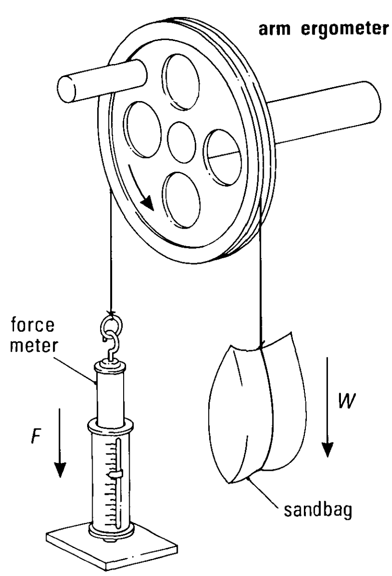
1a How does your output power compare with the value you obtained in Experiment 2?
b If it is different, can you explain why?

Experiment 4

You will need:
an arm ergometer
a sandbag
a force meter
a stop-clock, or watch

When you turn the handle of an 'arm ergometer' you do work against the friction between the rope and the wheel. The frictional force you work against is the difference between the weight of the sandbag and the reading on the force meter.

One of your partners will have to read the force meter while you turn the handle. The other will time you for 30 s while you count the number of wheel turns you make. You will be told the distance round the wheel; this is the circumference, *C*. It will probably be 1 m.



a
- Work at a rate you could keep up for some time. You may find it is a good idea to turn the wheel for half a minute or more before you start counting the turns.
- Record the number of complete turns of the wheel that you make in 30 s.

b
- Work out the energy transferred in one turn of the wheel.

work done per turn = $(W - F) \times C$

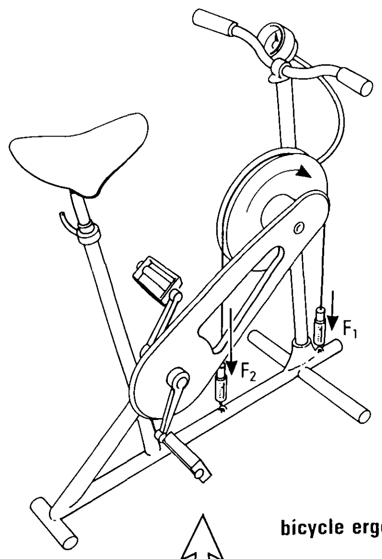
- Work out the total energy transferred in 30 s.
- Now calculate your output power.

CONTINUED

Worksheet P8A [side 3]
Power

Experiment 5

You will need:
a bicycle ergometer
a stop-clock, or watch



This is a similar experiment to Experiment 4, except that in this one you use your legs. Instead of counting the number of times the cycle ergometer's wheel turns, use the counter attached to it (like the sort that records miles on a bicycle). You must read the number on the counter before you start and at the end of your experiment.

The bicycle ergometer may have two force meters – one on each end of the friction band. Your partner will have to read both while you cycle. The difference in their readings will give the frictional force you are working against.

a
- Cycle at a steady speed for 30 s.
- Record the number of turns the wheel makes against friction in 30 s.

b
- Work out the energy transferred for one turn of the cycle wheel.
- Work out the total energy transferred in 30 s.
- Calculate your output power.

2a Which of Experiments 1 to 5 gave the greatest output power?
b Explain why. (You may have to use knowledge from your work in Biology to answer this.)

Finding your maximum power

This is an optional experiment you can do if you have time. Don't do this if you are not feeling very fit!

a ● Using either the arm ergometer or the cycle ergometer, measure the maximum power you can develop by working as fast as you can for 30 s.

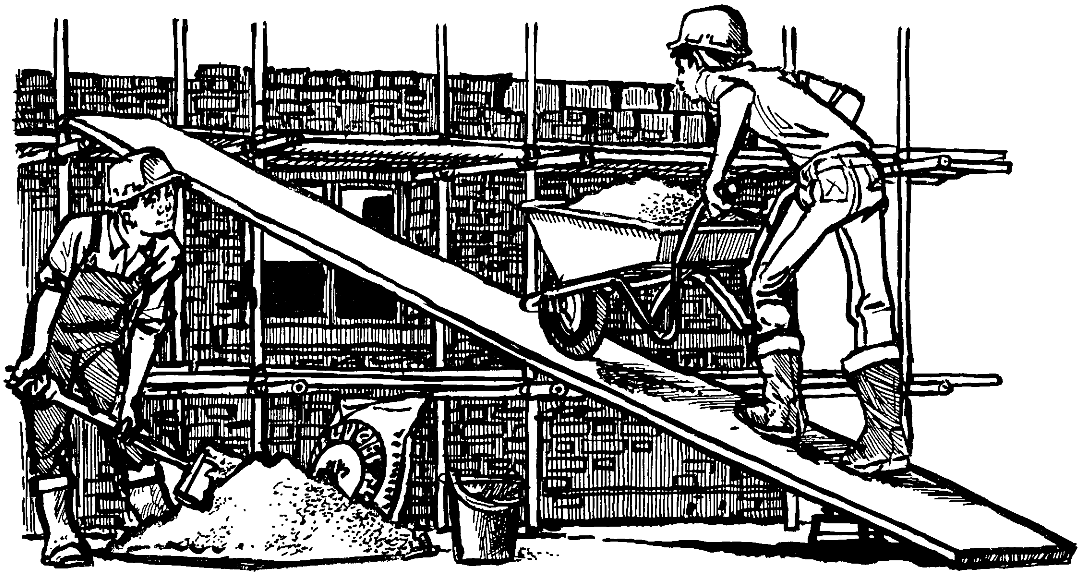
b ● Now compare this with the power you can keep up for a long period. You can measure this by working for several minutes and measuring your power for that longer period.

3a What result do you get?
b How do different people's results compare with yours?

Worksheet **P8B**
Using a ramp

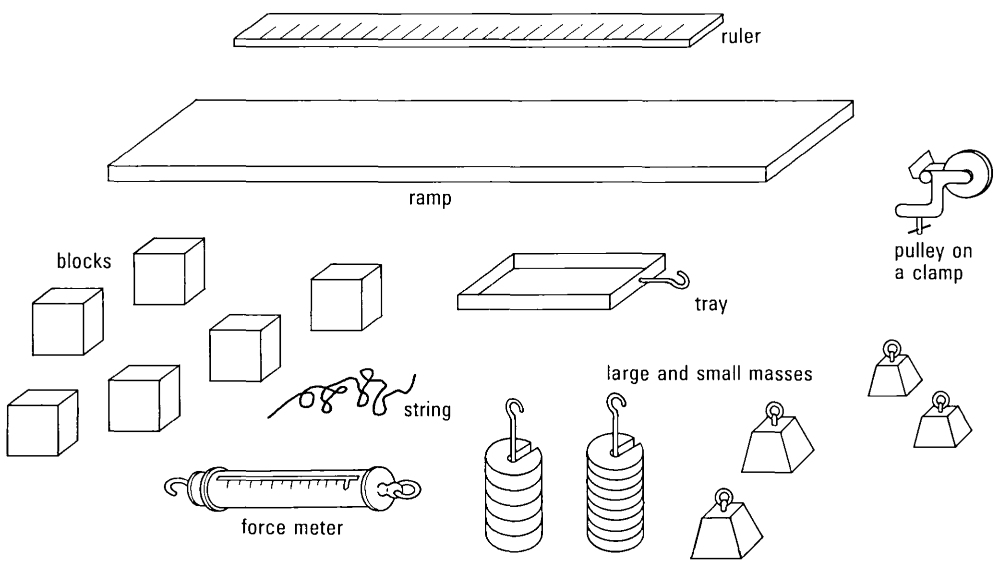
You are going to investigate the best way to use a ramp. A ramp is a machine for raising a load. The load can be put on a tray or board, or simply tugged up the ramp on its own.

When investigating the best way to use a ramp, remember that you do not want to use more force than necessary. On the other hand you do not want to waste more energy than necessary. You may not be able to achieve both these things with the same arrangement of your ramp, so you will have to find the best solution you can.



Investigation

a ● Plan and carry out an investigation into the best way to use a ramp. Your **Planning sheet** (P0) will help you do this. You may use some or all of the equipment shown here:



b ● What conclusions do you reach about the best way to use a ramp? You should back up your answer with measurements that you have made.

Worksheet **P9A**
Investigating warm materials

You are going to plan and carry out an investigation to find out which material is most suitable for keeping somebody warm on a cold, dry, windy day.

You should be able to work out for yourself what equipment you will need. If you are doing this investigation in school, your teacher will provide enough to get you started.

If you are doing this investigation at home, or you would like some more help, ask for the **Help sheet**.

Investigation

a
- Plan your investigation properly before you begin. Your **Planning sheet (P0)** will help you do this.
- Discuss it with your partners.
- Think about what you need to measure.

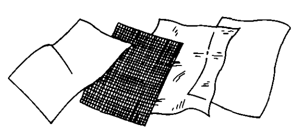
b
- Carry out your tests as carefully as you can.
- Check your measurements and be as precise as you can.

c
- Prepare a report about what you have done.

Worksheet P9A
Investigating warm materials
Help sheet

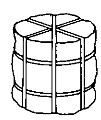
You will need:
a stop-clock, or watch
a thermometer
cans to hold warm water
at least 4 different types of lagging material, e.g. cotton, wool, plastic, nylon/wool mixture
scissors
sticky tape
rubber bands
pins

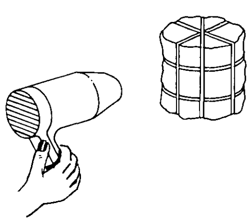
- Collect three or four different materials to test, for example, cotton, pure wool, plastic, nylon and wool mixture. (You could use old dusters, sheets, socks, polythene bags and so on for these.)



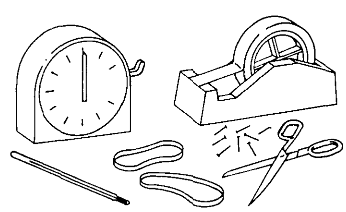
- Use an empty tin can to represent a person's body. Put warm water in your can to make it warm like a person.

- Make different 'jackets' for your tin with your materials. Try single and double layers. You could even make a 'sandwich' of different materials.





- Use a hairdrier (with its heater **turned off**) to represent the wind.



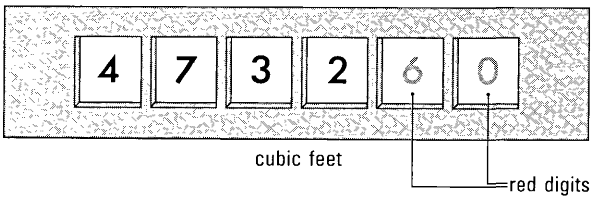
- You will need a thermometer to measure the water temperature. You will also need a clock. Some scissors, pins, sticky tape and rubber bands may also be useful.

Remember: there is no one 'correct' method. Your ideas are as good as anyone else's.

Worksheet **P9B** [side 1]
Reading gas and electricity meters

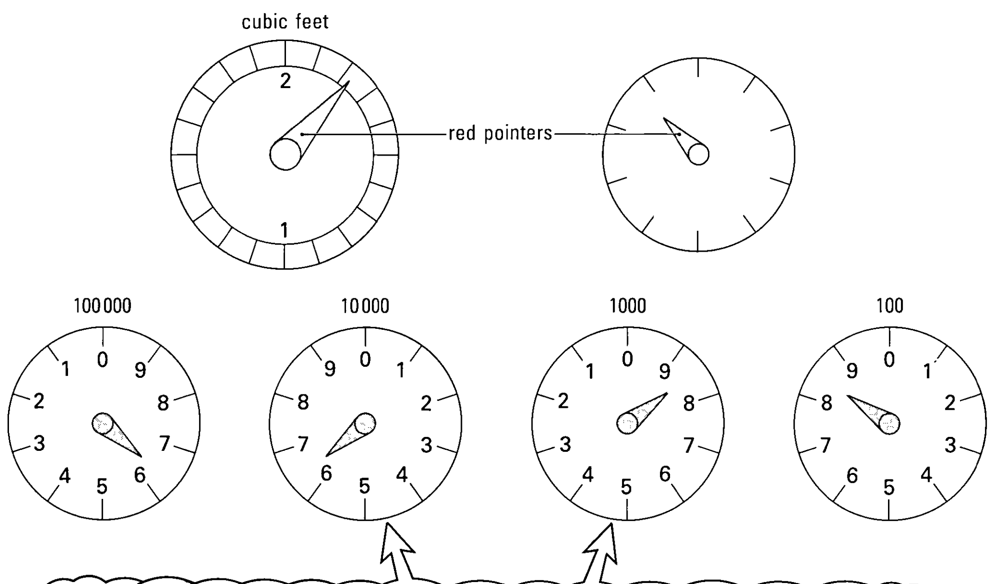
This worksheet will help you to read gas and electricity meters when you carry out your home heating investigation.

Gas meter: digital type



- Ignore the red digits.
- This reading is 4732 cubic feet:

Gas meter: dial type



Notice how the dials are numbered. Pointers turn in different directions. Some go clockwise ⟶ . Some go anticlockwise ⟵ .

- Ignore any dials with red pointers.
- Start with the dial which counts the biggest number. In the diagram above it is the 100 000 dial.
- If the pointer is between two numbers, choose the smaller number, **unless** the pointer is between 0 and 9; then choose 9.
- Read the dials in turn and write the numbers down.
- The reading above is 6688 hundred cubic feet.

Every time this number increases by 1 it means that 100 cubic feet of gas has passed through the meter. So the units that go with these numbers are 'hundreds of cubic feet'.

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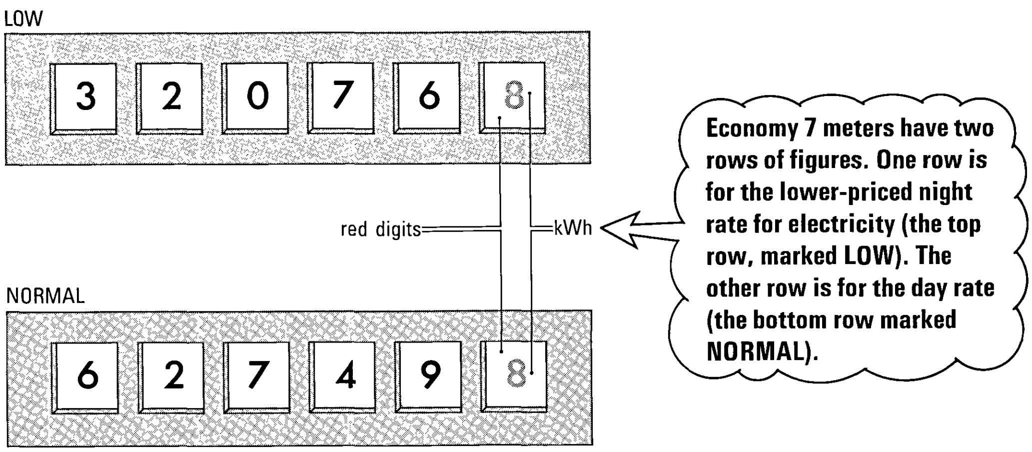
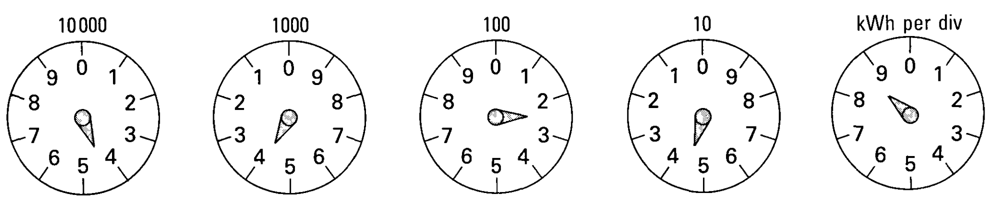
Worksheet P9B [side 2]
Reading gas and electricity meters

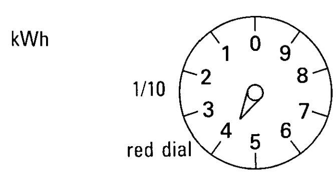
Electric meter: digital type



- Ignore the red digits.
- The readings above are: LOW 32076, NORMAL 62749.

Electric meter: dial type





- Ignore the red dial.
- Start with the dial which counts the biggest numbers.
- The reading above is 44 248 kWh.

Worksheet **P9C**
Heating water

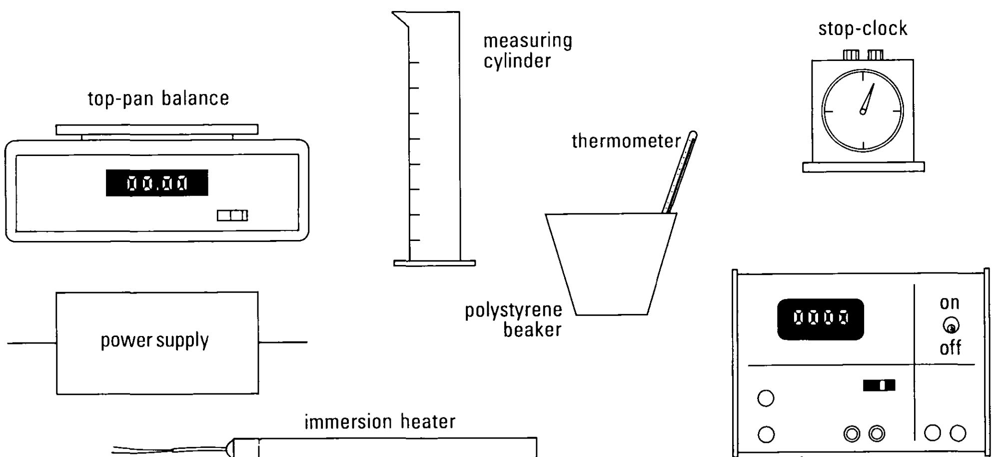
The specific heating capacity of water is the energy that has to be transferred to 1 kg of water to raise its temperature by 1 °C. From this we predict that the energy that has to be transferred to a mass to raise its temperature by a certain number of degrees can be found from the equation:

energy transferred = mass × specific heating capacity × temperature rise.
(J) (kg) (J per kg/°C) (°C)

You are going to check experimentally that this equation correctly describes the relationship between energy transferred, mass, and temperature rise.

Experiment

a ● Plan your experiment. You may use some or all of the equipment shown in this diagram:



If you are provided with a joule meter you will be told how to connect it between the power supply and the immersion heater.

b ● Now carry out your experiment.
● If you need more help with this experiment, ask for the **Help sheet**.

c ● Write a report. Your report should describe what you did, and present your results. At least one set of results should be displayed as a graph.
● In your report, say whether or not you think your results support the equation:

energy transferred = mass × specific heating capacity × temperature rise.

● Remember to write about any **errors** you think there may be in your results.

Worksheet P9C
Heating water
Help sheet

Testing the equation

To test the equation break it up into separate bits:

i If a constant mass of water is used, the temperature rise of the water should be proportional to the quantity of energy transferred to it.
ii For a constant temperature rise, the energy transferred should be proportional to the mass of the water.

You should test each of these things separately.

Measuring the mass of water

You do not need to measure the mass of water using a balance. Instead you can measure the volume of water used. 1 cm^3 of water has a mass of 1 g, so when you know the volume of water it is easy to work out its mass.

Measuring the energy transferred to the water

If you are provided with a joule meter it will be very easy to measure the energy transferred to the water. You will be able to vary this by keeping the heater switched on for different lengths of time.

It is not essential to have a joule meter to measure the energy transferred to the water. The immersion heater transfers the same amount of energy during each second it is switched on. So the energy transferred by the heater is proportional to the length of time it is switched on. You can use this length of time as a number to represent the energy transferred from the heater. Of course, you will not be able to measure the amount of energy transferred in joules in this way, but that does not matter.

If you are using a stop-clock on its own instead of a joule meter, here is what you should do:

You can test whether the rise in temperature is proportional to the energy transferred like this:

- Put the immersion heater in a measured quantity of water, say 150 g.
- Stir the water. Remember to keep doing this during the experiment.
- Switch on the immersion heater and start the stop-clock at the same moment.
- Now record the temperature of the water every 15 s.
- Switch off the immersion heater when the temperature has risen by 10°C.
- Plot a graph of 'temperature rise of water' against 'time for which heater has been switched on'.

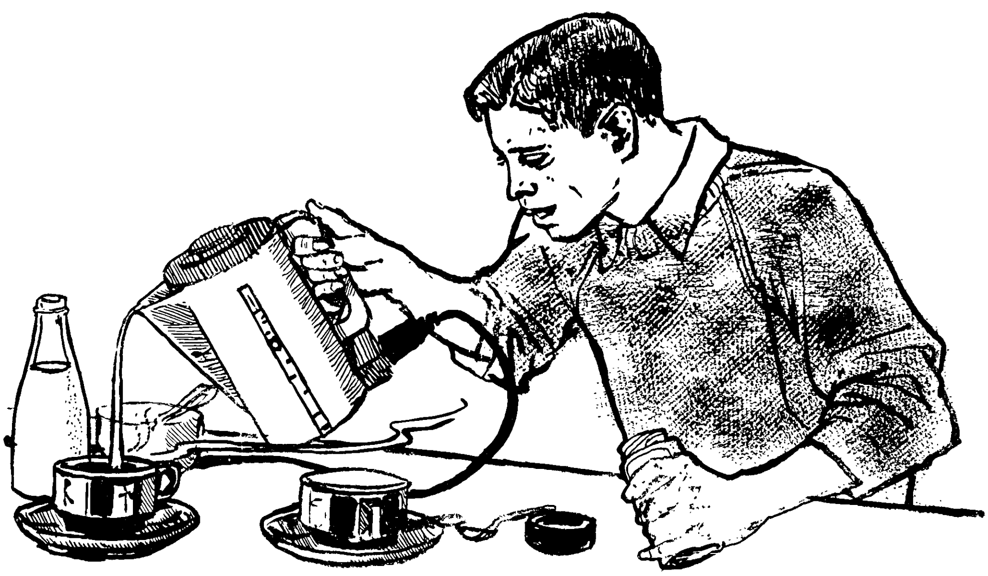
To find out whether the energy transferred is proportional to the mass of water, you will have to measure how long it takes the heater to raise the temperature of measured masses of water by, say, 5°C.

Worksheet **P9D**
How efficient is your electric kettle?

Whenever you heat up water in a kettle, some energy is always transferred to the surroundings. You will also nearly always heat up more water than you need. Both ways, energy is being wasted. In this worksheet you are asked to measure the efficiency of an electric kettle. Remember: you can find efficiency as a percentage like this:

$$\text{efficiency} = \frac{\text{useful energy transferred}}{\text{total energy transferred}} \times 100\,\%.$$

Investigation



Plan and carry out an investigation to measure the efficiency of an electric kettle. You will need to:

- Measure the energy transferred to some water in the kettle.
- Compare the energy transferred to the water with the energy transferred from the 'mains'. (A plate somewhere on the kettle will tell you the power drawn from the supply.)
- Calculate the efficiency of the kettle from your results.

1 How much energy is 'wasted' when you boil some water to make one cup of tea or coffee? (Don't forget any water left in the kettle!)

Traditional metal kettles are being replaced with electric 'jug' kettles. These are made of plastic and have a heating element right at the base of the jug. These kettles are tall compared with their width.

2 In the light of your investigation and the work you have done in Chapter **P9**, what are the advantages of a jug kettle over an ordinary one?

Worksheet P10A
Measuring a rise in internal energy

Energy must be transferred to any object to make its temperature rise. When the temperature of an object changes we say that its internal energy has increased.

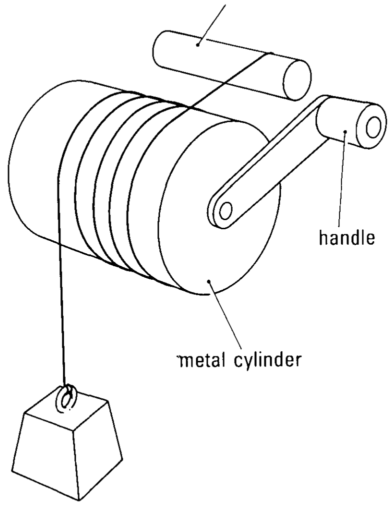
One way of raising the temperature of an object is to use friction. All the work done against friction goes into raising the temperature of the object. If we measure the work done against friction to raise an object's temperature we can find the increase in its internal energy.

Another way of raising the temperature of an object is to heat it electrically. You are going to measure the increase in internal energy of a metal cylinder when its temperature is increased. In Experiment 1 you should use friction to heat the cylinder. Experiment 2 is optional. It asks you to use an electrical method to heat the cylinder.

If you need any more help with these experiments, ask for the **Help sheet**.

Experiment 1

You will need:
mechanical heating apparatus and accessories



Plan and carry out an experiment to measure the increase in internal energy of an aluminium cylinder when its temperature increases by 1 °C. Here are some hints on how to carry out the experiment:

- Think of a way of finding out how much energy is needed to turn the handle **once**. Then do this.
- Calculate the total energy transferred when the handle is turned 200 times.
- Note the temperature rise produced.
- Work out how much the internal energy of the block increases for a 1 °C rise in its temperature.

Experiment 2 (optional)

You will need:
mechanical heating apparatus
electric heating accessories

- Use the same metal cylinder you used in Experiment 1.
- Think of a way of transferring energy from an electric supply to the cylinder to produce the same rise in temperature as in Experiment 1.
- Check your method is safe with your teacher before you try it.
- Find out how much energy is transferred to the cylinder.
- Compare the amounts of energy transferred in Experiment 1 and Experiment 2 to produce the same temperature rise.

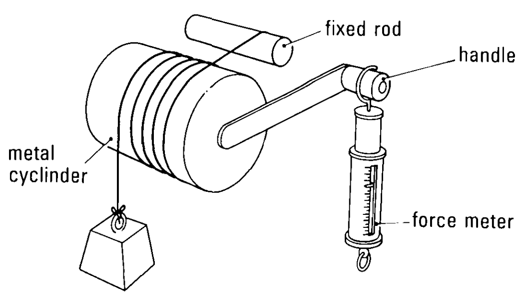
Worksheet P10A
Measuring a rise in internal energy
Help sheet

Working out how much energy is transferred by friction

You can work out how much energy is transferred when the handle is turned, like this:

energy needed to turn handle = force applied to handle × distance handle moves.

- Use a force meter (spring balance) to measure the force needed to turn the handle. Make sure the force meter always pulls at right angles to the arm.
- The distance through which the force moves is equal to the circumference of the circle through which the handle turns:



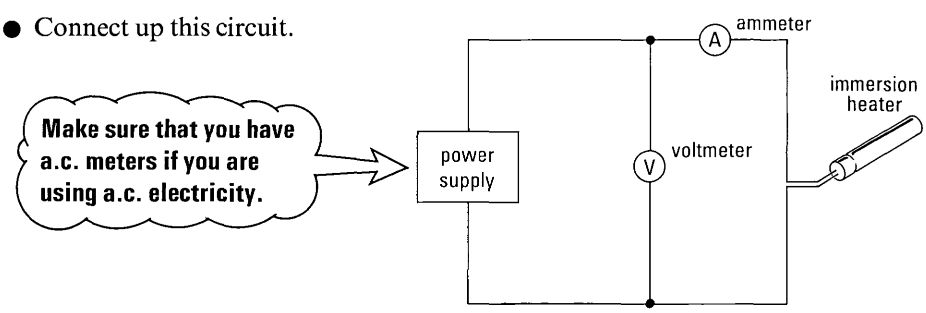
circumference of circle = 2π × radius of circle.

Measuring the energy transferred by an electric immersion heater

You should be able to insert an electric immersion heater into the block. Check the power of the heater. (It might be marked on it.) This tells you how much energy it transfers from the power supply each second. (Remember: 1 watt = 1 joule per second.)

If the power of the heater is not marked and you do not have a joule meter, follow this procedure:

- Connect up this circuit.



- Measure the current on the ammeter (A) .
- Measure the voltage on the voltmeter (V) .
- Find the power of the heater like this:

  power of heater = current × voltage.
  (W) (A) (V)

- Find the energy transferred from the power supply like this:

  energy transferred = power of heater × time it is in use.
  (J) (W) (s)

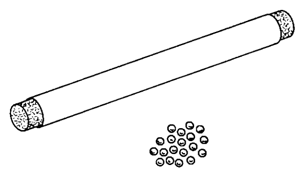
Worksheet P10B
Estimating the specific heating capacity of lead

You are going to measure the specific heating capacity of lead. You can do this by transferring energy to some lead shot and measuring the rise in the temperature of the lead.

Experiment

You will need:
a cardboard tube
bungs or corks for both ends of the tube
0.5 kg of lead shot
a polystyrene beaker
a metre rule
a 0–1 kg balance

In this experiment 0.5 kg of lead shot is tipped up and down a cardboard tube 50 times. Each time the lead falls down the tube it gains kinetic energy. When the lead hits the bottom of the tube this energy is transferred to the internal energy of the lead and its surroundings.

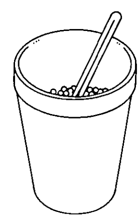


A force speeds the lead up as it falls down the tube. This force is the weight of the lead, which is 5 N. You can work out the energy transferred to the lead using this equation:

energy transferred = force × distance lead falls
(J) (N) (m)

This energy is transferred to the internal energy of the lead and its surroundings.

a ● Put the lead shot in the polystyrene beaker.
● Measure and record the temperature of the lead shot.



b ● Put the lead shot in the cardboard tube and close its ends.
● Quickly turn the tube upside-down so that the shot falls from one end to the other. Do this 49 more times.
● Take the bung out of the top end of the tube and turn it again so that the shot falls into the beaker. This means the lead has fallen down the tube 50 times in all.
● Record the temperature of the lead shot.

c ● Work out how much energy is transferred to the internal energy of the lead and its surroundings each time the lead falls down the tube.

1 Give a reason for assuming that almost all this energy is transferred to the internal energy of the lead.

d ● Now work out the specific heating capacity of lead.

Remember: the specific heating capacity is the amount of energy that has to be transferred to the lead to raise the temperature of 1 kg of lead by 1°C.

● Check your value against the value given in a book of data.

2 Give a reason for any difference between your value and the value given in the data book.

Worksheet P10C
Energy conservation

Although we believe that energy is conserved whenever it is transferred, it is quite difficult to do an experiment to show that this is so. Some of the energy that is transferred almost always goes to the surroundings and cannot be measured.

A 1 kg mass falling a distance of 1 m can transfer 10 J of energy. In this experiment you are challenged to transfer as much of this 10 J of energy as you can to a trolley in getting it moving. There are several different ways of transferring the energy, but there is no one 'correct' way.

To work out how much energy has been transferred to the trolley you will need to be able to use this equation:

kinetic energy $= \frac{1}{2}m\,v^2$.

This means you multiply the mass of the trolley by the square of its speed and then divide by two. You will meet this equation in Chapter **P6** of your Physics book. It does not matter if you have not read that chapter yet. There are always some things you have to take on trust!

Experiment

You will need:

a dynamics trolley	an electric timer
a trolley runway	a lamp and photodetector
a 1 kg mass	a piece of card 20 cm by 8 cm
a metre rule	an end stop
string	

You must choose any other pieces of equipment you need yourself. You must not use them to transfer additional energy to the trolley.

a ● Transfer as much as you can of the 10 J of energy from the falling mass to the trolley. You have to get the trolley moving as fast as possible.
● The trolley should start from rest on a level surface, and it must remain on the surface.

b ● Measure the final speed of the trolley using an electric timer, a lamp and a photodetector, as described in Worksheet **P4B**.

c ● Work out how much energy has been transferred to the trolley, using the kinetic energy equation.

d ● Write a report on your experiment. This should include a description of how you transferred the energy, what you planned to do, and how well your plan worked.

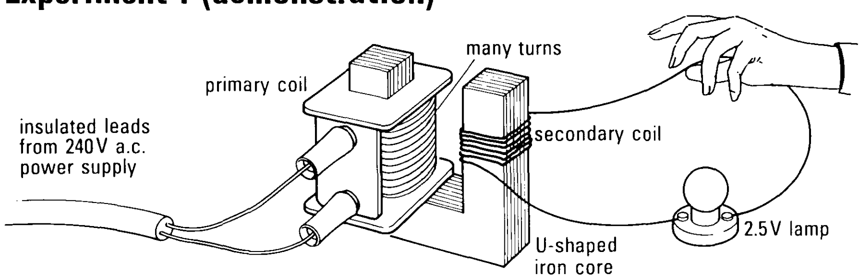
1 Suggest what happened to the rest of your 10 J of energy.

2 Work out the fastest possible speed your trolley could reach using the 10 J of energy.

Worksheet **P11A**
Transformers

This is an investigation into the behaviour of transformers. You will see two experiments. The first will be a demonstration experiment. The second may be a demonstration experiment or you may be able to do it yourself. You will record your observations. You must study your observations to find a pattern. Once you have found the pattern, you will be asked to use it to solve a problem.

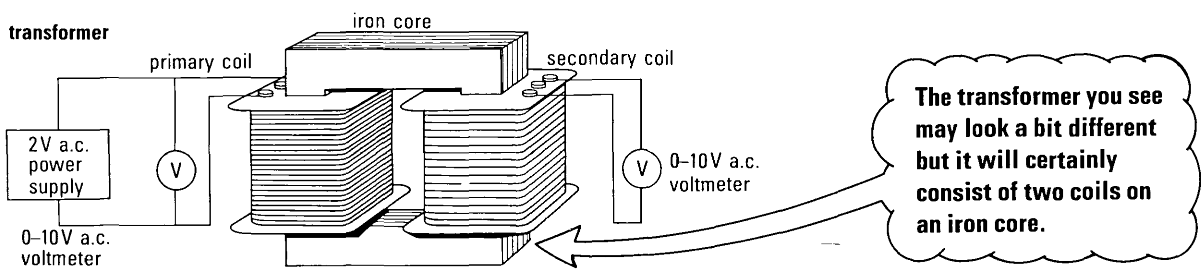
Experiment 1 (demonstration)



- Watch the lamp while turn after turn of wire is added to the secondary coil.

1 Describe what happens to the lamp.
2 What happens when an iron bar is placed across the U-shaped core?

Experiment 2



- The primary and secondary coils can be changed. Each coil has a different number of turns. The number of turns is marked on each one.
- Voltmeters indicate the voltage across each coil.
- See what happens when different coils are used.

3 Record your observations in a copy of this table:

number of turns on primary coil	number of turns on secondary coil	input voltage	output voltage

4 Can you see a pattern in these observations? If so, describe it.

Problem

- Make a 6 V lamp glow with full brightness by using a 2 V a.c. power supply.
- You will be given two iron C-cores and 3 m of insulated wire, as well as the lamp and the power supply. You may not use any other apparatus.

Worksheet **P11B** [side 1]
Using hydrogen

Read the following two articles which were originally published in *The Times* newspaper. They are about the possibility of the transporting of energy in the form of hydrogen gas. When you have read them, answer the questions at the end.

Nuclear energy: Use of hydrogen

Nuclear power stations should be built on floating platforms and the energy transported from them in the form of hydrogen rather than electricity. This revolutionary suggestion has been put forward by an Australian scientist, Professor J. O'M. Bockris of Flinders University, who argues that the use of hydrogen could solve several aspects of the World's growing energy problem.

According to Professor Bockris the platforms on which the reactors are floated should be sufficiently deep in the water to allow waste energy to be transferred away easily. Electricity generated by the reactors could then be converted into hydrogen by electrolysis.

That involves placing the positive and negative plates from the power source in water, with the result that oxygen is released at the anode (positive) plate and hydrogen at the cathode (negative) plate. The hydrogen can then be piped to distribution stations and then to consumers, where the hydrogen would be converted back into electricity by the use of fuel cells. Such cells are used on Apollo space missions, and operate on the principle of reverse electrolysis, the hydrogen being converted back into direct current, the only side-product being pure water.

Professor Bockris claims a number of important advantages for his scheme.

In the coming decades a considerable increase in energy demand is expected and his system avoids air and heat pollution, the two bugbears of conventional energy production. Again, electricity transported as hydrogen would be cheaper to transmit over distances greater than 400 kilometres. Over distances greater than 1600 kilometres the cost of hydrogen transmission, according to Professor Bockris, would be half that of overhead power cables.

Conversion of the hydrogen back into electricity would produce about 14 litres of pure water a day for each household in the United States, at the present rates of electricity consumption. By the year 2000, according to present estimates, domestic energy consumption in the United States will have increased ten-fold. If fuel cells are used the production of electricity will provide each family's supply of drinking water, at no extra cost.

Equally, Professor Bockris points out, energy could be stored. With electricity this is not really possible at present, but hydrogen could be stored as a liquid at −253°C, and turned back into a gas on demand. Hydrogen could be used to run cars, ships, and trains, by means of combinations of fuel cells and batteries. Transport would then be non-polluting, Professor Bockris claims, as well as quieter and cheaper, without any loss in efficiency.

Aircraft could run on liquid hydrogen, travelling two or three times as far as petrol-powered jets on the same weight of fuel, and one-man helicopters might become a reality. Large amounts of hydrogen would become available to industry cheaply, making the production of aluminium, ammonia, and iron more economical.

As the final advantage of his system, Professor Bockris points out that fusion reactors, which may become commercially available by the end of the century, will need deuterium, a heavy form of hydrogen. Deuterium is also a by-product of electrolysis.

What are the drawbacks to this grand scheme? Professor Bockris believes that there are only three: people's reluctance to change things, the absence of education and training in electrochemical engineering, and the public's fear of hydrogen, a fear the professor believes is no longer justified. Hydrogen mixed with the right quantities of oxygen is highly explosive, but Professor Bockris points out that railway trucks loaded with hydrogen pass through cities daily.

In conclusion Professor Bockris claims that his scheme provides not only the prospect of abundant energy but also as wealthy an economy as is wanted in the future, without the ecological hazards at present linked to energy production and consumption – hazards that could increase greatly as energy demands in the developed countries soar during the rest of this century.

By Nature-Times News Service.
Source: *Science*, 176, 1323, June 23, 1972.

CONTINUED

Worksheet P11B [side 2]
Using hydrogen

Resources: Hydrogen may replace petrol

Liquid hydrogen could replace petrol as the main fuel for road transport in the not too distant future. Estimates of the time when fossil fuels on Earth will be exhausted vary from roughly 30 years from now to 300 years ahead, but all agree that the rate at which Man is exhausting natural resources means that a substitute, or substitutes, for these fuels must be found.

Dr Lawrence Jones, a member of the University of Michigan points out in the American journal *Science*, that the cost of liquid hydrogen is now comparable to that of petrol, and suggests that this may well provide the necessary replacement for liquid hydrocarbon fuels.

Although nuclear power will probably become the main energy source for fixed power stations there is, according to Dr Jones, no serious possibility of using nuclear energy as a direct source of power for vehicles other than ships. The choices available are the electrochemical storage battery, the fuel cell, and the combustion engine (either internal, as in most car engines today, or external, such as the steam engine).

The fuel cell, in spite of its usefulness in some sophisticated roles, such as space travel, now seems unsuitable and uneconomic for mass use, although developments may change this. The battery, too, has too great a weight/power ratio. But a combustion engine using the lightest of all elements as fuel appears in many respects to be ideal.

Among the many advantages of liquid hydrogen as a fuel, Dr Jones mentions the complete freedom from any pollution problems, and the completely 'closed system' whereby the fuel can be recycled.

The only exhaust product from an internal combustion engine burning hydrogen would be water vapour. This would eventually return as rain to the oceans, from which water could be drawn off and separated into its elements electrically. The source of electrical power would be a static nuclear power station.

Even today, according to Dr Jones, hydrogen fuel is both economically and practically viable. As recently as 1958, liquid hydrogen was found only in the laboratory. But, because of the development of space flight, production totalling more than 150 tons per day, at a cost of 20 cents a pound, is now taking place in the United States. For a plant delivering 2500 tons a day, costs could be reduced to 8 cents per pound – roughly 3p. Hydrogen has already been tested as a fuel in conventional engines, where it burns satisfactorily at a compression ratio of 14:1. Alternatively, it would be simple to use liquid hydrogen as turbine fuel.

Liquid hydrogen is safer than gasoline in many ways. If it spills, the liquid immediately vaporizes and escapes into the atmosphere. In one case mentioned by Dr Jones, a liquid hydrogen tanker broke apart in an accident and spilled its load, but there was no fire and no lingering fire risk such as a pool of petrol would present.

The most important difficulty associated with the use of hydrogen as a fuel is the problem of evaporation. For the small user, who might leave his car for several days unused, it would be embarrassing to find that the fuel had disappeared into thin air. But Dr Jones suggests that this problem can be solved by using a reserve fuel tank of magnesium.

Hydrogen combines with magnesium to form the metal hydride, but the gas is easily released by warming to 260°C. This could be achieved, for example, by using waste heat from the exhaust, once the motor is running. The major fuel supply for long journeys would be stored in insulating tanks.

By Nature-Times News Service.
Source: *Science*, 176, 367, October 22, 1971.

1 What are the advantages in using hydrogen gas for transporting energy from power stations instead of using electricity?

2a What are the advantages in using hydrogen gas for transport instead of using petrol?
b What disadvantages are there?

3 Do you think it is likely that the transport of energy using hydrogen will replace electricity? Give some reasons for your answer.

4 Do you think it is likely that hydrogen will replace petrol for transport? Again, give reasons for your answer.

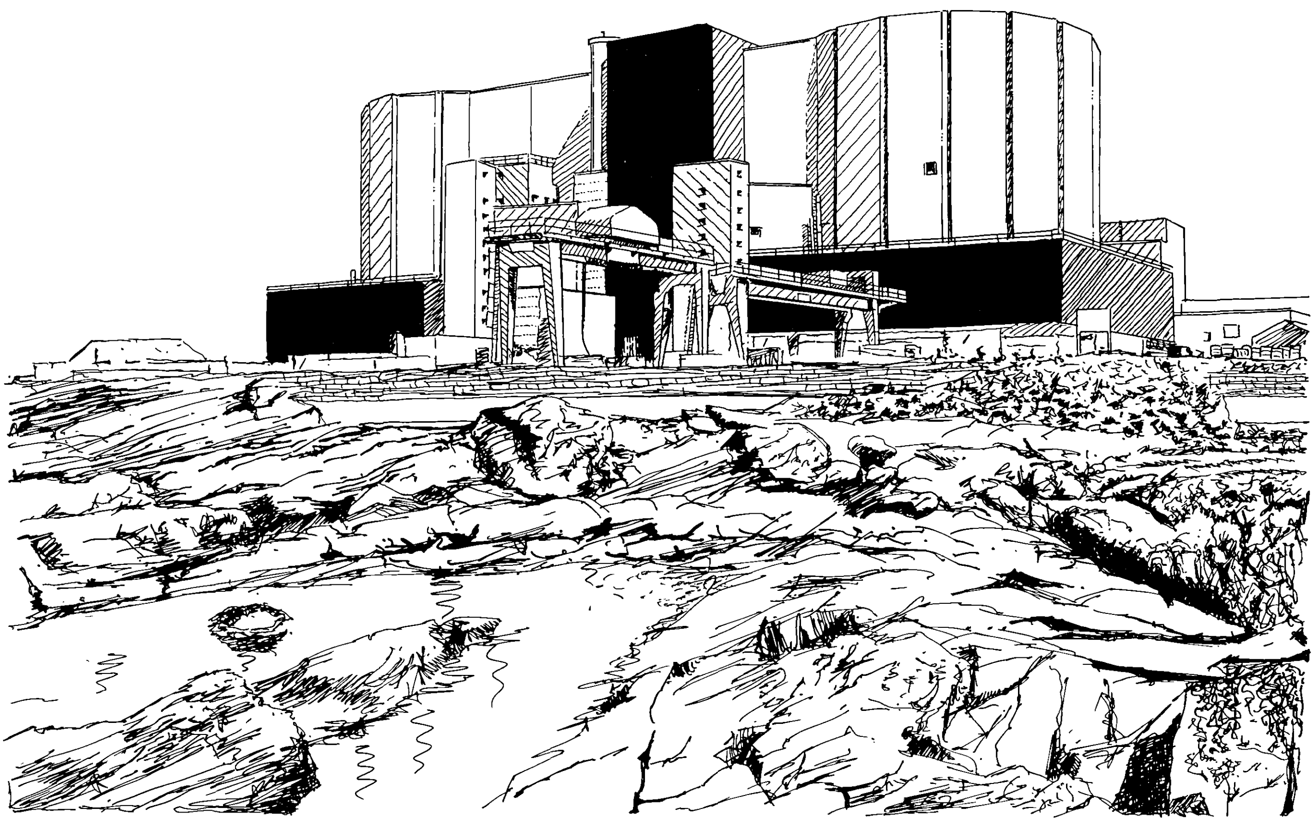
Worksheet **P12A**
Nuclear power

Introduction

Why does Britain have nuclear power stations?
Why are nuclear power stations built instead of coal-fired and oil-fired stations?
Are nuclear power stations safe? Can a nuclear power station explode like a nuclear bomb? Do they give out radiation?
What can be done about the waste produced by nuclear power stations?

You will be one of a group of five or six discussing the answers to some of these questions. Each group will elect a chairperson who will 'run' the meeting, and try to get answers to some questions.

To be able to discuss these questions properly, all of the group will have to know some facts about nuclear power. You will have learnt some of these facts from your work in Chapter 12 of your Physics book and from your previous work with radioactivity. But there are some more specialized things you need to know about as well. To help you, every member of the group except the chairperson will receive a sheet that will make him or her an 'expert' on some aspect of nuclear power. Each 'expert' will have some time beforehand to read their 'briefing' sheet.



Dungeness nuclear power station

Worksheet P12A
Nuclear power
Expert's briefing 1

What happens in a nuclear power station?

You will shortly be taking part in a group discussion on nuclear power. You are the only one in your group who has read this sheet, so you will be the expert on what goes on in a nuclear power station. After you have read this, the chairperson of your group will be asking the kinds of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Draw diagrams if it helps your answers.

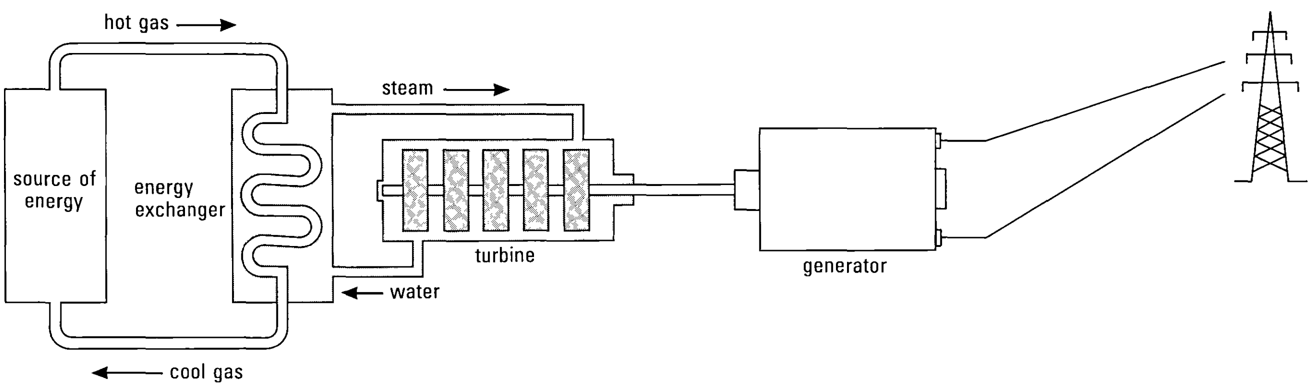
Briefing

A power station transfers energy to electricity. In all power stations, turbines are used to drive electrical generators.

In coal-fired and oil-fired stations, as well as nuclear power stations, the turbines are driven by high-pressure steam. In coal-fired and oil-fired stations, the energy which turns water into high-pressure steam comes from burning the fuels. Energy from the combustion heats up the water and changes it into steam.

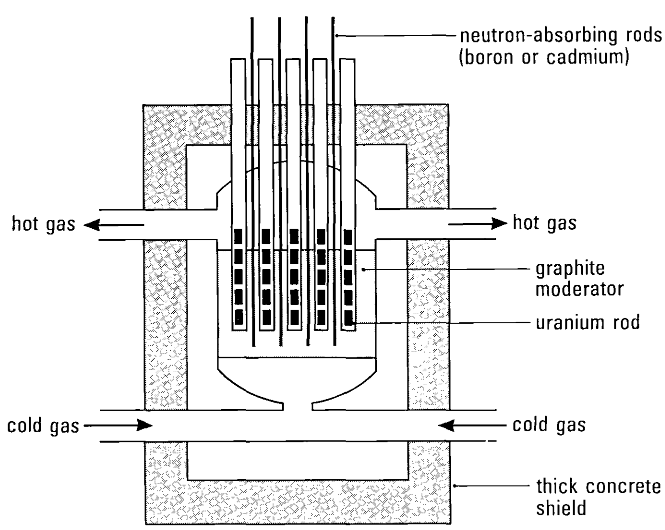
In a nuclear power station the water is heated by hot gases. These in turn have been heated by the fission of uranium in a nuclear reactor.

This diagram shows how electricity is generated in all power stations:



Nuclear reactors

Here is a simplified diagram of a reactor:



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Worksheet P12A
Nuclear power
Expert's briefing 1 (continued)

The uranium rods are the fuel. The graphite *moderator* slows down neutrons. This makes the neutrons more likely to cause fission. The *control rods* absorb neutrons. By raising or lowering the rods, the fission reaction can be made faster or slower.

As the fission reaction takes place, heat is given out. The heat is taken away by a *coolant*. In the type of reactor shown here, the coolant is a gas – usually carbon dioxide. The hot gas is pumped away to the 'heat exchanger', where it turns water to steam. The steam drives the turbines which drive the electrical generators.

During the fission reaction, some dangerously radioactive substances are formed. A thick concrete shield stops radiation getting out.

Different types of reactor

Gas-cooled reactors

Most of the reactors in British nuclear power stations are gas cooled, like the one shown in the diagram.

Water-cooled reactors

In the USA and many other countries, water-cooled reactors are used. As well as being a coolant, water is used as the moderator. Water-cooled reactors therefore have no graphite moderator. The job is done by the cooling water as it circulates through the reactor. The best known type of water-cooled reactor is the pressurized-water reactor (PWR).

Fast-breeder reactors

These reactors use a different element, plutonium, as their fuel. As well as producing energy, these reactors can be used to turn uranium-238 (^{238}U) into plutonium. This means they can 'breed' plutonium from ^{238}U. Plutonium is more useful than ^{238}U, because it is fissionable. The fission reaction does not need slow neutrons. 'Fast' neutrons can cause fission of plutonium. So far there is only one experimental fast-breeder reactor in Britain. It is at Dounreay, in the North of Scotland.

Worksheet P12A
Nuclear power
Expert's briefing 2

What happens to nuclear fuel after use?

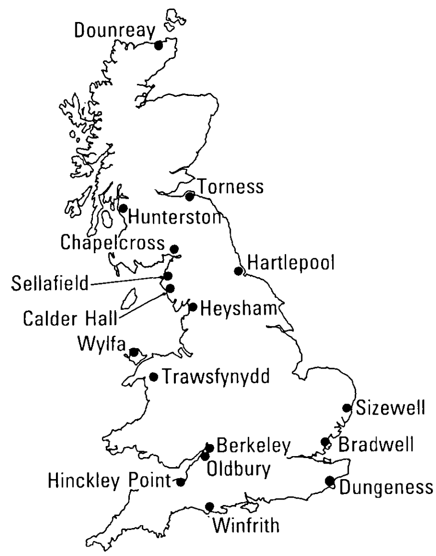
You will shortly be taking part in a group discussion on nuclear power. You are the only one in your group who has read this sheet, so you will be the expert on what happens to nuclear fuel after use. After you have read this, the chairperson of your group will be asking the kind of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Draw diagrams if it helps your answers.

Briefing

Where does nuclear fuel come from?

The fuel for nuclear power stations is uranium. It is mined in various parts of the world, then sent to Britain. At Springfields in Lancashire the uranium is refined. Some of it is enriched to make it a better fuel. The uranium is then made into rods and sent to the power stations.

The uranium rods in a nuclear reactor last for several years. After this time the old rods are removed. They are replaced by new ones.



Map showing Britain's nuclear power stations

What happens to the spent fuel rods?

The old, spent fuel rods are very radioactive. They contain *fission products* – the smaller atoms formed when uranium atoms split. These fission products often have unstable nuclei which give off radiation. The rods also contain unused uranium and another element called *plutonium*. Plutonium is useful because it is fissionable. It can be used as a fuel in fast-breeder reactors. Plutonium can also be used to make nuclear bombs.

After they have been removed from the reactor, the spent fuel rods must be treated very carefully. They are first put under water in storage tanks for a few months. During this, some of the most unstable fission products lose their power.

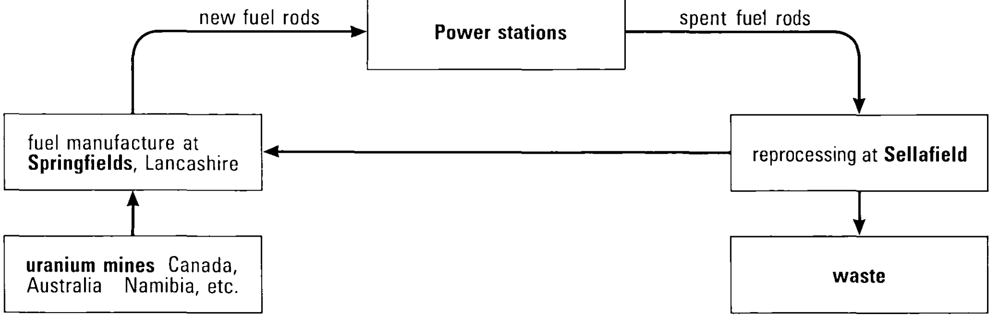
The fuel rods are now removed and sent to be reprocessed at Sellafield in Cumbria (see the map). They make the journey by road or rail in strong, thick, heavily protected flasks. They are still very radioactive.

At Sellafield, plutonium and uranium are separated from the spent rods. They are used for fuel, and some plutonium may be used to make nuclear weapons.

The rest of the spent fuel rods is waste. Some of this waste will stay highly radioactive for thousands of years. At the moment the radioactive waste is stored in stainless steel tanks at Sellafield. Scientists are trying to find ways of safely disposing of it. One possibility is to turn the waste into a solid, glassy form. It could then be buried deep in the Earth, or dumped far out at sea.

All this makes up the nuclear fuel cycle:

The nuclear fuel cycle



Worksheet P12A
Nuclear power
Expert's briefing 3

Problems and risks of electricity generation

You will shortly be taking part in a group discussion on nuclear power. You are the only one in your group who has read this sheet, so you will be the expert on the problems and risks of electricity generation. After you have read this, the chairperson of your group will be asking the kind of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Draw diagrams if it helps your answers.

Briefing

Electricity is a great benefit to our society – think what life would be like without it. But however electricity is generated, there are bound to be some problems and risks. This briefing sheet describes some of the risks of using nuclear energy. Coal is the other major source of electrical energy, and the risks involved in using coal are also described.

The risks of nuclear power

Risks from accidents
Nuclear power stations cannot explode like nuclear bombs. But it is possible that a reactor could overheat and leak. This would release dangerously radioactive substances and people living nearby could be killed and injured. Such an accident happened at a power station at Chernobyl, USSR, in 1986.

The Government safety rules for nuclear power stations in this country are very strict. The Central Electricity Generating Board, who run the power stations, say the risk of such a major accident is very low. But if one did happen, it would be very serious.

Risks from radiation and leaks
Nuclear reactors contain some very radioactive materials. These give off dangerous rays. However, the safety precautions are so strict that very little radiation gets out through the protective shields. Occasionally, though, a small leakage does occur by accident. For example, contaminated cooling water has been known to leak out from power stations in the USA.

Risks from waste
Nuclear reactors produce radioactive fission products. These will stay radioactive for thousands of years. They are kept very securely in strong tanks, but no way has been found of disposing of them for good. Furthermore, transporting of nuclear waste from one place to another could be a hazard, though of course it is always transported in very strong containers.

Risks from terrorists
Nuclear power stations produce plutonium. Plutonium can be used to make nuclear weapons. It is possible that terrorists could steal plutonium and try to make a bomb, although this would be a very difficult thing to do.

The risks of coal

Pollution of the air
Many pollutants are given off by burning coal. As well as smoke, coal produces acidic gases. These include sulphur dioxide and nitrogen oxides. These gases cause acid rain, which damages trees, fish and buildings. The gases can also affect people's health. Because there are so many large coal-fired power stations, they produce a lot of pollution between them. But power stations are not the only source of acid gases. Cars and lorries produce them too, for example.

CONTINUED

Worksheet P12A
Nuclear power
Expert's briefing 3 (continued)

Burning coal gives off carbon dioxide. Some scientists are worried that the vast amounts of carbon dioxide given off by coal-burning may have a damaging effect on the atmosphere and the weather.

Risks of coal mining

Mining is a dangerous occupation. Between 1982 and 1985 there were 26 accidental deaths in coal mines per year. Far larger numbers of miners risk dying of lung disease. Power stations use a large proportion of Britain's coal, so the risk to miners must be counted as a problem of coal-fired power stations. Uranium is also produced in mines, so the risks to uranium miners must also be considered. However, because uranium is such a concentrated energy source, it is mined in much smaller amounts.

Worksheet P12A
Nuclear power
Expert's briefing 4

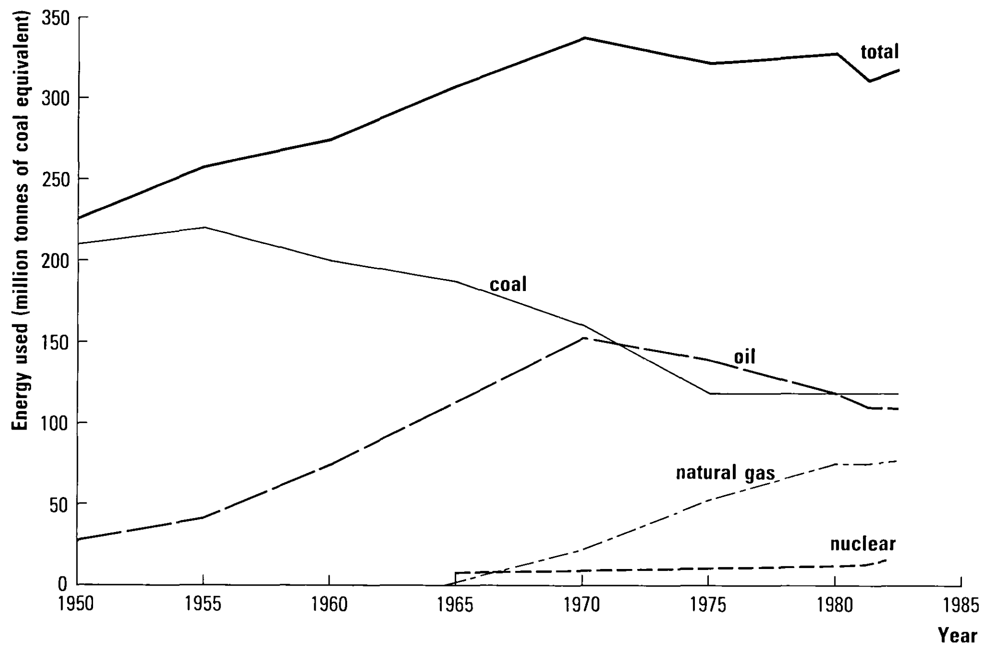
Britain's energy sources

You will shortly be taking part in a group discussion on nuclear power. You are the only one in your group who has read this sheet, so you will be the expert on Britain's energy sources. After you have read this, the chairperson of your group will be asking the kind of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Draw diagrams if it helps your answers.

Briefing

Britain is more fortunate than many countries where energy is concerned. Coal, oil and natural gas are all found in Britain, or under the sea around the British Isles.

This graph shows the changes in Britain's energy sources since 1950:



Britain's energy sources

Of course, not all of Britain's energy is used to generate electricity. For example, a lot of oil is used for road transport.

In 1983 the percentage contributions of different methods of electricity generation were as shown in this table:

Percentage contribution of different methods of electricity generation

Coal	Oil	Nuclear	Hydroelectric
75%	8%	15%	2%

Nuclear power is reckoned to be cheaper than coal or oil for generating electricity.

CONTINUED

Worksheet P12A
Nuclear power
Expert's briefing 4 (continued)

How much fuel do we have left?

Britain's fuel supplies will not last for ever. This table shows how long different fuels will last if they go on being used at the present rate:

Estimated lifetimes of different fuels

Oil	30 years	
Natural gas	50 years	
Coal	300 years	
Nuclear fuel (world reserves)	50 years	(in normal power stations)
Nuclear fuel (world reserves)	2000 years	(using fast-breeder reactors)

The Government have to plan ahead. The older power stations are inefficient and expensive to run. Eventually they have to be replaced. The Government have to decide whether or not to replace them with nuclear stations.

They also need to look at the figures for how much fuel is being used, and how much is left. Look at the graph again. Suppose you had been planning ahead in 1970. What total energy use would you have **predicted** for 1983? What was the **actual** amount? How much energy do you predict we will use in 1995? Planning ahead can be difficult!

Possible energy plans

Britain has to plan ahead to the time when oil and gas run out. There are several possibilities.

Save more energy
This can be done by using energy less wastefully. Cars can be designed to use less petrol. Houses can be better insulated so they waste less heat. New industrial processes can be less dependent on energy.

Use alternative energy sources
Examples of alternative energy sources are solar power, wind power and tidal power. At the moment hardly any electricity is generated by these methods in Britain, because they have not been sufficiently developed.

Build more nuclear power stations
You will shortly be discussing this possibility.

Build more coal-fired power stations
Most of Britain's power stations are already coal-fired. The supplies of coal are large enough to keep even more going. About three-quarters of Britain's coal output is used to generate electricity. But coal has other important uses, such as steel-making and as a source of chemicals. In the future, as oil supplies run out, coal may be used to make liquid fuels to replace oil.

Of course, these different possibilities could be used **together**. In fact many people think it is a good thing not to be too dependent on one single source of fuel.

Worksheet P12A
Nuclear power
Chairperson's briefing

You are the chairperson of the group. It is your job to ask questions and chair a discussion on nuclear power. Much of the success of the session depends on how well you do your job! Each member of your group (except for you) will have read one **Expert's briefing**. The Expert's briefings are:

1 What happens in a nuclear power station?
2 What happens to nuclear fuel after use?
3 Problems and risks of electricity generation
4 Britain's energy sources

You will begin by asking some specific questions about nuclear power, given in the first list below. These questions will probably be answered by one of the experts, though you should allow others to answer if they want to. **Try to act as a 'man or woman in the street' who is trying to find out about nuclear power**. Encourage the experts to answer in their own words – do not let them read out from the Briefing sheet! Let the experts draw diagrams on paper, a blackboard or on an overhead projector if they want to.

After the specific questions, you will raise some general points for discussion, given in the second list below. By this time, if the specific questions have worked properly, your group should have a reasonable idea of the facts behind nuclear power. Try to encourage everyone to enter into the discussion.

Specific questions

The number after each question refers to the expert who is likely to know the answer.

1 The nuclear reactor releases energy. How is this transferred to electricity? (1)
2 What is a PWR? (1)
3 What is special about fast-breeder reactors? (1)
4 How is radiation prevented from escaping from the reactor? (1)
5 Where does the uranium fuel for power stations come from? (2)
6 What happens when the fuel is used up? (2)
7 What happens to all the radioactive waste produced by power stations? (2)
8 Some people say nuclear reactors are dangerous. What are the possible dangers? (3)
9 Are there dangers from other types of power station? If so, what are they? (3)
10 How much of Britain's electricity is generated in nuclear power stations? (4)
11 What is the fuel in other types of power stations? (4)
12 Why do new power stations have to be built? Why can't Britain use the existing power stations already built? (4)
13 Apart from building nuclear power stations, what other possible ways are there of providing energy after oil and gas have run out? (4)

General points for discussion

Encourage everyone to take part. Some of these may have already been covered in the 'Specific questions' session, in which case you could leave them out.

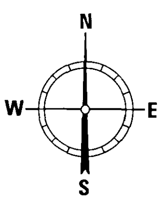
- Do we need to build nuclear power stations? Why aren't coal and oil sufficient?
- Are nuclear power stations as dangerous as some people say? Are other kinds of power stations just as dangerous?
- Would the money spent on nuclear power be better spent on saving energy or on developing alternative energy sources?
- What is the disadvantage of depending on only one energy source, such as coal or oil, for electricity generation?
- Draw up a list of the advantages and disadvantages of using nuclear power.

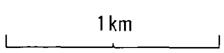
Worksheet **P12B**
Ashton Island

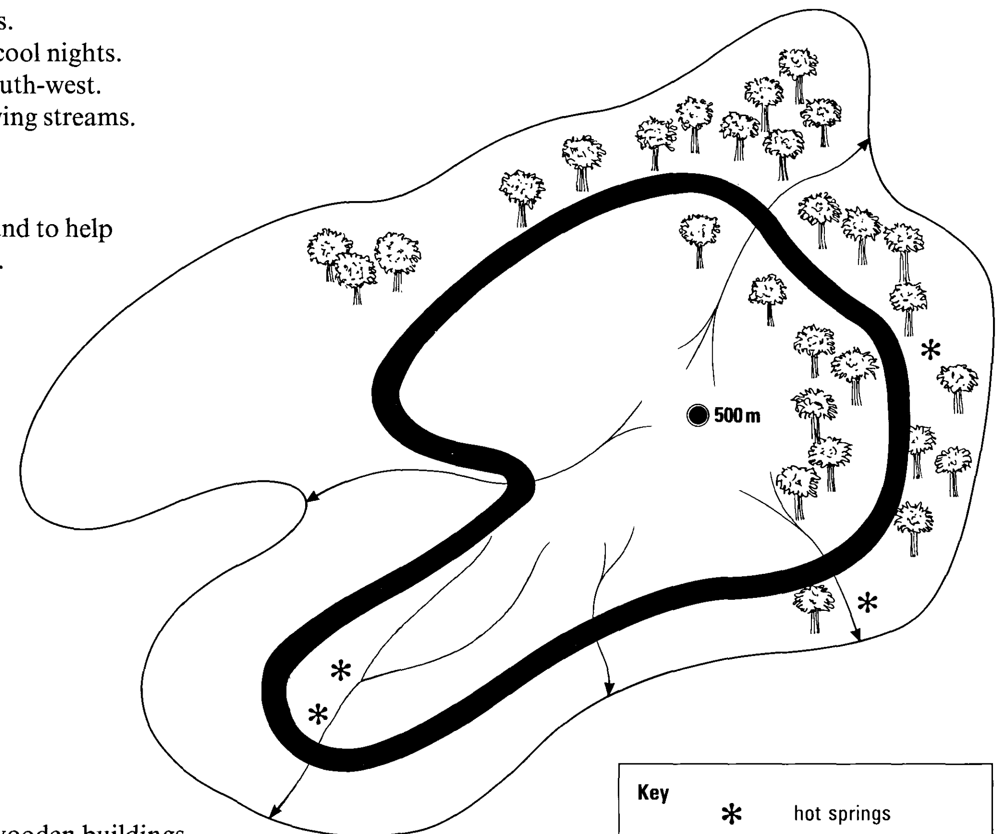
Ashton Island is in the Pacific Ocean and many miles from the mainland. You are a member of a 20-strong scientific team which is planning to study the island for five years. You are the expert given the job of providing all the energy which the team will need.
The island has:

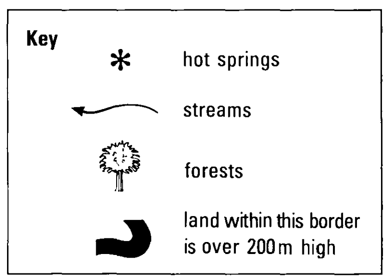
- no oil, coal or natural gas.
- hot weather by day, but cool nights.
- strong winds from the south-west.
- mountains with fast-flowing streams.
- forests.
- hot springs.

Use this map of Ashton Island to help you answer questions **1** to **8**.









1 The team will need four wooden buildings and a laboratory. Describe two ways by which the buildings could be heated.

2 Describe a source of hot water for the buildings.

3 Describe two possible ways of supplying heat for cooking food.

4 How would you supply the electricity needed to run machinery?

5 The team will have medicines and chemicals which must be kept cool at all times. How would you make sure that the supply of electricity to run the refrigerators was continuous?

6 Which natural resource on the island should be carefully conserved?

7a Copy the map of the island. (Use colours instead of shading if you wish, but remember to change the **Key** if you do so.)
b Mark on your map where you would plan to site the buildings.
c Mark on your map the various energy-producing installations you would provide and show how the energy would be transferred (if necessary) to the buildings.
d Explain your reasons for choosing these particular sites.

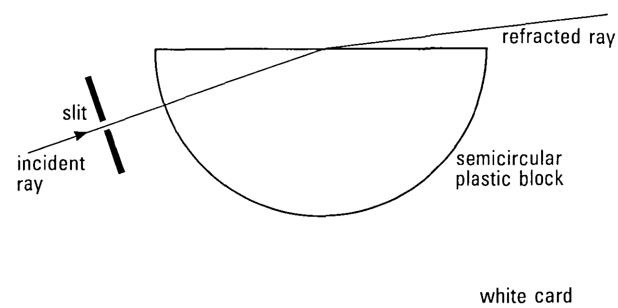
8 So far we have not mentioned the *cost* of providing energy. Would your answers be different if the team had only a limited amount of money to spend on supplying energy? Explain your answer.

Worksheet **P13A**
Optical fibres

The following experiments will help you understand how optical fibres can transmit light from place to place.

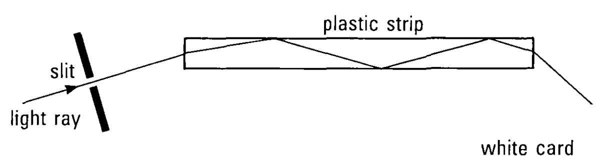
You will need:
a semicircular transparent plastic block
a transparent plastic strip
a glass rod with smooth-cut ends
an optical fibre
a light source (for Experiments **c** and **d**)
a lamp, holder, stand and shield from a ray optics kit
a metal plate with a slit in it
a power supply for the lamp
black paper
white card (e.g. a postcard)
a protractor
a stand, boss and clamp

a ● Send a light ray through the curved side of a semicircular glass block to the middle of the flat side. This is called the incident ray. The ray should pass through the curved side without bending and then emerge from the flat side as shown in the diagram.
● Change the angle the incident ray makes with the flat surface.



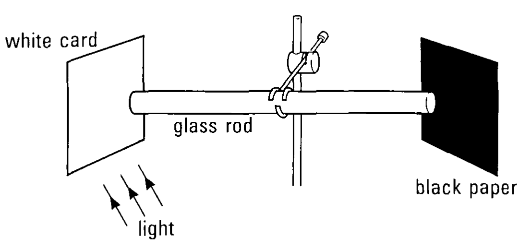
1 What happens to the refracted ray?
2 Describe how you can make an internally-reflected ray.
3 What is the size of the critical angle?

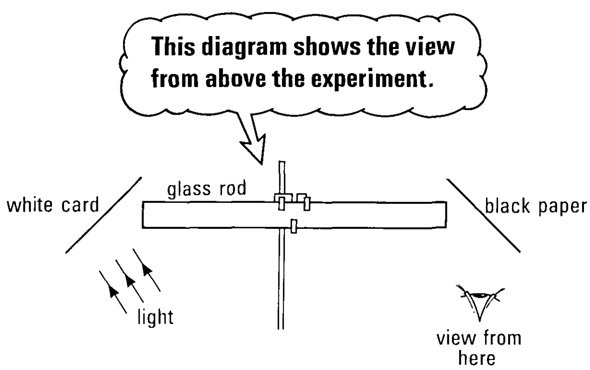
b ● Send a light ray into the short edge of the plastic strip.
● If necessary, alter the angle the ray makes with the short edge until the ray passes down the strip as shown in the diagram.



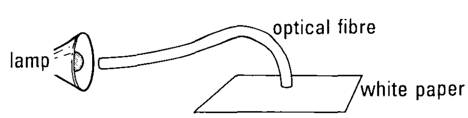
4 Explain how the ray passes along the strip.

c ● Look at the far end of the glass rod against a black background. Notice how light picked up from the white paper passes down the rod.





d ● Use the optical fibre to see how light from the lamp can be passed down the fibre.



5 How much can the fibre be bent and still pass light?

Worksheet **P13B**
Optical fibres, telecommunications and technology

The following questions are about the use of telephones and optical fibres for communications. You are also asked to think about the ways in which new technologies influence our lives. You are expected to write only a **brief** answer to each question.

1 Choose one business or company you know about. What difference would it make to them if telephones did not exist?

2 What are the advantages to telephone engineers of using optical fibres instead of copper wires?

3 What job is done by each of the following in an optical fibre communication system?
a the transmitter **b** the receiver **c** the laser light source **d** the optical fibre itself.

4 How can optical fibres be used to link computers together?

5 Optical fibres are part of a new technology. When telephones were first invented, they also were part of a new technology. Suggest reasons why:
a telephones were not developed before the 1870s;
b optical fibres were not developed until the 1960s.

6 New technology often replaces older technology. For example, optical fibres are replacing telephone wires. New technology can often have a big effect on people's lives. For two of the following examples of new technology, say:
a which, if any, older technology it is replacing;
b why it is replacing older technology;
c what effect the change has on our lives.

i electronic calculators
ii videocassette recorders
iii microcomputers
iv digital watches

7 In its time, each of the following inventions belonged to a new technology. Which older technology did each one replace?
a the steam engine
b polythene
c electric lighting
d the ballpen.

8 Apart from fibre optics, what other major technological developments do you think we might see in telecommunications in the future?

Worksheet **P13C** [side 1]
Noise

This is an enquiry into noise and some of its effects on the environment. The first part explains how noise is measured and asks you to consider some of its effects. The second part asks you to make an enquiry into noise in your school.

Finding out about noise

Sit still and listen to the sounds around you. Some may be pleasant, but some may be sounds you would prefer to do without. We use the word 'noise' to describe sounds we would rather do without.

1 Make a list of all the sounds you can hear around you. Which of them would you describe as a noise?

Hearing and sound

Sounds can differ in pitch and in loudness. The pitch of a sound is determined by the frequency of the sound vibration. A high frequency gives a high pitch, and a low frequency a low pitch. The loudness of a sound depends on how much energy is transferred to the ear by sound. Loudness is measured in decibels (dB).

The human ear can only detect a certain range of pitch and loudness. 0 dB on the loudness scale corresponds to the quietest sound you can hear – called the 'threshold of hearing'. At the top of the scale, a sound of 130 dB would cause pain.

Comparing the loudness of different sounds

Using the decibel scale, we can compare the loudness of different sounds:

	Loudness in dB	
Threshold of pain	130	Jet aircraft taking off
Road drill 1 m away	120	
The loudest anyone can shout	110	Rock group
Food mixer 1 m away	100	Baby crying loudly
Inside a noisy truck	90	Passing train 25 m away
Inside a small car	80	Loud radio
Inside a large shop	70	Vacuum cleaner 1 m away
Inside a busy office	60	Telephone conversation
Normal conversation	50	Quiet street
Quiet conversation	40	Birds singing
	30	Library reading room
Soft whisper	20	
Falling leaf	10	
Threshold of hearing	0	

2 Using this scale, estimate the noise level in decibels in:
a a room at home
b your classroom
c a thunderstorm.

3 What is the highest noise level you think you could put up with all day?

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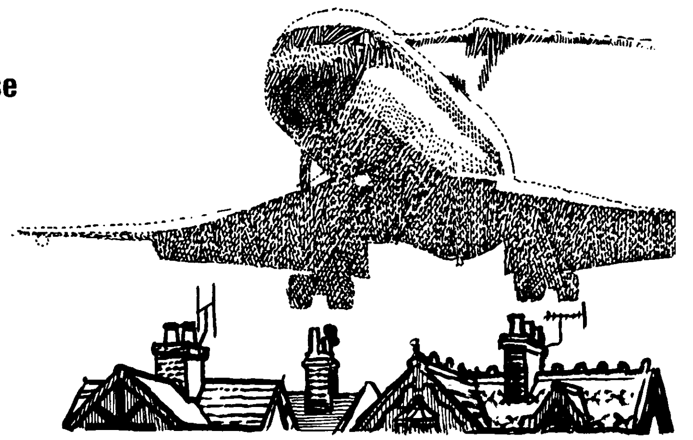
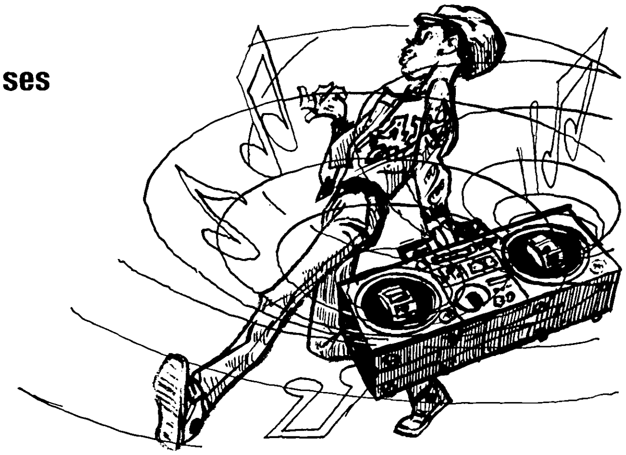
Worksheet P13C [side 2]
Noise



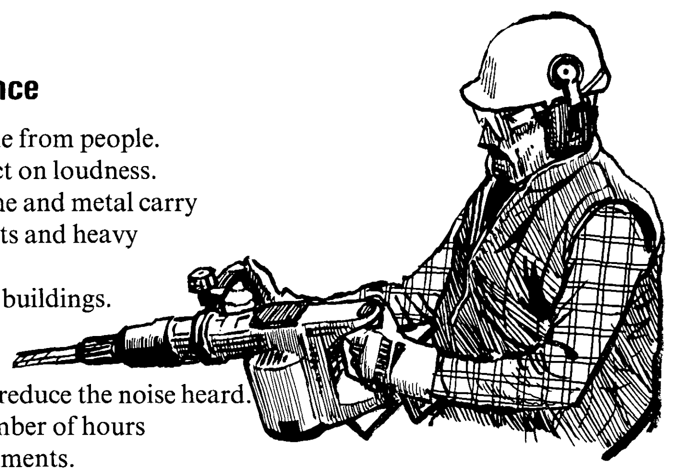
Here are some times and places where noise can be a nuisance

- When you have to work in a factory where machinery makes a constant loud noise
- When you are trying to read or do any task that requires concentration.
- If you live near a busy road – or worse, an airport.



Here are some things that can create noises that are a nuisance

- Motor bike, car and lorry engines
- Aircraft engines
- Noisy machinery
- Loud music – when you don't want to listen to it.



Here are some ways of reducing noise nuisance

- Move the things making the noise as far away as possible from people. Quite small changes in distance can have a substantial effect on loudness.
- Anything that vibrates will carry sound well. Glass, stone and metal carry sound well, but cloth and foam rubber do not. Thick carpets and heavy curtains can absorb sound inside buildings.

  Double glazing can reduce the amount of noise entering buildings. However it can be costly to install.

  Walls, trees and fences can reduce noise levels as well.
- Special ear protectors are available that can be worn to reduce the noise heard.
- Laws have been passed in recent years that limit the number of hours industrial workers may spend in particularly noisy environments.

Using the information above, and any other information you may be able to obtain, suggest what steps you would take in each of the following cases:

4 To reduce the noise nuisance for people who live near major airports.

5 To make sure that people who are fond of pop music suffer no damage from the high sound levels often involved.

6 To ensure that people can work safely and happily in a factory containing noisy machinery.

CONTINUED

Worksheet P13C [side 3]
Noise

How noisy is your school?

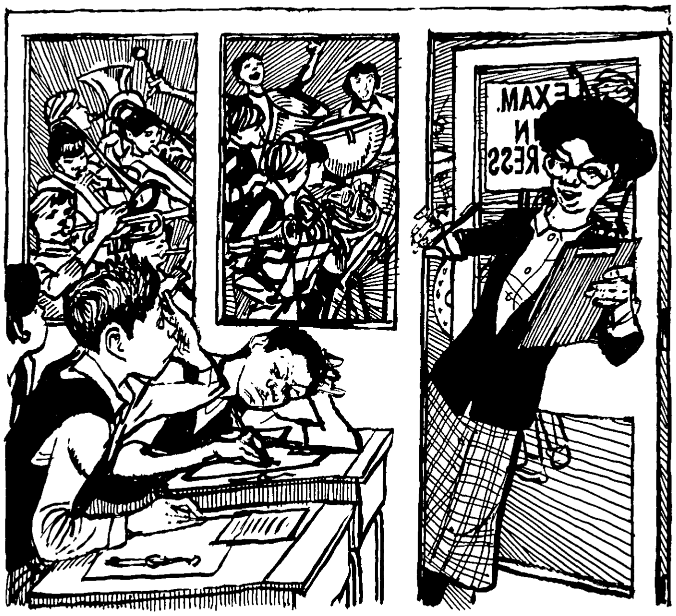
Imagine you are on a committee which is preparing a report on noise problems in your school. Find out the opinions of those who work in the school, using this survey.

a What are the problems?

● First you should decide where noise might be a nuisance. Here are some possible problems to consider:

i Noise getting into rooms from outside, for example, traffic or aircraft noise.
ii Noise carrying from room to room.
iii Noisy activities, for example, some CDT work, games, school kitchen, music.
iv Difficulties in hearing in a particular room because of the size or shape of the room itself.

● Look and listen yourself and talk to people in the school who will be able to suggest where the noise problems are. Talk to teachers and others who work in the school, as well as other pupils.



b What do people think about the problems?

● List your problems in a table like the one shown below. Then carry out a survey of the opinions of pupils and teachers. Ask them to judge the nuisance value of each problem. (The problems given in this table are examples only.)

Problem	**not noticeable**	**noticeable**	**irritating**	**very irritating**
Aircraft noise				
Traffic noise in art room				
Noise in rooms next door to music room				
Echoes in assembly hall				
Noise in canteen				

● For each boy or girl you ask, put a letter X in the appropriate box according to their opinion. For each teacher or other person who works in the school, put a letter S. Then add up the total scores for each problem. Do this separately for the X's and the S's.

● Write out a list of problems in order of seriousness.

1 What are your recommendations to the committee on noise, and how do you suggest the problems might be solved?

2 Do the people who work in the school and the boys and girls in the school agree about the problems? If not, try to explain why.

Worksheet **P14A**
Waves on a spring

With these experiments you can explore the way waves can pass along a spring. In many of the experiments you will find it best to send a single pulse (one up and down or to and fro action) rather than a continuous wave, along the spring.

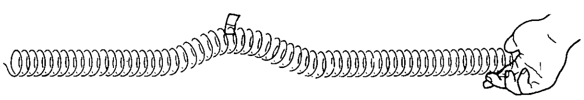
If you are going to do the experiments yourself, you will have to work in a group of two or three people. The spring should rest on a smooth floor or on a bench. To make a transverse *wave*, or *pulse*, you should move your hand from side to side, so that the spring remains touching the floor or bench.

One of you should hold one end of the spring to keep it stretched. Someone else should hold the other end of the spring and make the waves. It is easier to watch what happens to the waves if you are doing neither of these things, so take it in turns to watch and to make waves on the spring.

You will often find it easier to see what happens to the waves if you watch from one end of the spring rather than from the middle.

You will need:
a 'slinky' spring
sticky tape to mark a coil

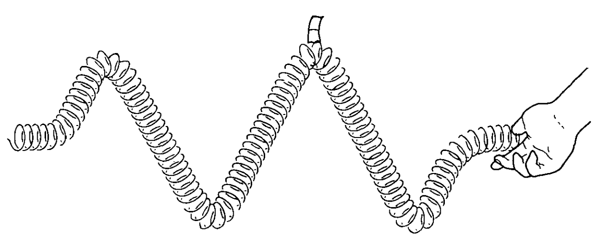
a ● Mark one coil with a piece of sticky tape.
● While a partner holds one end of the stretched spring, give the other end a sharp flick sideways to send a single pulse down the spring.



A wave like this is called a *transverse* wave.

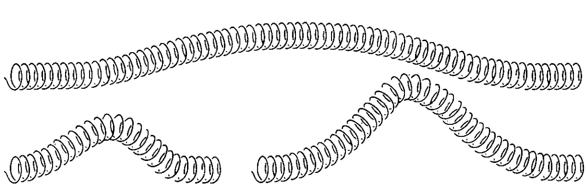
1 Describe what happens to the marked coil as the pulse passes along the spring. In which direction does the pulse move? In which direction do the coils move?

b ● Make a many-loop wave by flicking your hand from side to side several times.



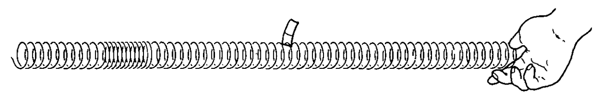
2 Describe what happens to the marked coil as the wave passes it.

c ● Make tall pulses and short pulses, wide pulses and narrow pulses. (You can do this by changing the speed at which you flick the spring.)



3 Do different pulses take different times to travel from one end of the spring to the other?

d ● Gather up some coils of the stretched spring in a bunch and let them go.



A wave like this is called a *longitudinal* wave.

4 Describe what happens to the marked coil as this different type of wave passes down the spring. In which direction does the wave move? In which direction does the coil move?

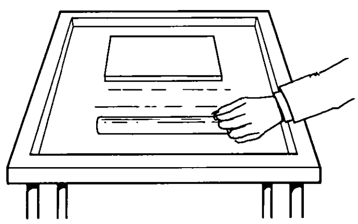
Worksheet P14B [side 3]
Experiments with a ripple tank

Waves change speed

You may find it hard to see exactly what happens when a wave passes from deep to shallow water. If so, your teacher will either give you or demonstrate a wave generator that will produce continuous waves. Continuous waves are easier to see because they last longer. On the other hand they can produce very confusing results as different waves will overlap each other in the tank.

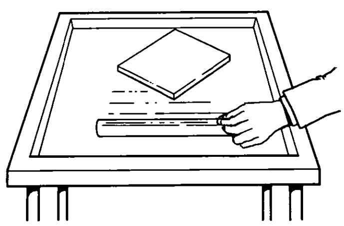
Measurements made on water ripples show that the speed depends on the depth of the water in the ripple tank. If part of the tank is made very shallow by placing a thick glass or plastic plate in it, the ripples crossing the plate will travel more slowly than the ripples in the deeper water.

a ● Put a plate of glass or plastic about 3 mm thick in the tank. Run water out until it just covers the top of the plate.
● Send 'straight' waves towards the plate. Make sure the front edge of the plate is parallel to the incoming waves.



1 What happens to the spacing between the shadows of the wave crests when the waves pass into shallow water?
2 What has happened to the wavelength of the waves?

b ● Now turn the plate so that the front edge makes an angle with the incoming waves.



3 What happens to the waves when they hit this edge?

c Try changing the angle of the plate.

4 What happens to the waves that pass over the plate?
5 Make a sketch of what you see. On your sketch draw lines to represent the waves and mark the direction in which the energy is being transferred.

6 You have done some experiments with light in which you made it change direction by passing it into glass. Did the light turn in the same direction as water waves do when they pass into shallow water?

7 Suppose light were a wave! What could you say about the speed of light in glass compared with its speed in air?

Worksheet P15A
Colour

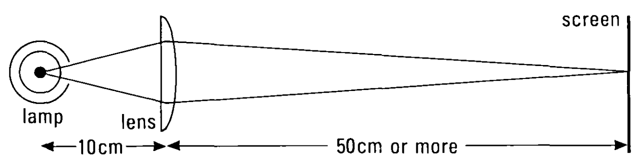
This worksheet shows you how to set up a pure spectrum using a prism. Then it asks you to find out whether the prism makes the colours, or whether they were there in the white light to start with.

You will need:	
a lamp, holder and stand with a lamp shield	a power supply for the lamp
two metal plates, each with a single slit	two 60° prisms
a +7D plano-cylindrical lens	a screen

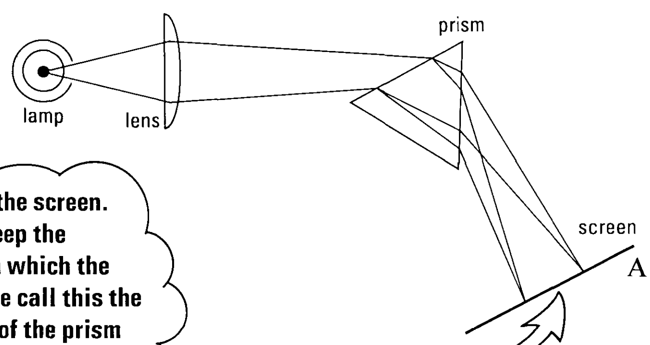
Setting up a spectrum

A spectrum can be produced by passing white light through a prism. Care is needed to produce a spectrum in which the different colours can easily be identified.

a ● Make a sharp image of the filament of a lamp on a screen about 50 cm or more away from the lamp.



b ● Now place the prism in the light beam and move the screen round until you see a spectrum of colours on it. Keep the screen the same distance from the lens.



You will find that the spectrum moves to and fro on the screen. (You may even have to move the screen in order to keep the spectrum on it.) There is one position of the prism in which the spectrum is as far across towards A as it can get. We call this the position of minimum deviation. This is the position of the prism which will give you the sharpest spectrum.

● Keeping the prism where it is, turn it clockwise and anticlockwise to find the position of minimum deviation.

Testing an explanation

The first person to record doing this experiment was Isaac Newton. When he produced the spectrum he asked himself a very important question:

'Are the colours which the prism produces originally a part of the white light falling on it, or are the colours produced by the prism itself?'

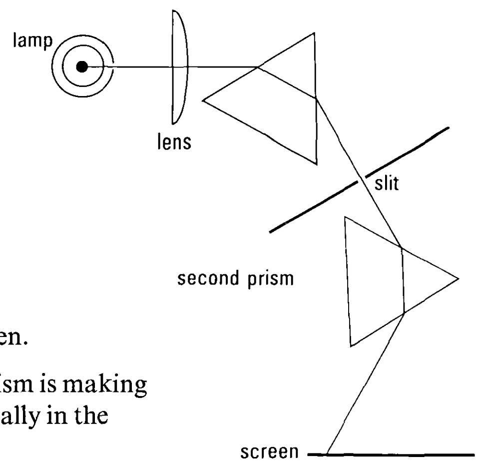
There are two experiments that you can do to test which of these explanations is the correct one.

- Try to think what these experiments are and then try them out.
- Record your ideas and the results of your experiments.
- If after some thought you need help, ask for the **Help sheet**.

Worksheet P15A
Colour
Help sheet

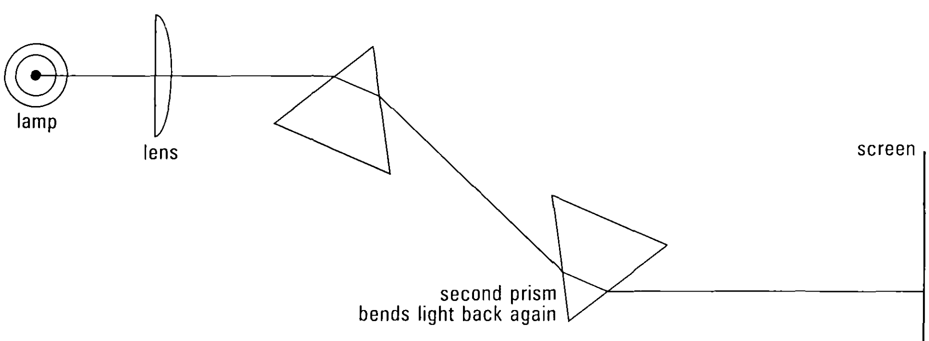
This **Help sheet** will help you test whether the colours of the spectrum are produced by the prism or whether they are a part of the original white light. You will need to use a second prism and a screen with a single slit in it.

a
- Put a slit across the light from the first prism so that light of only one colour gets through it.
- Now put the second prism in the path of this light.
- Move the screen so that the light beam falls on it.
- Record what you see on the screen.



1 Does what you see suggest that the prism is making the colours or that the colours are originally in the light?

b
- Remove the slit and turn the second prism around like this:



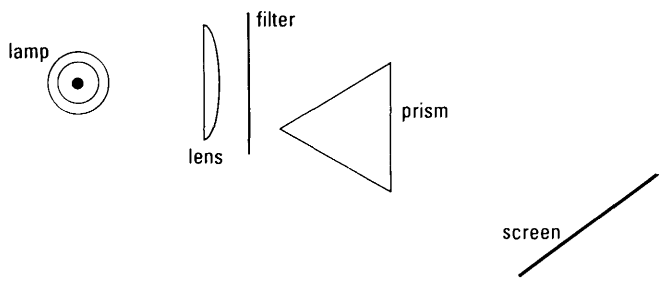
- Reposition the screen so that the light beam falls on it again.
- Record what you see on the screen.

2 Does what you see suggest that the colours are made by the prism or that they are originally present in the white light?

Worksheet **P15B**
Examining colour filters

You are going to examine the effect coloured filters have on white light.

> *You will need:*
> a lamp, holder and stand with a lamp shield
> a metal plate with a single slit
> a +7D plano-cylindrical lens
> a power supply for the lamp
> a 60° prism
> a screen
> blue, green and red colour filters
> a variety of coloured objects



a ● Put a piece of red transparent plastic (called a red filter) into the path of the light falling on the prism.

1 What can you see on the screen?

b ● Now place the filter the other side of the prism so that the light spectrum falls on it.

2 What can you see on the screen?

3 What do you think the piece of red plastic does to white light?

4 Why do you think the piece of plastic is called a filter?

c ● Now repeat your experiment using green and blue filters.

5 What happens to the colours on the screen?

6 What are the green and blue filters doing to the white light?

d ● Predict what will happen to the light on the screen if you put a red and a blue filter together in the path of the light falling on the prism.
● Now try it.

> **A green object is green because it reflects only the green part of the white light falling on it.**

7 What would you expect to see if you looked at a green object through a red filter?

8 What would you expect to see if you looked at a green object through a green filter?

e ● Try looking at as many different coloured objects as you can through coloured filters. Each time predict what you will see **before you look**.
● Record everything you do and see. You may have to do the next set of experiments before you can explain all your observations!

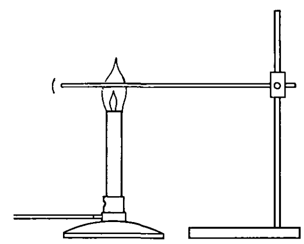
Worksheet P15C
Colour vision

These experiments will help you to understand how we can obtain a wide range of colours using just red, green and blue light.

You will need:

a lamp, holder and stand with a lamp shield	a power supply for the lamp	sodium chloride (common salt)
a metal plate with a single slit	two 60° prisms	a steel wire
a +7D plano-cylindrical lens	a Bunsen burner	two small plane mirrors
yellow, cyan and magenta colour filters	a stand, boss and clamp	a screen

Pure yellow light

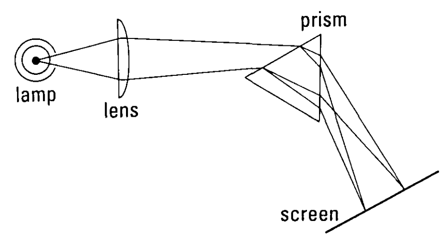


a ● Place a wire covered with table salt in a Bunsen flame.
● Look at the light that is produced.

b ● If possible look at the same light after it has passed through a prism.

The light is a pure yellow, and is not split up into any other colours by the prism.

Yellow, magenta and cyan filters



a ● Set up a prism, screen, lens and white light source like this:
● Put a yellow filter in the path of the light passing through the prism.

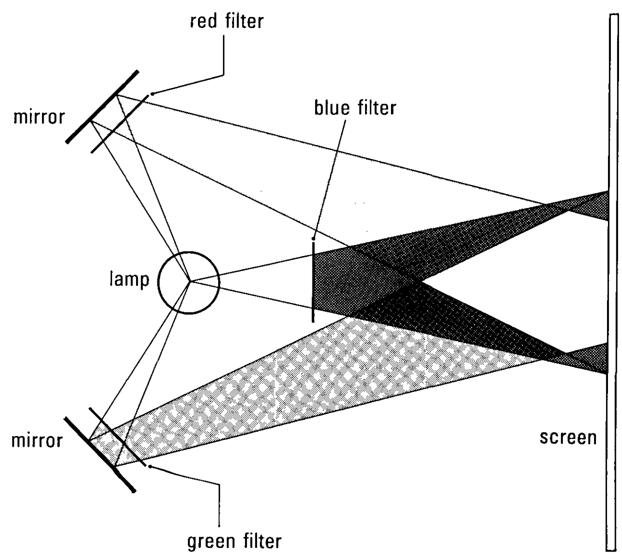
1 Describe what you see on the screen.

b Repeat step **a** using a magenta filter (which is a purply colour) and a cyan filter (which is a blue–green colour).

2 Describe what you see on the screen.
3 What does each filter do to white light when it passes through it?

Mixing primary colours

You will have seen that yellow, magenta and cyan filters each let light of several different colours pass through them. Red, green and blue filters pass light of only one colour. Red, green and blue light cannot be split up into more colours by a prism. For this reason they are called *primary* colours. This experiment involves mixing lights of different primary colours. You may do this yourself, or it may be demonstrated to you.



a ● Set up your apparatus as shown opposite:
● Put the blue filter in the path of the **direct** beam as the blue filter always passes least light.

b ● Try mixing pairs of colours on the screen by adjusting the mirrors. (For example, try mixing red and blue.)

4 Describe what you see when you mix each pair of colours.
5 What do you see if you mix all three colours?

Worksheet P15D
Secondary colours

The colours produced by mixing together beams of primary colour light are called *secondary* colours. Yellow, cyan and magenta are all secondary colours. The experiment on Worksheet **P**15C showed you how all the colours of the spectrum could be produced by mixing just red, blue and green light. This is called *colour addition.*

Colour photographs and colour slides work differently. They have to produce their colours from white light. The way they do this is called *colour subtraction.*

You are going to investigate colour subtraction.

> *You will need:*
> a darkened room to work in
> a white light source (for example, a slide projector)
> yellow, cyan and magenta colour filters
> some coloured objects or brightly coloured paper to make up a picture

a ● Hold a magenta filter up to any white light source.
● Now hold up a yellow filter so that it half overlaps the magenta filter.

1 Describe and explain what you see through the filters.

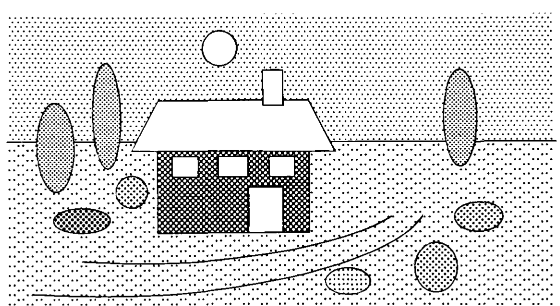
b ● Change the yellow filter for a cyan filter.

2 Explain what you see now.

c ● Finally, try a yellow filter and a cyan filter together.

3 Explain what you see.

d ● Make a picture from brightly coloured objects or paper:
● Look at the picture under light which has passed through a yellow filter. (It is best if a group can arrange to see this in a well-darkened room using a slide projector to provide the light.)



4 Describe and try to explain what you see.

e ● Now repeat the experiment, first using magenta light and then using cyan light.

f ● Look at some colour pictures in a magazine. Use a magnifying glass to see if you can work out how the colour pictures have been produced.

Colour vision is a very complicated thing and depends as much on what the brain thinks it is seeing as on the actual light present. Such things are very important to people concerned with design, stage lighting and painting.

Here is one last thing to try. You may do it yourself, or it may be demonstrated to you. You need a well-darkened room and two or three slide projectors!

g ● Project some white light onto a screen.
● Now partly-overlap the white light with some red light of the same intensity from another projector.

5 What colour has the 'white' light become? Explain what has happened if you can.

h ● Try some other colours!

Worksheet **P15E** [side 1]
The electromagnetic spectrum

The longest electromagnetic waves have a wavelength of about 10^6 m (that is, 1 000 000 m). The shortest electromagnetic waves are so short that 1 million million or 10^{12} of them in a line would only be 1 cm long.

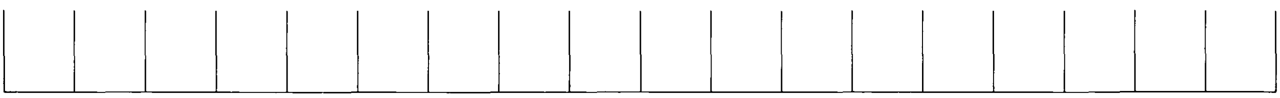
How can we represent such a wide range on a chart? Suppose we decide to make 20 cm (the width of a page) represent 10^6 m. Radio waves with a wavelength of 1 m would be represented by a line $\frac{20}{1\,000\,000}$ cm (or 0.000 02 cm) long.

We could not possibly draw such a fine division.

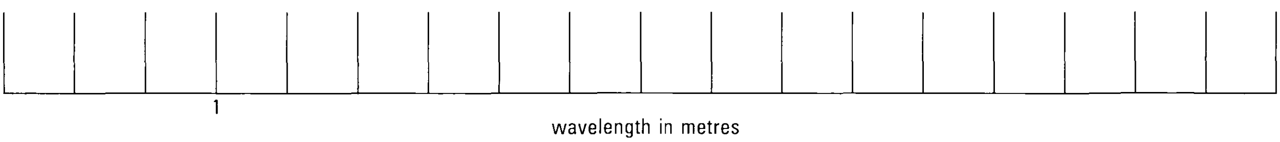
Drawing a special scale

To show very large and very small numbers on the same chart we use a special type of scale. Here is how to draw it:

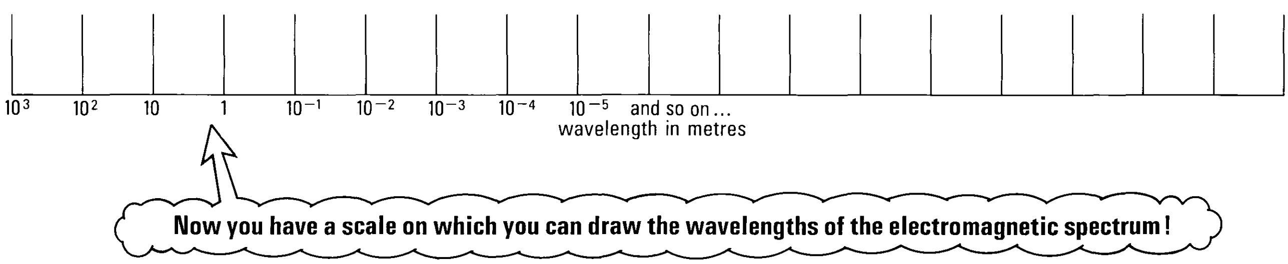
a ● Draw a line 18 cm long across a piece of paper. Draw marks on it every 1 cm like this:



b ● Label the fourth mark with the number 1. This will represent a wavelength of 1 m.
● Label the scale 'Wavelength in metres'.



c ● Now label all the other marks so that each one represents a number one-tenth the size of the number on its **left**. Your scale should look like this:



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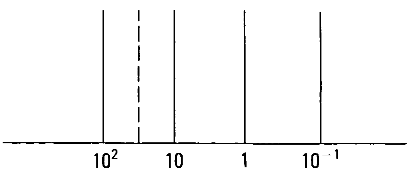
Worksheet P15E [side 2]
The electromagnetic spectrum

The sort of scale you have drawn is very useful for making charts and graphs of numbers that extend over a large range. It is called a *logarithmic scale*. When using this type of scale you have to be careful about 'reading between the lines'. Look at this section of scale:



Which of the following numbers best represents the value indicated by the dotted line?

15 30 50 90

The answer is in fact 30, but 50 would have been a good guess. Don't make the mistake of thinking it is about 15 (far too small) or about 90 (far too large).

Making a chart of electromagnetic waves

a ● Make a chart of the electromagnetic spectrum using the scale you have drawn. Use data from your Physics book and any other book you can find.
● Mark the range of wavelengths occupied by these types of waves:

gamma rays
microwaves
X-rays
radio waves
ultra-violet rays
visible light
infra-red radiation

● Divide up the radio waves into UHF (they are the TV waves), VHF, short, medium and long-wave radio. (You may find that some of the ranges overlap.)

b ● Copy the table below. Add as much information as you can about the different parts of the electromagnetic spectrum.

Type of radiation	Wavelength in m	Frequency in Hz	Sources of the radiation	Detectors	Notes (uses, dangers . . .)

Worksheet **P15F** [side 1]
Earthquakes

Earthquake damage

An earthquake is a violent shaking of the ground, normally lasting a minute or less. The record for the longest earthquake is seven minutes. Earthquakes are caused by the movement of rocks near the Earth's surface. An earthquake usually occurs only when movements in the Earth's crust have set up very large forces in it. Once these forces are large enough to slide neighbouring rocks past each other a large amount of energy is released. An earthquake in Peru in 1970 is estimated to have released energy equal to the amount which would be released by burning 250 000 tonnes of coal.

The energy transferred by an earthquake may be released several hundred metres below the Earth's surface. Waves carry the energy outwards to the Earth's surface. Vibrations from the waves produced by violent earthquakes, such as the one in Peru, can be picked up on the other side of the Earth.

Earthquake waves

Earthquakes produce three types of waves. The first sort is a longitudinal wave – called a P-wave. You can remember this because P stands for 'pressure'.

1a Give an example of another longitudinal wave.
b Why is 'pressure wave' another good name for a longitudinal wave?
2 As a P-wave passes through the rocks they will vibrate. Which way will they move in relation to the direction in which the wave is travelling?

The second sort of wave produced by an earthquake is a transverse wave called an S-wave. You can remember this from the fact that 'S' is the first letter of 'shake'.

3a Give another example of a transverse wave.
b Why is 'shake wave' a good name for a transverse wave?
4 Which way will the rocks vibrate when an S-wave passes through them?

The third type of wave is called an L-wave. It travels over the surface of the Earth like ripples on a pond.

5 Are L-waves longitudinal or transverse waves?

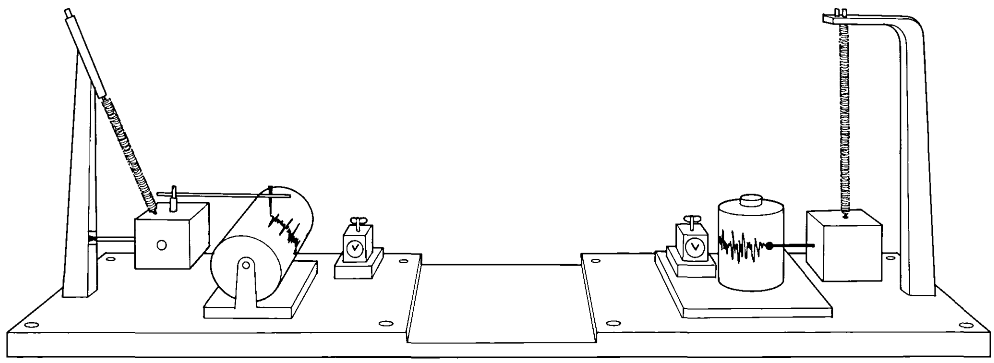
CONTINUED

Worksheet P15F [side 2]
Earthquakes

Seismometers

Seismometers are instruments that record earthquake waves. The heavy masses are connected to pens. These draw an ink line on paper which is kept moving under them.

An earthquake wave will cause the Earth to vibrate. The recording paper on its drum will move with the Earth, but the heavy masses will stay still. So a wavy trace of the Earth's movement is recorded on the paper.



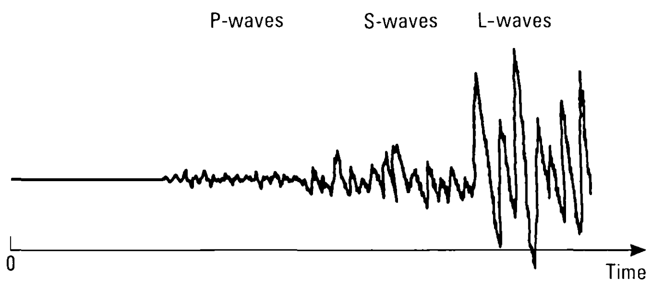
Two seismometers

6 Describe an experiment you have seen or read about which shows that a heavy mass will move very little when a quickly-changing force is applied to it.

7 The diagram shows two seismometers. Explain why a *third* seismometer is needed to detect all possible earthquake waves arriving at the point where the seismometers are placed.

8 The word 'seismometer' comes from a similar word – 'seismic'. Earthquake waves are often called 'seismic waves'. What does the word 'seismic' mean?

This diagram shows a record of the arrival of three earthquake waves at a group of three seismometers. (The three records have been combined so that you can compare the times of arrival of the waves.) ▶



9 Which wave arrived first?

10 Both P- and S-waves had travelled through the Earth to arrive at the seismometers. Which wave (P or S) travelled faster?

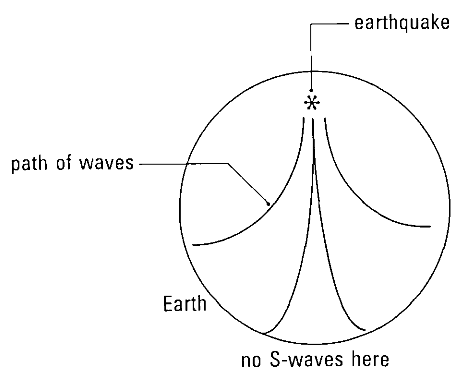
Earthquake waves change direction

Scientists have made records of the waves from a single earthquake at different places around the world. By comparing the records they have shown that the waves must travel on a curved path through the Earth.

11 What name do we give to this type of change in direction?

12 Why do you think the waves travel on a curved path rather than a straight path?

Earthquake records show that only P-waves from the earthquake reach the far side of the Earth. No S-waves are detected there. Scientists believe this shows that the very centre of the Earth is liquid.



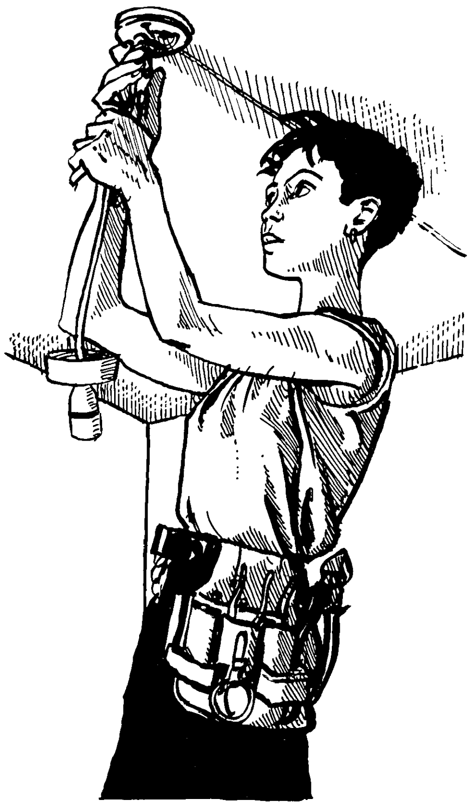
13 Try to explain why they come to this conclusion.

Worksheet **P16A** [side 1]
Simple circuits

These experiments will help you to revise some ideas about electricity that you will already have come across in science. They will also give you some practice in wiring up circuits. It is very important to be able to wire up circuits correctly, either to do a particular job or to follow a circuit diagram.

Draw the circuit diagrams in your notebook where you are asked to do so. When you have to read an ammeter, do so carefully and accurately.

You should ask your teacher to check each circuit before 'switching on'.


Wiring up a light socket.

For Experiments 1 and 2 you will need:
two lamps in lamp holders
a cell (battery) in a holder
an ammeter
connecting wires

Experiment 1: Lighting lamps

a
- Make a circuit to light a lamp to full brightness.
- You may only use the apparatus you have been given.

b
- Now alter your circuit so that the battery will light two lamps to full brightness.

c
- Draw circuit diagrams of the two circuits you have made.

Use the correct symbols for everything in your circuits. You will find a table of these on page 248 of your Physics book.

Experiment 2: Using an ammeter correctly

a
- Connect up the same circuit that you made in Experiment 1 to light a lamp to full brightness.
- Now put an ammeter in the circuit, to measure the current.

b
- Draw the circuit, using the correct symbols.
- Write down the reading on the ammeter.

When you read an ammeter, do so as accurately as possible.

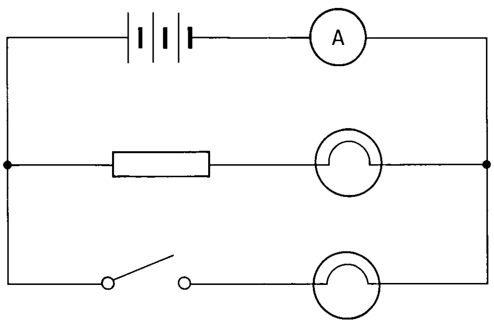
CONTINUED

Worksheet P16A [side 2]
Simple circuits

For Experiments 3 and 4 you will need:
three cells in holders
two lamps in holders
three resistors, one unmarked, one marked X and one marked Y
a switch
an ammeter
a variable resistor
connecting wires

Experiment 3: Wiring up a circuit from a circuit diagram

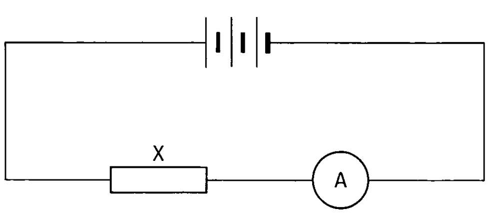
a ● Using the apparatus you have been given, wire up the circuit shown in this diagram:



b ● Write down the reading on the ammeter with the switch open, and with the switch closed.

Experiment 4: Using resistors

a ● Wire up this circuit using the resistor marked X, an ammeter and a battery:



● Write down the reading on the ammeter.

b ● Now exchange the resistor marked X for one marked Y.
● Write down the reading on the ammeter.

1 Which resistor is the greater of the two?

c ● Now add a variable resistor to your circuit so that it is in series with the fixed resistor marked Y and the ammeter.

2 What is the effect on the ammeter readings of altering the value of the variable resistor?

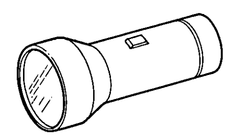
Worksheet P16B
Using electricity in the home

This worksheet will give you some practical experience of using electricity in the home.

Warning: **Whenever you are making electrical connections, make sure you know what you are doing! Always switch off and disconnect first, and follow instructions carefully.**

You will need:
2 electric torches, one of which is not working
13A mains plug
3 core mains wire
a selection of fuses
electric cell in holder
lamp in lamp holder
screwdriver
wire strippers

Electric torches

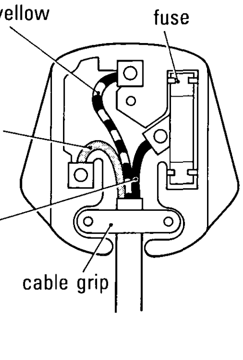


a ● Take an electric torch to pieces.
● Draw a diagram of the circuit made by the battery and the light bulb. Mark on your diagram the parts of the torch that act as the connecting wires between the battery, switch and light bulb.

b ● You will be given another torch which is not working. Find out why it is not working and then make it work.
● You will need to test both the light bulb and the battery. Make up your own circuit to do this.

Three-pin plugs

It is important to be able to wire up a three-pin plug correctly and safely. This diagram shows how the wires should be connected.



a ● Wire up the three pin plug you have been given so that the wires are securely connected to the correct pins.
● Make sure the cable is firmly held by the cable grip.

b ● A friend tells you that his Dad never bothers about the striped wire, and 'just joins the bottom two' – without worrying about the colours! 'It always works' he says. Tell your friend two ways in which his Dad is taking a risk.

Fuses

You will be given a number of fuses of the sort that are used in 13A plugs. Some of them are not working.

a ● Design and make a circuit to test whether a fuse is working.

b ● Use your circuit to sort the fuses into two groups: 'working' and 'not working'.

Worksheet **P16C** [side 1]
Electric currents

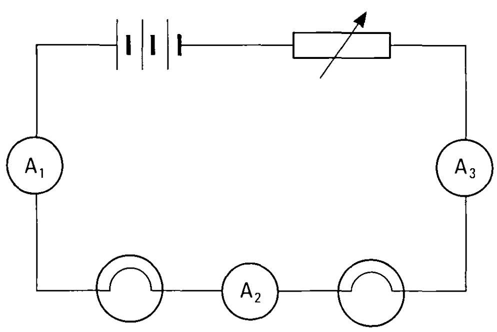
The experiments described in this worksheet will give you some experience of the behaviour of electric currents.

You may either be able to do these experiments yourself or you may see them demonstrated. Either way, you should answer the questions on the worksheet.

For Experiments 1 and 2 you will need:
three cells in holders
a variable resistor
two lamps in lamp holders
three ammeters
connecting wires

Experiment 1 : Electric currents in a series circuit

Two lamps, a battery, a variable resistor and three ammeters have been connected up to form this circuit:



a ● Write down the readings of the three ammeters

b ● Now alter the variable resistor so that the lamps are dimmer.
● Write down the new readings of the ammeters.

1 What has been the effect on the ammeter readings of changing the variable resistor?

c ● Try another value for the variable resistor.

2 What happened to the brightness of the lamps?

3 Suppose that for a particular setting of the variable resistance, the reading of the ammeter A_1 was 0.5 A. What would you expect the readings of the other two ammeters to be?

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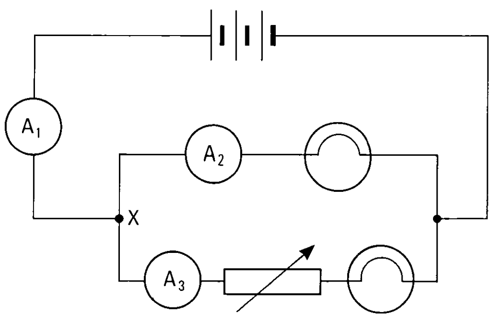
Worksheet P16C [side 2]
Electric currents

Experiment 2: Electric currents in a branching circuit

The next circuit has been connected up like this:
This is a branching circuit.



a ● Write down the readings of the three ammeters.

Ammeter A_1 is reading the rate of flow of electric charge into the junction marked X. Ammeters A_2 and A_3 are measuring the rate of flow of electric charge away from the junction marked X.

● Add the reading of A_2 to that of A_3.

1 Is the result of your reading equal to the reading of A_1? Would you expect it to be?

b ● Now change the variable resistor.
● Write down the readings of the three ammeters.

2 Is the reading on A_1 equal to the reading on A_2 **plus** the reading on A_3?

Experiment 3 (optional): A more complex branching circuit

For this last experiment you will be shown a more complex branching circuit of ammeters and other circuit components.

a ● Draw a diagram of the circuit.

b ● Write down the readings of all the ammeters.

c ● Find as many relationships between the readings as you can.
● Say whether these relationships are what you would expect if the ammeters are measuring the rate of flow of electric charge around the circuit.

Worksheet **P17A** [side 1]
Voltage

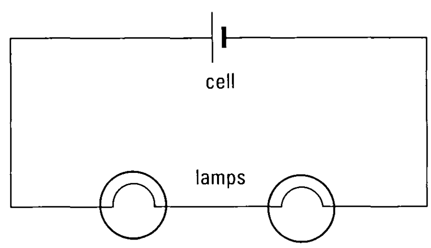
These experiments will give you experience in using a voltmeter and understanding what it measures. Do not spend longer than necessary on each experiment.

You will need:
two cells in holders
two lamps in lamp holders
a voltmeter
connecting wires

Experiment 1: Lamps in series

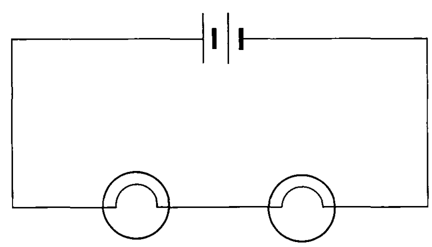
a ● Set up a circuit with **one** electric cell connected to **one** lamp. Note that one cell lights one lamp fully. The lamp needs all the energy from the cell to light fully.

b ● Now connect two lamps in series like this:



One electric cell will not light both lamps fully when they are placed in series. This is because the electric charge has to pass through both lamps before getting back to the cell. The two lamps have to share the energy from the cell.

c ● Now add a second electric cell in series with the first like this:



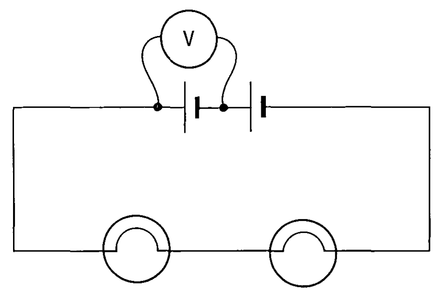
1 Are both lamps now fully lit? Explain why.

2 If you have read the section 'Potential difference' on page 266 of your Physics book, draw a 'hill diagram' to show the change in energy of the charge as it travels round the circuit.

Experiment 2: Using a voltmeter

You can use a voltmeter to explore the two-cell circuit from Experiment 1.

a ● Attach two long leads to the voltmeter and connect them across the first cell like this:



● The red terminal (+) of the voltmeter should be connected to the positive (+) terminal of the cell.
● Write down the voltmeter reading.

1 How many joules of energy can each coulomb of charge transfer from this cell?

b ● Now connect the voltmeter across both cells.
● Write down the voltmeter reading.

2 How many joules of energy can each coulomb of charge transfer from two cells connected in series?

c ● Disconnect the voltmeter and connect it across one of the lamps.
● Write down the voltmeter reading.

3 How many joules of energy does each coulomb transfer to the lamp?

CONTINUED

Worksheet P17A [side 2]
Voltage

d ● Disconnect the voltmeter and connect it across the other lamp.
● Write down the voltmeter reading

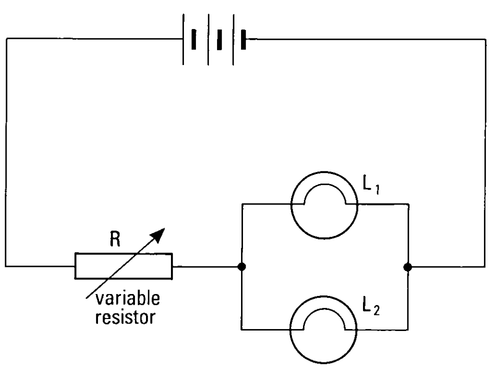
4 How many joules of energy does each coulomb of charge transfer to the second lamp?

e ● Now connect the voltmeter across both lamps.
● Write down the voltmeter reading and compare it with the reading you noted down when the voltmeter was connected across both cells.
● Comment on these two readings.

f ● Connect an ammeter in your circuit so that you can read the current through the lamps.
● Write down the ammeter reading.
● Draw a circuit diagram with the ammeter in the circuit and a voltmeter connected across one lamp

Experiment 3: A more complex circuit

a ● Connect up this circuit:



● Connect a voltmeter across L_1 and adjust R until the voltmeter shows that L_1 is fully lit. (L_1 and L_2 are the same as the lamps that you used in the previous experiments in this worksheet.)
● Write down the reading on the voltmeter.

b ● Now connect the voltmeter, first across L_2 and then across R.
● Write down the voltmeter readings.

1 What can you say about the voltmeter readings across L_1 and L_2?

Each coulomb of charge will transfer the same energy no matter which of the two branches it goes down. It is like going down the same hill in two different directions – both ways you reach the bottom!

c ● Connect the voltmeter across two cells.
● Write down the reading on the voltmeter.
● Add together the reading of the voltmeter across R and the reading of the voltmeter across one of the lamps.

2 How does the result of your addition compare with the reading you have just taken across the two cells?

Worksheet **P17B** [side 1]
Power in electric circuits

You have already learnt that:

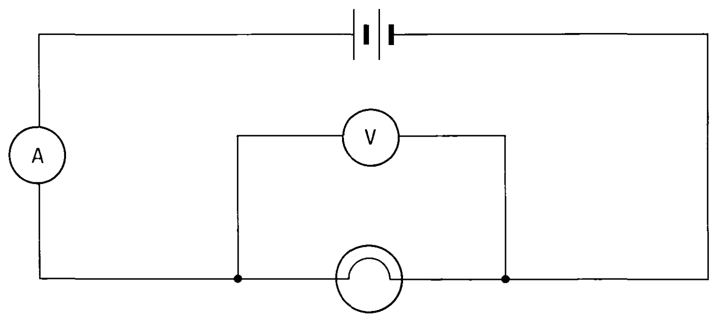
Electric power = voltage × current.

These experiments give you some practice in using this relationship.

You will need: two cells in holders a lamp in a holder an electric motor a voltmeter an ammeter connecting wires

Experiment 1: Power transferred in a lamp

a ● Wire up the circuit shown in this circuit diagram.



b ● Record the current passing through the lamp and the voltage across it like this:

The voltage across the lamp is________V.

The current through the lamp is________A.

c ● Work out the energy (in joules) transferred during each second by the electric charge passing through the lamp.
● To do this, write out your working in the following way. This will make the calculation clear and easy to follow:

The current through the lamp = ________A.

This means that ______ coulombs of charge pass through the lamp each second.

The voltage across the lamp = ________V.

This means that each coulomb of charge transfers ________joules as it passes through the lamp.

Therefore in one second ________ coulombs of charge pass through the lamp,

each transferring________joules of energy.

So the energy transferred by the electric charge passing through the lamp in each

second = ________coulombs × ________joules/coulomb.

Thus the power of the lamp = ________joules/second,

= ________watts.

CONTINUED

Worksheet P17B [side 2]
Power in electric circuits

Experiment 2: Power transferred by a small electric motor

a ● Now replace the lamp in the circuit in Experiment 1 with the small electric motor.

b ● Record the current passing through the motor and the p.d. across it like this:

The voltage across the motor is__________V.

The current through the motor is__________A.

c Work out the power of the motor when it is running, by laying out your working in the same way as you did for the lamp.

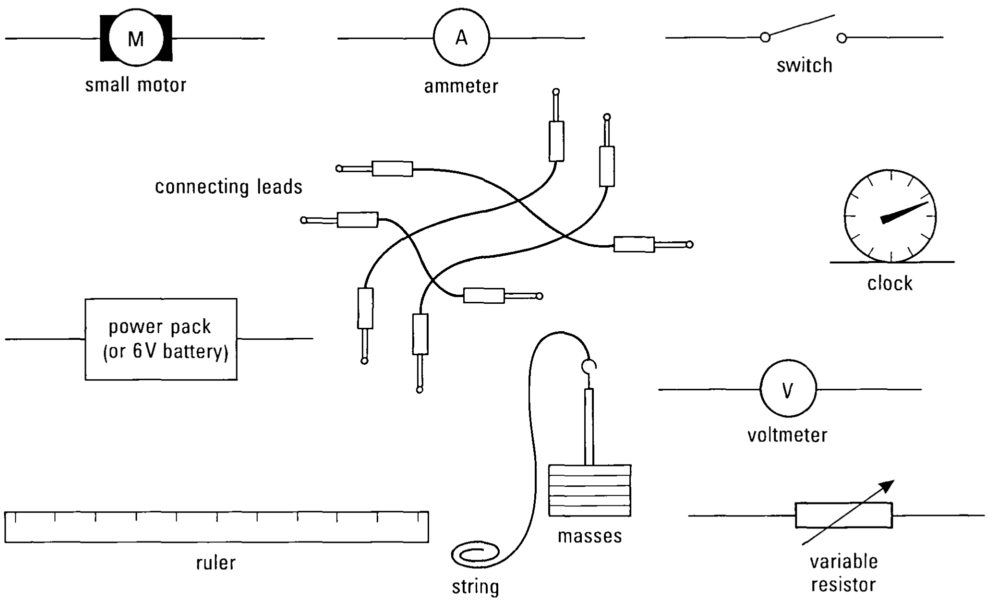
Worksheet P17C is an investigation into the efficiency of an electric motor. If you have time, you can go on to this now.

Worksheet P17C
The efficiency of an electric motor

This is an investigation into the efficiency of an electric motor. Thousands of electric motors are used in industry and in our homes to make the energy available from fuels perform useful jobs.

The electric motors used in industry need to have high power and be highly efficient. They are thus designed differently from the small motor you will use in this investigation.

● Plan and carry out an investigation to measure the efficiency of the electric motor in raising the 0.5 kg load. You may use some or all of the equipment shown below.



In this diagram electric components have been illustrated using their circuit symbols.

● If you have time, investigate the effect on the efficiency of the motor of:

i changing the load the motor has to raise.

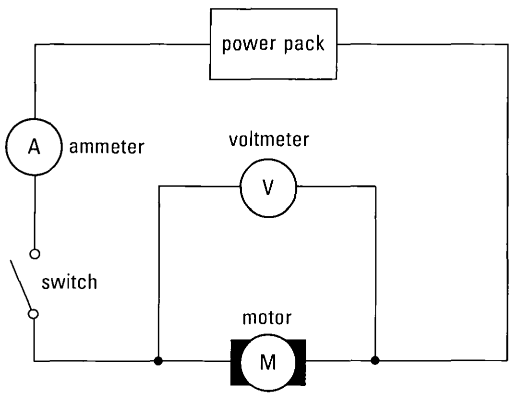
ii changing the speed with which the motor raises the load.

$$\textbf{efficiency} = \frac{\textbf{'useful' energy output}}{\textbf{total energy input}}$$

● If you need more help, ask for the **Help sheet**.

Worksheet P17C
The efficiency of an electric motor
Help sheet

a Setting up the circuit



b Carrying out the experiment

- Attach a 0.5 kg mass to the string and wind part of it round the motor axle.
- Adjust the voltage and current so that the mass is raised by the motor at a steady speed.
- Time how long it takes the motor to lift the mass 1 m.
- Record the current through the motor and the p.d. across it.

c Working out the input energy

- Write out your working like this:

The current through the motor = ________ A,

= ________ coulombs per second.

The p.d. across the motor = ________ V,

= ________ joules per coulomb.

So the input power is equal to the energy transferred every second = ________ × ________ W.

The energy transferred to the motor while the mass is raised 1 m = input power × time,

= ________ × ________,

= ________ J.

d Working out the output energy

The pull of the Earth on the mass is 10 N for every 100 g mass (0.1 kg). Work out the pull of the Earth on 0.5 kg.

The pull of the Earth on 0.5 kg = ________ N.

The work done in raising the mass 1 m = force × distance raised,

= ________ N × ________ m,

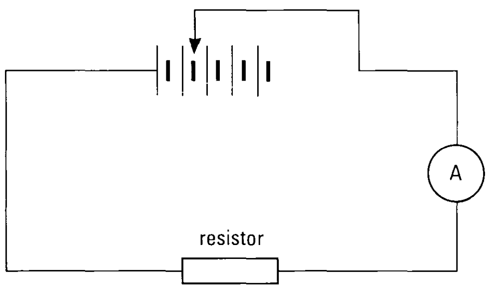
= ________ J.

Worksheet **P17D** [side 1]
Controlling the size of an electric current

These experiments are intended to show you some of the things that control the size of an electric current in a circuit. They may be demonstrated to you, or arranged as a 'circus' for you to do.

> *You will need:*
> five cells in holders
> a 10 Ω resistor
> an ammeter
> connecting wires

a ● Starting with one cell increase the number of cells in the circuit and note what happens to the ammeter reading.

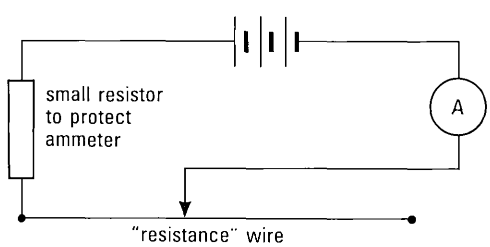


1 Copy and complete the following sentence using a word from the box at the end of side 2 of the worksheet.

Increasing the voltage of the supply ________ the size of the electric current.

> *You will need:*
> three cells in holders
> a resistance wire fixed to a board
> an ammeter
> connecting wires
> a 4.7Ω resistor to protect the ammeter

b ● Vary the length of wire in the circuit and note what happens to the ammeter reading.



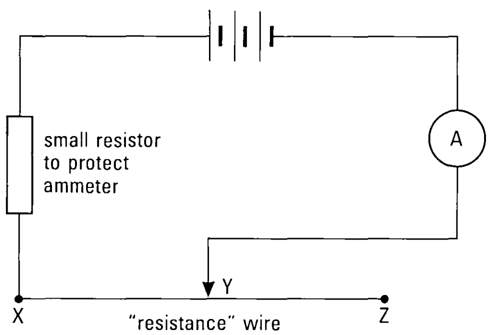
2 Copy and complete the following sentence using a word from the word box.

Increasing the length of the wire in the circuit makes the current ________.

CONTINUED

Worksheet P17D [side 2]
Controlling the size of an electric current

You will need:
three cells in holders
two resistance wires, one thin, one thick
a piece of copper wire
an ammeter
a 4.7 Ω resistor
connecting wires



C
- Connect Y to X. Write down the ammeter reading.
- Connect Y to Z. Write down the ammeter reading.
- Replace XZ with the thick piece of wire of the same material. Write down the ammeter reading with Y connected to Z.
- Replace XZ by the piece of copper wire. Write down the ammeter reading with Y connected to Z.

3 Copy and complete the following sentence using words from the word box.

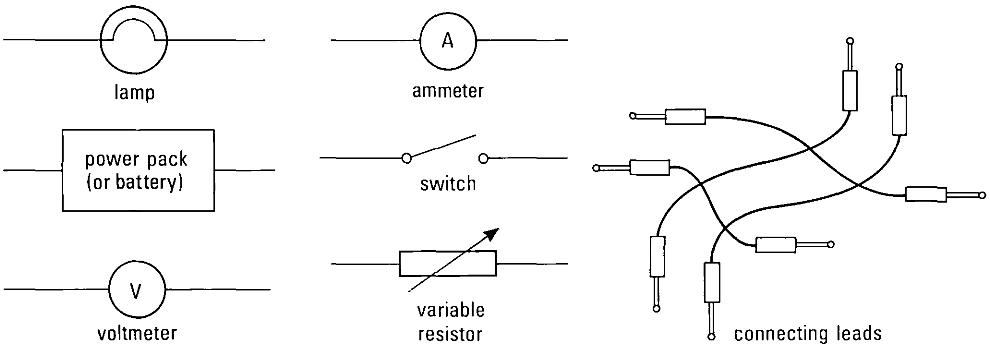
Thick wires have a ________ resistance than thin wires of the same material; pieces of thick, copper wire have almost ________ resistance and are used as connecting wires in a circuit.

Word box
smaller larger increases decreases zero

Worksheet **P17E**
The resistance of a lamp

You are going to investigate the way the resistance of a lamp varies with the p.d. across it.

● Plan and carry out the investigation using the equipment shown below. Make a circuit which will enable you to measure the resistance of the 6 volt lamp at voltages from 1 V up to 6 V.



1a From your results, plot a graph of the resistance of the lamp (on the *y*-axis) against the current flowing through the lamp (on the *x*-axis).
b Try to explain the shape of the graph.

2a Calculate the current flowing through a 240 V, 60 W mains lamp when it is in normal use.
b Using the results from this investigation, estimate the current that will flow through the mains lamp when it is first switched on.
c How could you check your estimate?

Worksheet P17F
Electrical resistance

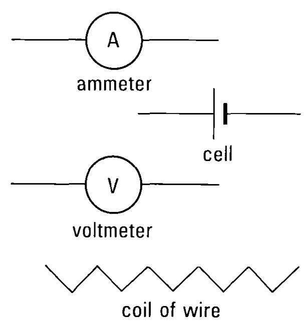
These experiments should help you to understand the idea of electrical resistance.

You will need:
two cells in holders
an ammeter
a voltmeter
a coil of resistance wire
resistance wire mounted on a board
connecting wires

Experiment 1: Measuring electrical resistance

The aim of this experiment is to measure the resistance of the wire coil.

a ● Connect up the components (shown opposite as their circuit symbols) into a suitable circuit so that you can measure the current through the coil and the p.d. across it.



b ● Draw a circuit diagram of your arrangement.

c ● Now work out the resistance of the coil. Write out your working like this:

The current through the coil = ________A.

The p.d. across the coil = ________V.

The resistance of the coil is given by: $\frac{\text{p.d. across coil}}{\text{current through coil}}$.

So the resistance of the coil = ________Ω

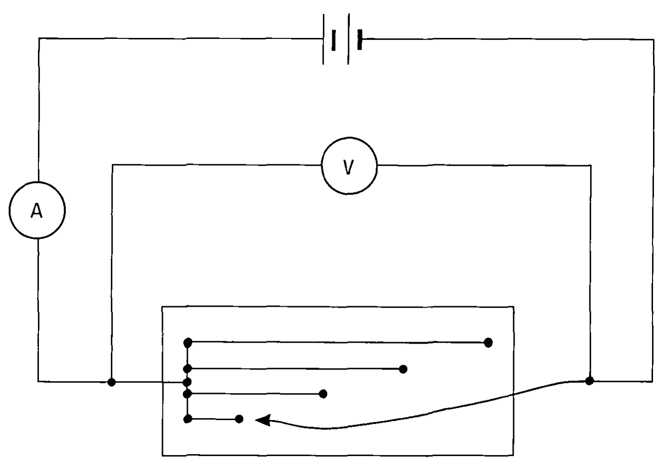
Experiment 2: The relationship between a wire's length and resistance

The aim of this experiment is to explore the way the resistance of a piece of wire changes with its length.

a ● Connect up the board holding four pieces of resistance wire into a circuit so that you can measure their resistance.

b ● Connect the top wire into the circuit.
● Write down its length, the current through it and the p.d. across it.
● Work out the resistance of the wire.

c ● Repeat step **b** for each of the other three wires.



1 There is a **relationship** between the length of the wire and its resistance. What is it?

2a Plot a graph of the wire's length (y-axis) against the wire's resistance (x-axis).

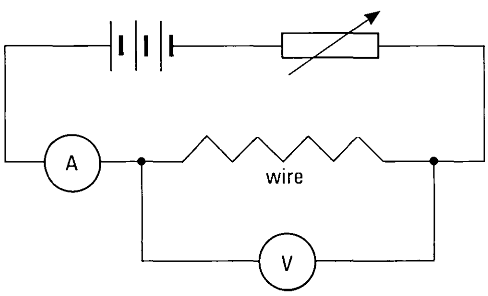
b What sort of graph do you get?

Worksheet P17G
Ohm's law

You are going to investigate the relationship between the current flowing through a wire and the p.d. across it.

You will need:
three cells in holders
a variable resistor
0.5 m of resistance wire
an ammeter
a voltmeter
connecting wires

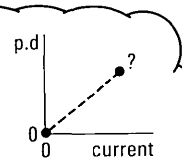
a ● Set up this circuit:



b ● Obtain a series of pairs of readings of the **current** through the wire and the **voltage** across it. Three or four pairs will be enough, but they should be spread from 0 to the largest value your instruments will read.

1 How do current and p.d. seem to be related for your wire?

First look at your measurements and guess.
Then test your guess by arithmetic:
divide the p.d. by the current.
Then plot a graph of p.d. (*y*-axis) against current (*x*-axis).



2 What does your graph tell you?

3 Calculate the resistance of the piece of wire from measurements on your graph.

Worksheet **P18A** [side 1]
Electric vehicles

This worksheet is about the advantages and disadvantages of electric vehicles when compared with petrol-driven vehicles.

Vehicles need energy

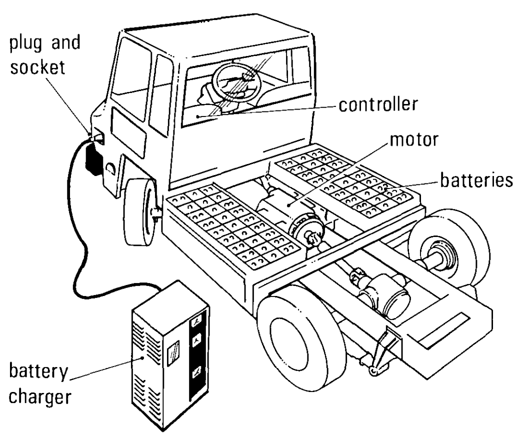
Vehicles need a supply of energy. First of all they need energy to accelerate. Then, as you saw in Chapter 8 of your Physics book, they need a supply of energy even when running at a steady speed. A 1 tonne car travelling at a steady 45 km/hr transfers about 225 kJ of energy in warming up itself and the surroundings for every 1 km it travels. To provide this energy the vehicle needs an energy store.

1 What provides this energy store in an ordinary car?
2 What is the energy store in an electric car?
3 Some electric vehicles do not carry an energy store. Instead they collect their energy as they go along. Give an example of such a vehicle.
4 Why do vehicles need energy in order to accelerate?
5 Explain why a heavy vehicle needs more energy than a light vehicle to accelerate to the same speed.

How do electric vehicles work?

Electric trains can collect their electrical energy from overhead wires or conductor rails. But other electric vehicles need to carry their energy, stored in batteries. The batteries drive an electric motor. The main parts of the system are shown in this picture of an electric lorry.

After the vehicle has been used for a while the batteries have to be recharged.



Charging an electric lorry

The advantages of electric vehicles

Many people see great advantages in battery-driven electric vehicles over petrol-driven vehicles. Here are some of them:

- Cheaper to run
- Quiet running
- Cheap to maintain
- Easy to start in winter
- Safe
- Pollution-free
- Ideal for start–stop driving
- No road tax

These look impressive advantages. So why don't we see more electric vehicles in our streets? Electric milk floats, yes, but not electric cars, lorries, buses or bikes. The rest of this worksheet examines why.

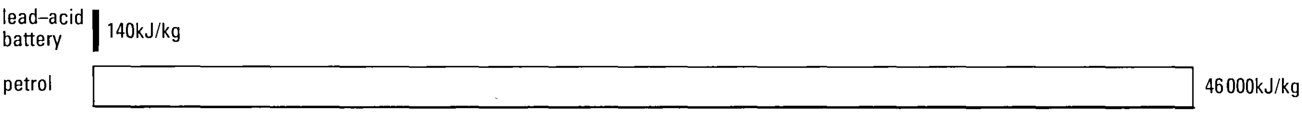
CONTINUED

Worksheet P18A [side 2]
Electric vehicles

How do electric vehicles compare with petrol vehicles?

How much energy do electric and petrol vehicles store?

To store electricity you need a battery. A lead–acid battery (which is the type usually used in electric vehicles nowadays) will store 140 kJ of energy for every kg of its mass. By comparison, 1 kg of petrol stores 46 000 kJ of energy. The chart below shows you the difference.



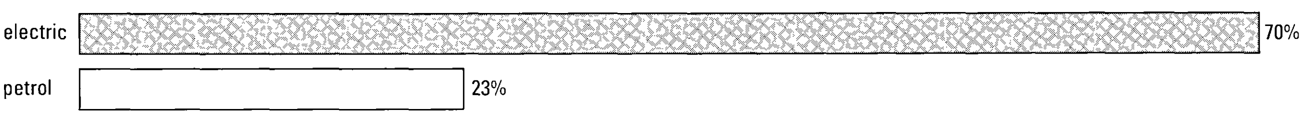
6 Use these figures to explain why the batteries in electric vehicles need recharging much more frequently than petrol tanks need refilling.

How efficient are the engines?

There is an energy cost in keeping any vehicle on the move. This energy cost comes from changing speed, climbing hills, and overcoming the friction of the surrounding air, tyres, and so on. As you saw in Chapter 8 of your Physics book, the energy price we have to pay is usually higher than the energy cost. We defined the efficiency of an engine as:

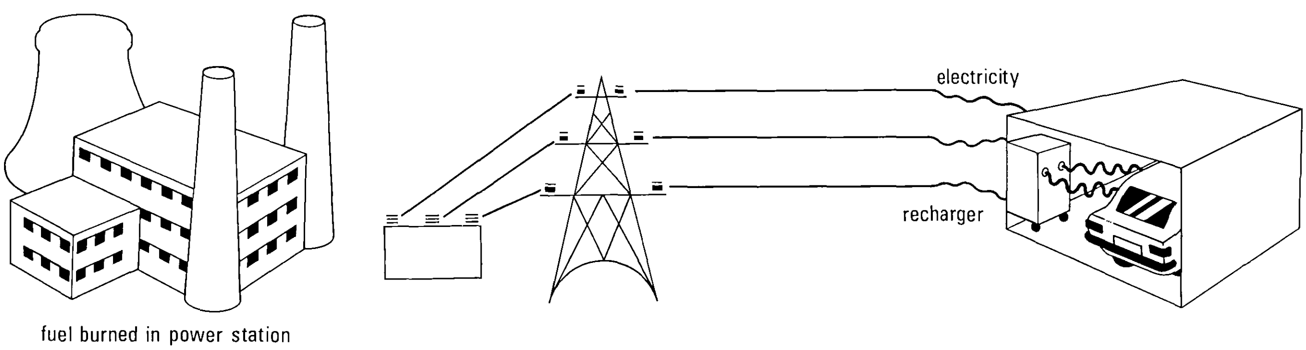
$$\frac{\text{energy usefully transferred}}{\text{total energy transferred}}$$

The chart below compares the efficiency of a petrol engine with the efficiency of an electric motor.



Electric batteries have to be recharged using electricity that has gained its energy from a power station. Power stations transfer energy from fuels to electricity. Their efficiency is approximately 30%.

7 Explain whether there is any overall energy saving in the use of electric vehicles.



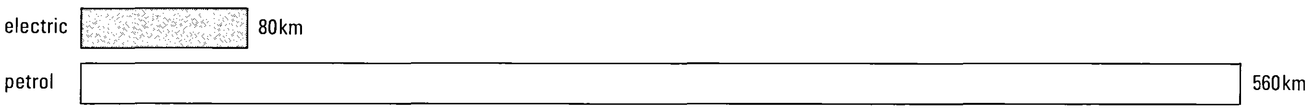
Recharging an electric vehicle

CONTINUED

Worksheet P18A [side 3]
Electric vehicles

What is their range of travel?

The distance a vehicle can travel on one battery charging or one tank refill is called its range. The chart below compares the range of a typical petrol vehicle and a typical electric vehicle.



8 Explain why it is not possible to travel more than about 80 km per day in an electric vehicle.

How quickly can the energy store be 'topped up'?

When the petrol tank of a car is empty it is refilled at a pump. It takes a petrol pump less than 5 seconds to transfer 1 kg of petrol to the car's tank. Each kg of petrol stores 46 000 kJ. This means that a petrol pump 'tops up' a car's energy store at a rate of at least 10 000 J per second.

A lead–acid battery is recharged by connecting it to a 12 V supply. Suppose the recharging current is 6 A.

9 At what rate does the electricity supply 'top up' the energy store of an electric vehicle?

10 It has been suggested that electric vehicles could have their energy store recharged by running 'battery exchange stations'.
a How would this help?
b What disadvantages might such stations have over petrol filling stations?

How heavy are the vehicles?

Electric motors are four or five times heavier than petrol motors of the same power output. The batteries they carry, even for their limited range, have more mass than a full tank of petrol.

How much pollution do they cause?

Electric vehicles cause hardly any pollution on the streets. Petrol vehicles give off a number of polluting gases such as oxides of sulphur and nitrogen.

11 Using the ideas you have just read, sum up briefly the reasons why electric vehicles are still uncommon, in spite of their advantages.

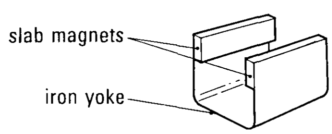
Worksheet **P18B** [side 1]
Electric currents and forces

By doing these experiments you can investigate the force on a current-carrying wire when it is placed close to a magnet.

You will need:
a power supply
a support block
PVC covered copper wire
0.25 m bare copper wire (0.45 mm diameter – thick)
0.25 m bare copper wire (0.28 mm diameter – thin)
an iron yoke
two slab magnets
wire strippers

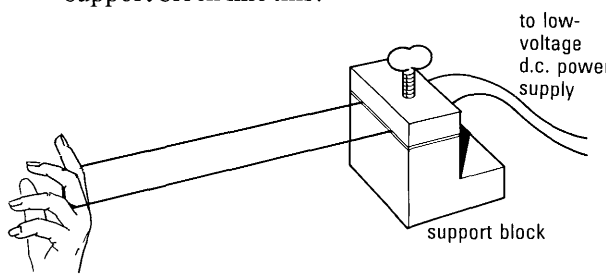
Experiment 1

a ● Make up a C-shaped magnet using two 'slab magnets' and an iron yoke, like this:

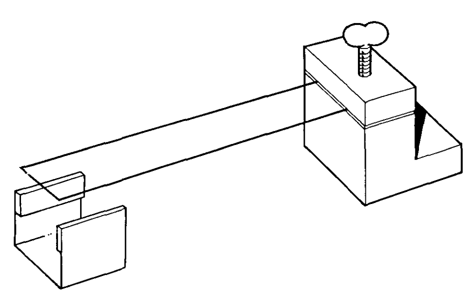


Make sure you have N and S poles facing each other across the gap, and not N and N by mistake. You can check this by holding the two slab magnets face to face. If N and S poles face each other they will attract.

b ● Take about 0.25 m of the thin bare copper wire. Connect the ends to your low-voltage d.c. power supply.
● With two fingers pull the wire out into a long loop.
● Anchor the two sides of the loop with a support block like this:



c ● Let the loop run out and sag far beyond the block. Hold the C-shaped magnet so that the end of the wire loop is in the space between the poles.
● Turn the current on and off and watch what happens. Try holding the magnet pointing in several different directions.
● Draw some rough sketches to record what happens.
● **Before you draw any conclusions, go on to the next experiment.**



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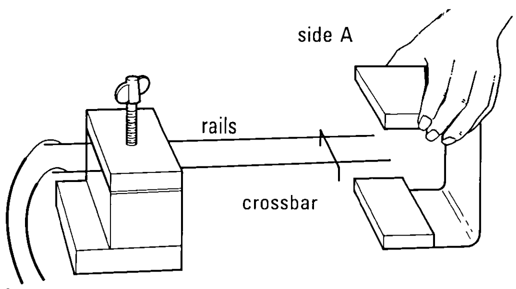
Worksheet P18B [side 2]
Electric currents and forces

Experiment 2

a ● Use the same C-shaped magnet. Using 0.25 m of the thick bare copper wire, make two straight rails and a movable crossbar that can slide on the rails, like this:



You need clean wire to make good electrical contact between the crossbar and the rails.

● Connect the rails to your low-voltage d.c. power supply.

b ● Hold the C-shaped magnet as shown in the sketch and turn on a large direct current.

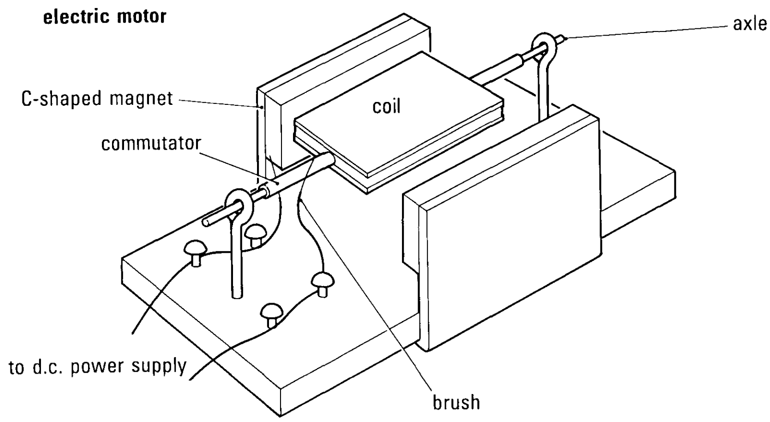
● Repeat the experiment with the C-shaped magnet the other way up (side A at the bottom, rather than at the top as shown).

c **When you have carried out your investigations, discuss the results with your teacher and other members of your class.**

Worksheet **P18C** [side 1]
Building an electric motor

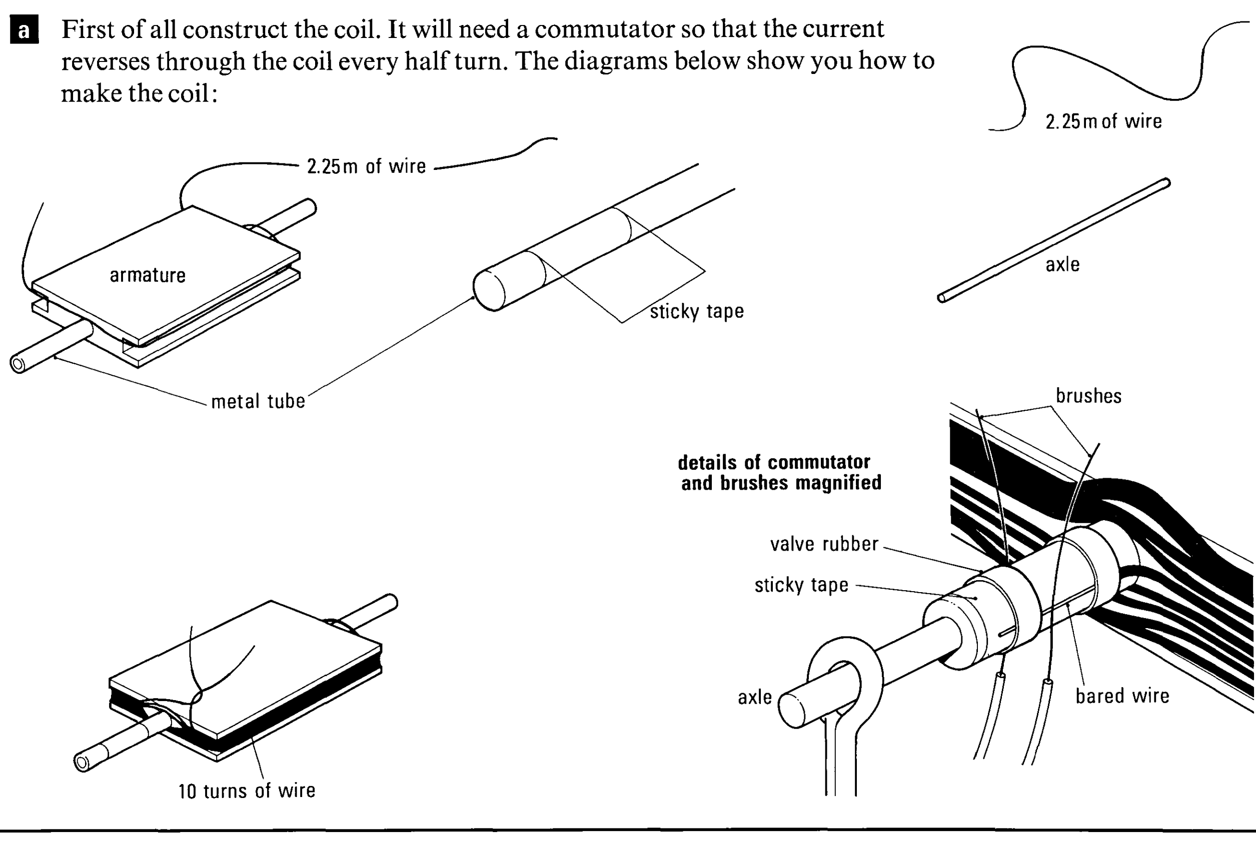
If you follow the instructions on this worksheet carefully you should be able to build a model electric motor that actually works.

An electric motor has a coil built on an axle so that it can revolve freely. A magnet provides a magnetic field which makes catapult forces on the coil.



You will need:
PVC covered wire to wind the coil
an iron yoke
two slab magnets
a base on which to build the motor
a short knitting needle, to act as the axle
two split pins to support the axle
four rivets
an armature to wind the coil on
valve rubber
sticky tape
a d.c. power supply
wire strippers

a First of all construct the coil. It will need a commutator so that the current reverses through the coil every half turn. The diagrams below show you how to make the coil:



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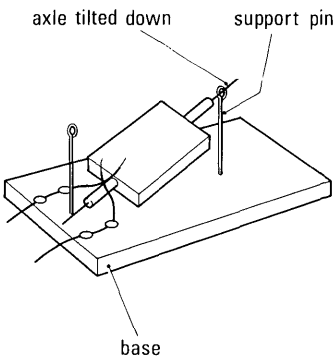
Worksheet P18C [side 2]
Building an electric motor

b ● Fit the axle support pins on the base.

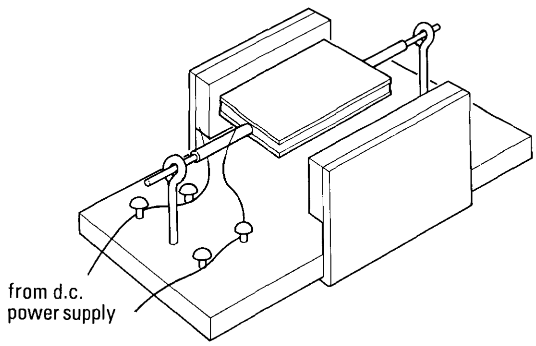
● Now strip the insulation off the ends of two pieces of wire to make brushes. Fix them to the base with rivets and bend them so that they overlap like this:



● Slide the coil onto its supports so that the commutator pushes the brushes apart.

c ● Make a C-shaped magnet in the same way as you did in Worksheet **P18B**.

● Slide the base, with its coil in place, carefully between the magnets. Like this:



● Connect your motor to the power supply. Give the coil a turn with your fingers and see if it will run.

Do not be disappointed if your motor does not work first time. Check all your contacts and try again.

d ● If you have time, plan and carry out an investigation into the efficiency of your electric motor.

Worksheet P18D
Magnetism and electricity

Electric currents have a magnetic field around them, just as magnets do. These experiments explore the effect of the field on a small compass, and show you how to find the field pattern around a wire carrying a current.

You will need:
a power supply
insulated copper wire
card and supporting blocks
a plotting compass
iron filings
wire strippers

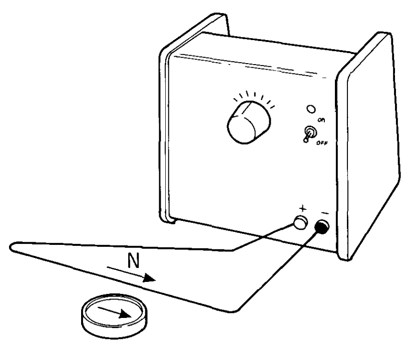
Experiment 1

Try the experiment that made Oersted famous for all time!

a ● Take about 40 cm of wire and attach it to your power pack.
● Bend the wire so that it lies just above a compass needle and in a direction that **is the same as the natural direction of the needle.**

b ● Turn on a large current in the wire.

Do not keep the current running for too long, as the wire can get quite hot.



1 What happens to the compass needle?

2 What happens if you try reversing the current?

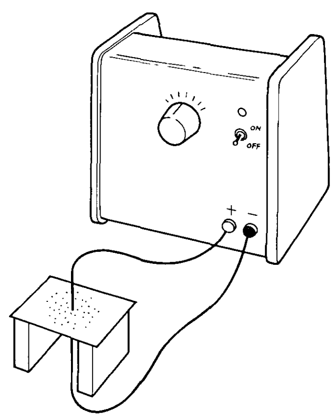
Experiment 2

a ● Make a hole in the centre of a piece of card, and place the card on wooden support blocks.

b ● Take about 0.5 m of insulated wire, run it through the hole in the card, and connect its ends to the power supply.

c ● Switch on the current and sprinkle iron filings on the card.
● Tap the card gently with a pencil or a finger and watch what happens.

Do not keep the current running for too long, as the wire can get quite hot.



● Sketch the magnetic field pattern shown by the filings.

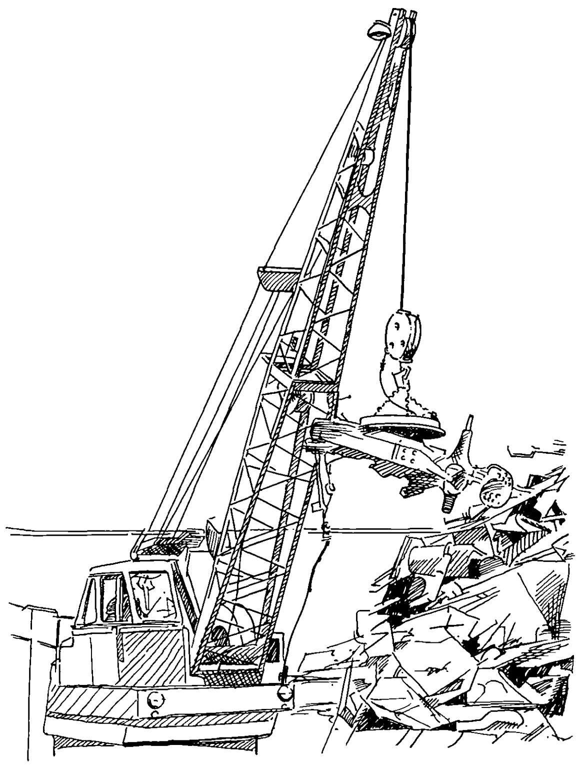
d ● Tip the iron filings onto a spare sheet of paper. Use a small compass to explore the field on the card, near the wire. (Do not forget to switch on the current again!)

1 Describe what you see.

2 Describe what happens when you reverse the current.

Worksheet **P18E**
Electromagnets

Plan and carry out an investigation into what affects the strength of an electromagnet. This worksheet tells you enough to get you started and then leaves you to plan your own work.

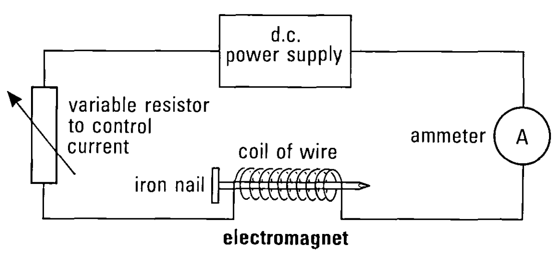


Lifting scrap with an electromagnet

You will need:
a low-voltage d.c. power supply
some means of controlling the size of current, e.g. a variable resistor
an ammeter
long lengths of copper wire – preferably some thick and some thin
iron nails, or steel rods
some way of measuring the strength of the electromagnet

a ● Make a simple electromagnet by winding a few turns of wire round a bundle of nails.

b ● Make a circuit containing your power supply, an ammeter and your electromagnet, like this:



Check the circuit with your teacher before switching on.

c ● Invent a way of measuring the pull of the electromagnet.

d ● Now try to find ways of making the electromagnet stronger or weaker.
● Remember to record everything you do.

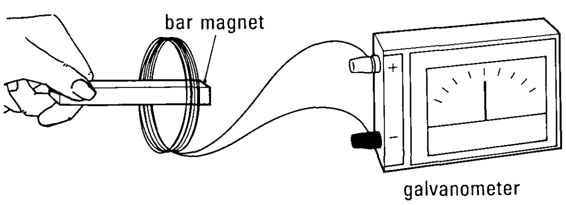
Worksheet **P18F** [side 1]
Induced currents

These experiments will help you explore how an electric current can be induced in a wire.

You will need:
two small bar magnets
insulated copper wire
a galvanometer
an iron yoke
two slab magnets
two laminated iron C-cores and a clip to hold them together
a cell

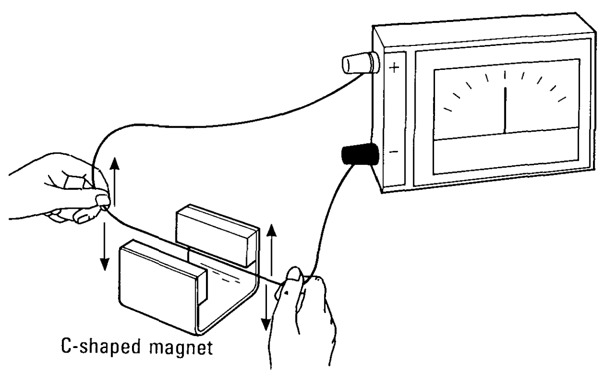
a Take about 2 m of insulated wire. Wind a small coil of many turns, big enough to put your thumb through. Have plenty of spare wire at the end of the coil.

- Connect the end of the coil to a galvanometer. Try moving a small bar magnet towards the coil and away from it, **slowly**. Try moving it a little faster. Try moving it **through** the coil.



1 What happens to the galvanometer?
2 Are there any other ways you can make the needle of the galvanometer move?

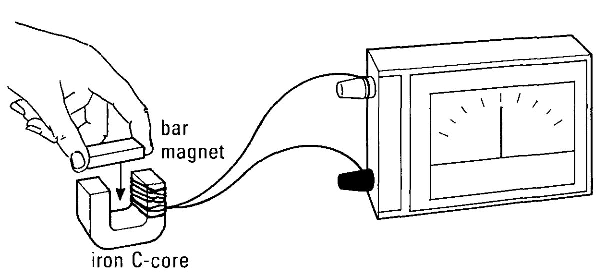
b
- Try the experiment shown in the diagram. Make a C-shaped magnet as you did in Worksheet **P18B**. Take about 1 m of insulated wire and connect its ends to a galvanometer. Try moving the wire in the gap between the faces of your horseshoe magnet.



3 What happens when you move the wire?

c Take about 2 m of insulated wire. Wind a coil of 20 turns on a C-core. Leave plenty of spare wire at each end.

- Twist the wires together where they leave the coil, to prevent the coil unwinding.
- Connect the ends of the wire to a galvanometer.
- Bring a small magnet near the C-core.

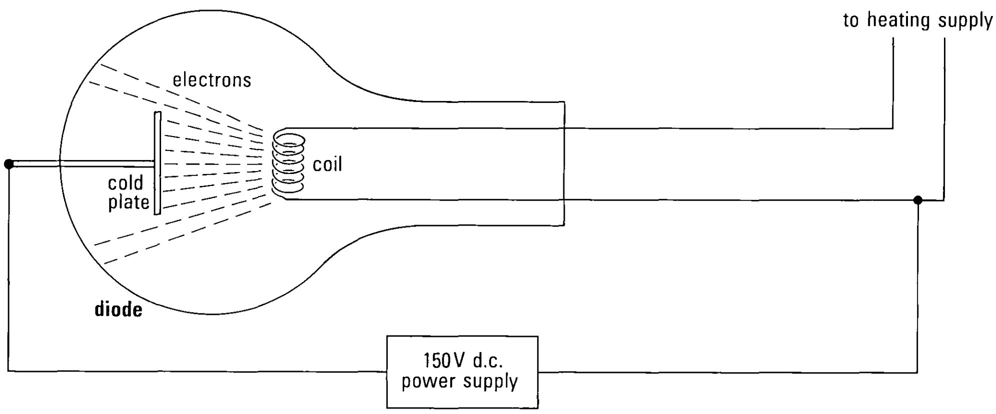


4 Does the iron core in the coil make any difference to the amount the needle moves on the galvanometer?

CONTINUED

Worksheet P19A [side 2]
The diode

There is evidence to suggest that atoms contain small particles of matter called electrons, each of which carries a negative charge. Atoms can both lose and gain electrons, so becoming charged. The behaviour of a diode in a circuit can be understood if we assume that heating the filament 'evaporates off' some electrons, which then carry the electric current across to the cold plate.



Use the description above to explain the following:

1 The fact that no current flows through the diode when the filament is cold even though there is a high voltage across the diode and the cold plate is positive.

2 The change in the current through the diode when the heating voltage across the filament is changed.

3 The fact that no current flows through the diode if the cold plate is negative relative to the filament.

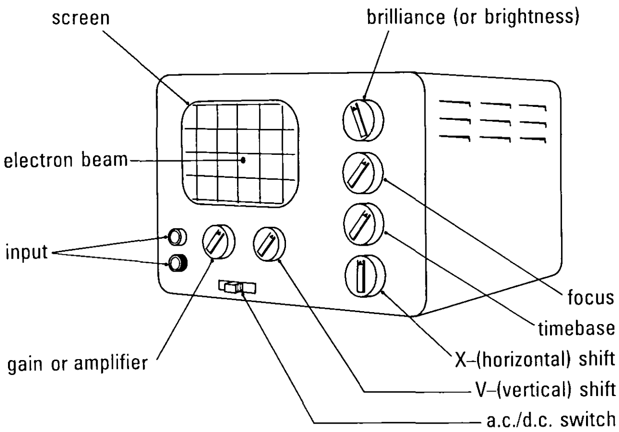
4 The change in current through the diode when the high voltage across it is reduced.

5 The way the current through the diode changes when the voltage across it is increased from zero to a high voltage.

Worksheet **P19B** [side 1]
The cathode ray oscilloscope

The cathode ray oscilloscope (CRO) is one of the most widely used scientific instruments. It has almost replaced the chemist's retort as a symbol of science. The aim of this investigation is to familiarize you with the cathode ray oscilloscope so that you can use it in future work.

This diagram shows the main controls on an oscilloscope. Your oscilloscope may not have these controls in quite the same place, so your first task is to find out where they are.



You will need: an oscilloscope three cells in holders a low-voltage a.c. power supply a microphone connecting wires

Investigation 1 : Getting started

1 Make a sketch of the front panel of your oscilloscope and mark in all the knobs and switches.

a ● Switch on your oscilloscope. After a few seconds you should see a bright spot in the centre of the screen. This is the point where the electron beam inside the cathode ray tube strikes the front of the tube.

b ● Now find out which controls correspond to the controls marked in the diagram above.

2 Label each control in your diagram.

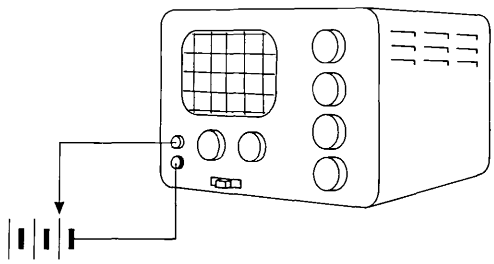
c ● Alter each control and see what (if anything) happens to the spot on the screen.
● Finally, make sure you end up with a spot in the centre of the screen. (The spot should not be so bright that there is a halo of light around it.)

CONTINUED

Worksheet P19B [side 2]
The cathode ray oscilloscope

Investigation 2: Connecting a battery to the input of a CRO

a ● First make sure the a.c./d.c. switch is switched to d.c., and that the spot is in the centre of the screen.
● Connect a 1.5 V cell across the input to the CRO.



1 What happens to the spot on the screen?

b ● If the spot vanishes from the screen, turn the *gain* control anticlockwise (↶) until the spot reappears.
● If the spot hardly seems to move, turn the *gain* control clockwise (↷) until the spot reappears.
● If you still have no spot on the screen, ask your teacher for help.

c ● Now adjust the *gain* control so that the spot moves one division on the screen when the cell is connected to the input.

2 What happens to the spot if you reverse the connections from the cells to the input?

3 What happens to the spot if you connect first two cells and then three cells to the input?

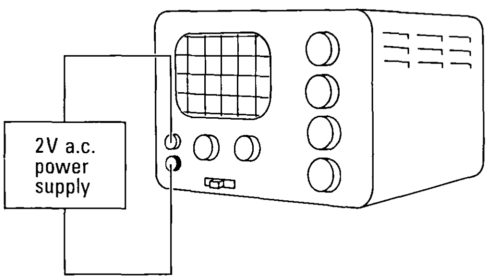
4 Explain how a CRO can be used as a voltmeter.

CONTINUED

Worksheet P19B [side 3]
The cathode ray oscilloscope

Investigation 3: Exploring changing voltages with a CRO

a ● Make sure the *gain* control is still set so that one d.c. cell gives a spot movement of one division on the screen.
● Connect the output from a 2 V a.c. power supply to the input of the CRO.



1 What happens to the spot on the screen?

The spot turns into a line because the supply produces an oscillating voltage. This makes the electron beam move up and down 50 times a second – too fast for the eye to follow.
You can see these oscillations by using the *time base* built into the CRO. The time base produces a voltage that can move the electron beam horizontally across the screen at the same time that the input voltage moves it up and down.

b ● To see the oscillations, switch on the *time base*.

2 Sketch what you see on the screen.

c ● Try varying the speed of the *time base*. (If you have difficulty doing this, your teacher will show you how.)

3 What happens to the pattern on the screen as the speed of the *time base* is increased?

d ● Adjust the *time base* control so that three or four complete oscillations are displayed.

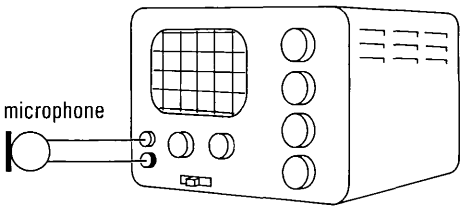
4 Work out how long it takes the electron beam to cross the screen.

CONTINUED

Worksheet P19B [side 4]
The cathode ray oscilloscope

Investigation 4: Looking at oscillations produced by sound waves

a ● Connect a microphone to the input of the CRO.
● Adjust the *gain* control and the *time base* so that the CRO will display the output of the microphone when it picks up a sound.



b ● You can now carry out a number of investigations into sound.
Some suggestions are given below, but you do not have to keep to them. Invent some of your own if you like.

c ● Compare quiet sounds with loud sounds.

1 Describe their difference in terms of what happens to the picture on the CRO screen.

d ● Compare high-pitched sounds with low-pitched sounds.

2 How do the frequencies of these sound waves compare with each other?

e ● Try to measure the frequency of your speaking voice.

This is quite difficult as the sound output of your voice has quite a complicated pattern. But estimate how many complete oscillations occur in the length of the time base.
Then find out how many complete oscillations from your low-voltage supply you can fit in the length of the time base. Remember, the low-voltage supply gives you 50 oscillations per second.

f ● Compare the patterns on the screen produced by each other's voices.

3a Are the patterns different? If so, in what ways?
b Do you think these patterns could be used to identify people? (It is possible to produce 'voiceprints' that are as unique as fingerprints!)

g ● Compare the patterns produced by different musical instruments.

Tuning forks (and high-pitched recorders and flutes) give particularly simple wave patterns called 'pure tones'.

4 Try to explain why one instrument 'sounds' different from another.

5 Write a report on what you have found out in your investigations.

Worksheet P20A
Switches

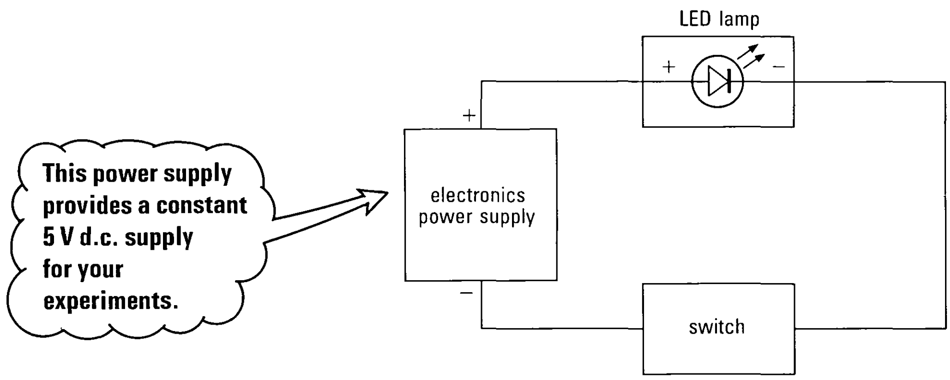
These experiments introduce you to simple electronic circuits. The first experiment introduces switches of various types. The switches can be turned on or off by hand, or by light, by a change in temperature, or by a magnetic field. The second experiment illustrates one way a control unit can be used in an electronic circuit.

The equipment you will need is shown in the diagrams. You should use the correct power supply for the electronics kit you are using.

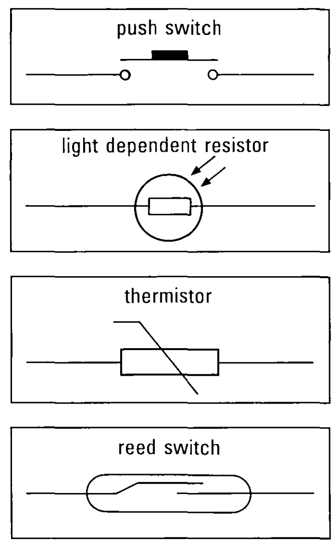
Experiment 1: A simple electronic circuit

a ● Try each of the switches in turn in this circuit:

b ● Make a note of the behaviour of each switch.



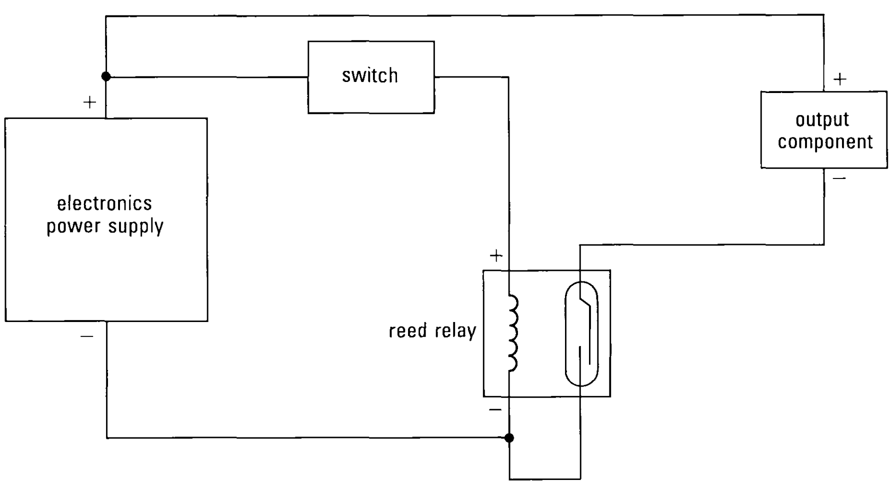
Switches



Read section P20.2 of your Physics book before trying Experiment 2.

Experiment 2: Using a reed relay

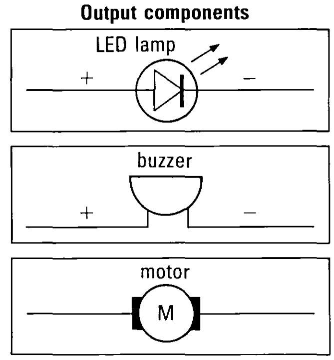
a ● Use each of the switches in turn to control the input to a reed relay.
● Try connecting in any of the output components.
● Observe how the switches can control the outputs through the reed relay.



Switches

Use any of the switches from experiment 1.

Output components



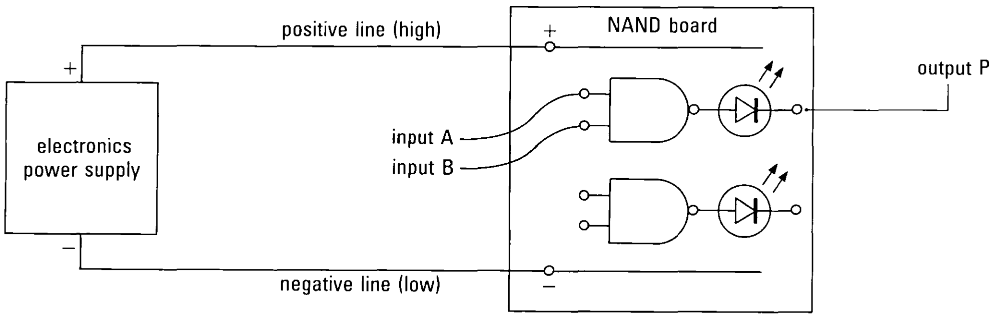
b ● Now use a similar circuit to answer questions **4**, **5** and **6** on pages 308 and 309 of your Physics book.

Worksheet **P20B** [side 1]
NAND control units

This worksheet introduces you to a more complex control unit called a NAND unit, and shows you what it can do.

Your NAND board may have two NAND units on it. Use only the top one for Experiment 1. Each NAND unit may have an LED lamp already connected to its output.

Experiment 1: Using a NAND control unit



a ● Connect inputs A and B to either the positive (**high**) line or the negative (**low**) line.

b ● Copy and complete this table showing the output P (**high** or **low**) in each case. The first line has been completed for you.

Input A	Input B	Output Q
low	low	high

● When you have completed your table, look at figure 20.19 in your Physics book for another way of summarizing your results.

1 What is the output P of the NAND unit if both inputs (A and B) are left unconnected?

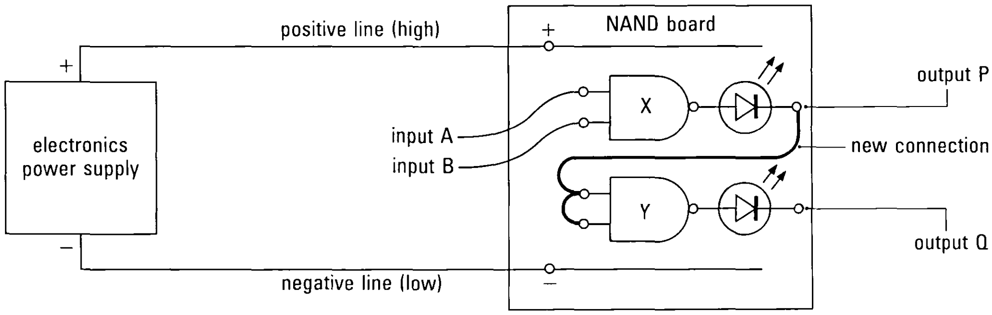
2 How do inputs A and B seem to behave if they are left unconnected? Do they behave as though connected to the positive (high) line, or the negative (low) line?

'Floating high' or 'floating low'

You should have found in answer to question 2 that when the inputs are unconnected, they behave as though they were connected to one of the lines. We say that if unconnected inputs behave as if they are connected to the positive line, they 'float high', and if they behave as if they are connected to the negative line, they 'float low'. It is usually best to connect inputs to a high or low line so you know whether they are high or low, instead of leaving them unconnected.

Worksheet P20B [side 2]
NAND control units

Experiment 2: Using two NAND units



a ● Connect the output from the first NAND unit to input A of the second NAND unit. Leave input B of the second NAND unit unconnected.

b ● Complete this table in the same way as you did for Experiment 1. (The first line has again been completed for you.)

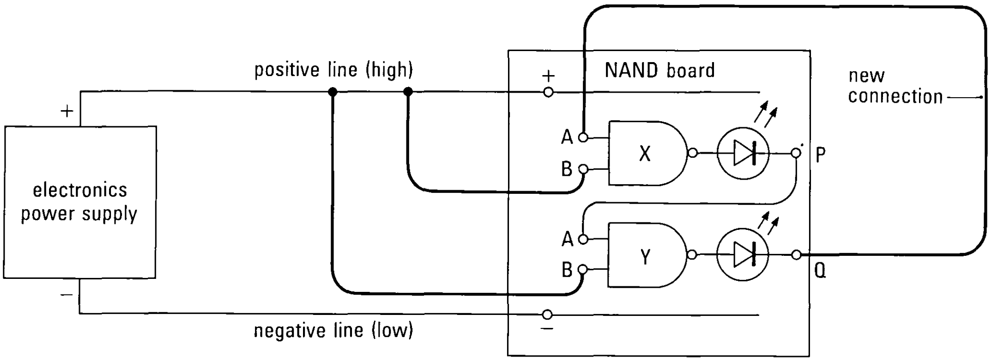
Input A	Input B	Output Q
low	low	low

1 Can you think of a problem to which this new control unit could provide a solution?

Worksheet **P20C**
A bistable unit

A bistable unit uses two NAND units connected together. A bistable unit is a very important part of many electronic circuits, such as circuits which will count. This experiment shows what a bistable unit can do and gives you a new problem to solve.

a
- Connect the output of NAND unit **X** to input A of NAND unit **Y**.
- Connect the output of NAND unit **Y** to input A of NAND unit **X**.
- Connect both B inputs to the positive line.



Your circuit should look like this. You should find that the output LED of one NAND unit is *on*, while the other LED is *off*.

A circuit consisting of two NAND units connected together like this is called a *bistable unit*.

b
- To make the unlit lamp come **on** and the other lamp go **off**, do as follows:
- Find out which NAND unit is connected to the lamp which is **off**.
- Disconnect the B input of this NAND unit from the positive line. Connect it momentarily to the negative line and then reconnect it to the positive line.

1 You will probably find it is not necessary to connect input B to the positive line in order to make the bistable unit work. Why is this? (Hint: Look back at Worksheet **P20B**.)

2 How can the lamps be changed again?

c
- Disconnect both B inputs from the positive line and add push switches so that you can momentarily connect **either** B input to the negative line.
- Try switching the lamps from **on** to **off** and **off** to **on** using the push switches.

d
- Now try replacing one of the push switches with an LDR switch, or a reed switch. Find out what happens.

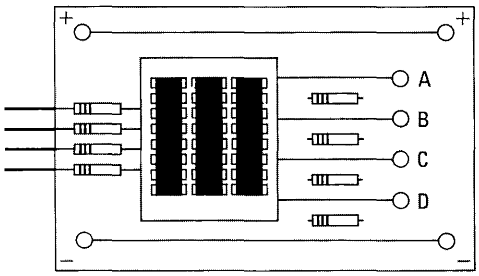
3 Can you think of a use for this circuit?

The burglar alarm

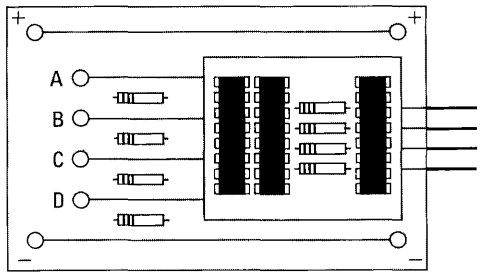
Now use your bistable circuit (and any other components you like) to make a burglar alarm. The alarm must sound a buzzer when ‘set off’ by the burglar, and the buzzer must carry on sounding whatever the burglar does next!

Worksheet P20D
Using input and output interfaces

Introducing interfaces



output from computer



input to computer

This diagram shows a pair of interfaces that can be connected to a BBC microcomputer. Many other interfaces have been manufactured, both for the BBC microcomputer and for other microcomputers as well. The interfaces you use, or see in use, may well be different from those shown in the diagram.

The precise details of how a particular interface should be used differ from one interface to another. Because of this, the manufacturer of the interfaces you are using provides detailed instructions for their use. You should follow the manufacturer's instructions when using your particular interfaces.

Giving instructions to a computer

A computer may not be able to act directly on the set of instructions you have written for turning lights off and on. Computers work using a special set of coded numbers called machine code. To turn lights on and off (or to do anything else) the computer has to have these special codes. There are three ways a computer can be given the coded instructions it needs:

- You can give these coded instructions to the computer from the keyboard. This is very laborious and it is usually done using a special set of more easily understood codes called *assembly language*. Giving a computer instructions in this way is called *machine language programming*. You may be able to do this. It is like learning a foreign language in order to speak to someone from another country.
- If you can't speak a foreign language you could employ an interpreter. Most computers do the same – they have an interpreter built in to them so that it is much easier to give them instructions in 'plain English'. But even then there are lots of rules about how the instructions are given and the 'plain English' that is used can look a bit weird. So the instructions are called a computer language. Examples of such languages are BASIC, PASCAL, C, and FORTH. You may have heard of some more. You may be able to turn your set of instructions for lighting traffic lights into one of these computer languages; the most likely one is BASIC.
- The third way of communicating with the computer, which you can use with some computers and their interfaces, is to use a specially easy language that has been written for you to use. This only works with certain computers, and the interfaces from certain manufacturers. Your teacher will be able to tell you whether you can use this specially written language.

Whichever method you use, your teacher will provide you with details about how to give instructions to the computer in order to make it turn lights on and off. When you have practised with these, try solving the problems set for you on pages 312–3 of your Physics book.

Worksheet **P21A** [side 1]
Sending messages using electricity

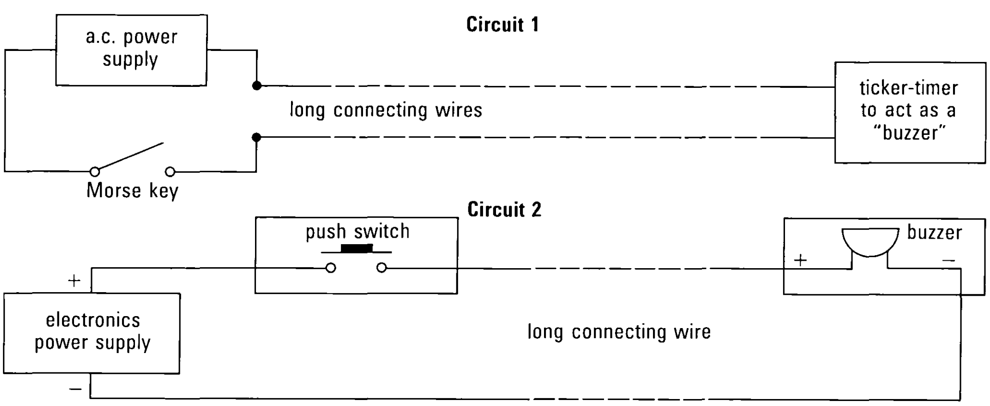
There are a number of ways of sending messages using electricity. In these experiments you can experiment with sending messages by Morse code and by using a microphone and loudspeaker.

Experiment 1: Using the Morse code

You will either need:
a Morse key
a ticker-timer, to act as a 'buzzer'
an a.c. power supply for the ticker-timer
connecting wires

or you will need:
an electronics power supply
a switch
a buzzer

a ● Set up **one** of these circuits:



b Use the circuit to send a short message in Morse code.

The Morse code

A .–	H	O –––	V ...–	1 .––––	6 –....
B –...	I ..	P .––.	W .––	2 ..–––	7 ––...
C –.–.	J .–––	Q ––.–	X –..–	3 ...––	8 –––..
D –..	K –.–	R .–.	Y –.––	4 ....–	9 ––––.
E .	L .–..	S ...	Z ––..	5	0 –––––
F ..–.	M ––	T –			
G ––.	N –.	U ..–			

1 How quickly can you send information using the Morse code? (Work out the speed in letters per second.)
2 Design a circuit so that two people can send and receive messages. The circuit must allow only one person to send a message at any one time. (You may be given the opportunity to build your circuit.)

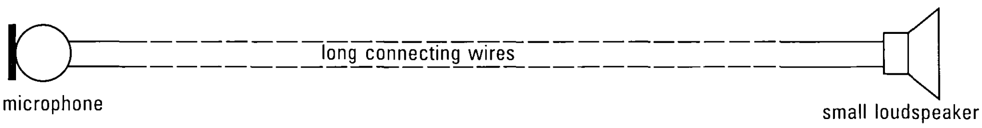
CONTINUED

Worksheet P21A [side 2]
Sending messages using electricity

Experiment 2: Using a microphone and loudspeaker

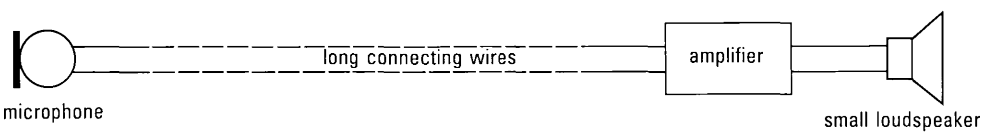
You will need:
two small loudspeakers, one of which you can use as a microphone
an amplifier
connecting wires

a ● Connect the microphone to the loudspeaker with a long pair of wires, like this:
● Speak into the microphone.



1 Can you be heard from the loudspeaker?

b ● Now try connecting in the amplifier close to the loudspeaker like this:



Be careful not to put the microphone too close to the loudspeaker.

2 What effect does the amplifier have on the sound from the loudspeaker?

3a What happens if you put the microphone too close to the loudspeaker?
b Can you explain what happens?
c The effect is called 'positive feedback'. Can you think of a reason for this name?

c ● Now try the effect of connecting the amplifier close to the microphone end of the long wires.

4a Which arrangement is best?
b Can you think of a reason why one arrangement is better than the other?

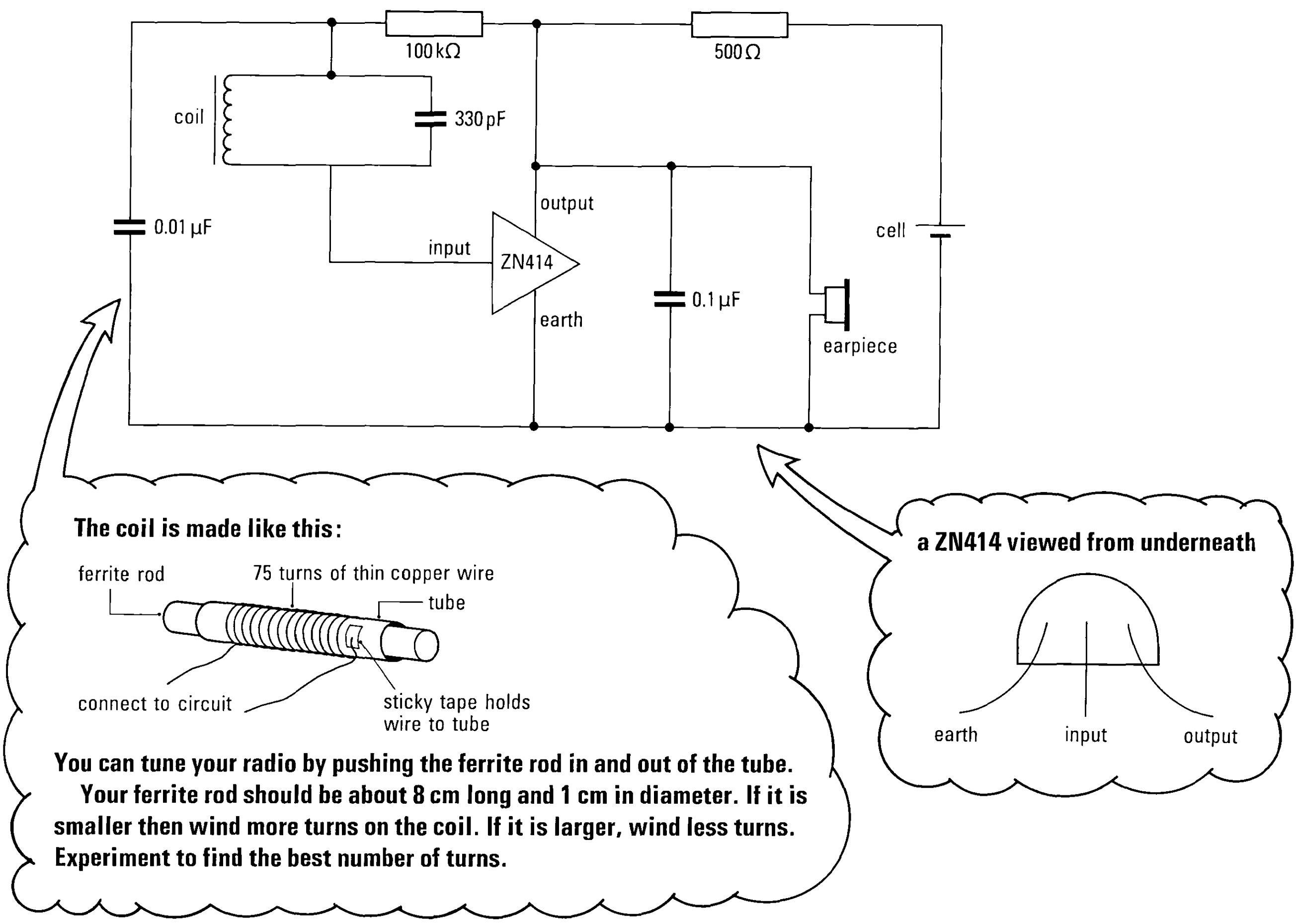
Worksheet **P21B**
A simple radio receiver

The circuit diagram below shows a simple radio receiver you can build for yourself. Your teacher will show you how to connect together the various components.

Once you have managed to receive something on your radio, try to find answers to the questions at the bottom of the worksheet.

You will need:

a cell to power your radio	a 330 pF capacitor
a ZN414 radio integrated circuit	an earpiece
a 100 kΩ resistor	a ferrite rod
a 500 Ω resistor	a cardboard tube
a 0.1 μF capacitor	sticky tape
a 0.01 μF capacitor	a long thin piece of copper wire



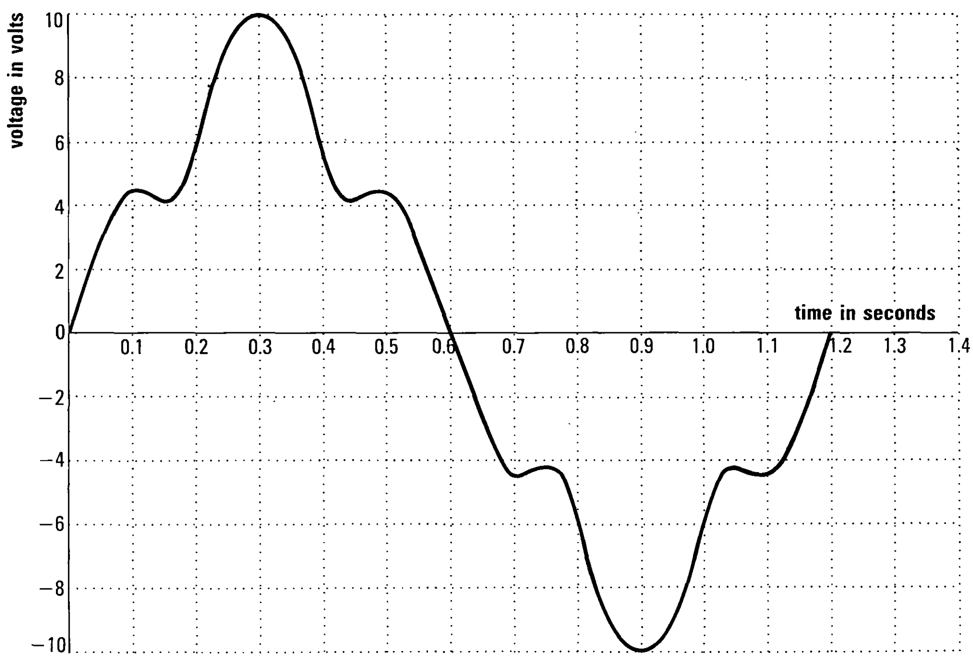
1 Use a list of radio programmes to identify the station you are tuned in to.
2 Look up the frequency of the waves transmitting this station.
3 What is the wavelength of the waves you are receiving?
4 What is the name given to the family of waves on which radio broadcasts are transmitted?
5 Draw the part of the circuit which picks up your particular station.

Worksheet P21C
Sampling an analogue signal

In Chapter P21 of your Physics book you saw how it is possible to transmit information about sound waves as a sequence of numbers. The process of turning a continuously varying electric voltage into numbers is called *sampling*.

Once these numbers have been received they are turned back into a changing voltage again. If the sampling has been done correctly, these voltages should give a good copy of the original signal.

This graph shows you a section of a sound vibration picked up by a microphone and displayed on a CRO:



1a Copy the tables opposite into your book.

b Read off values of the voltage from the graph for each of the times in the tables opposite. Enter the values in your copies of the tables.

2 Plot each set of readings on a separate sheet of graph paper, one for each table.

3 Which set of readings gives the better copy of the original pattern on the CRO screen?

4 What things do you think have to be taken into account when deciding how often the voltage in a varying signal should be sampled?

time in seconds	voltage in volts
0	
0.2	
0.4	
0.6	
0.8	
1.0	
1.2	

time in seconds	voltage in volts
0	
0.1	
0.2	
0.3	
0.4	
0.5	
0.6	
0.7	
0.8	
0.9	
1.0	
1.1	
1.2	
1.3	

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