1 Simple phenomena of magnetism

Videos & questions on the CD ROM

There are several elements that are magnetic, the most important of which are iron, cobalt and nickel. Scientists have developed alloys and ceramics made from complicated combinations of elements to get the exact properties that they want. Some of these materials are **magnetically hard** (such as steel, which is an alloy of iron, and other elements such as carbon or tungsten). This means that they stay magnetic once they have been magnetised.

When we refer to a 'magnet', we mean **a permanent magnet** that is made of magnetically hard materials.

Other materials are **magnetically soft** (such as pure iron), which means that they do not stay magnetic – this is particularly useful in some electromagnetic devices such as the electromagnet and the relay.

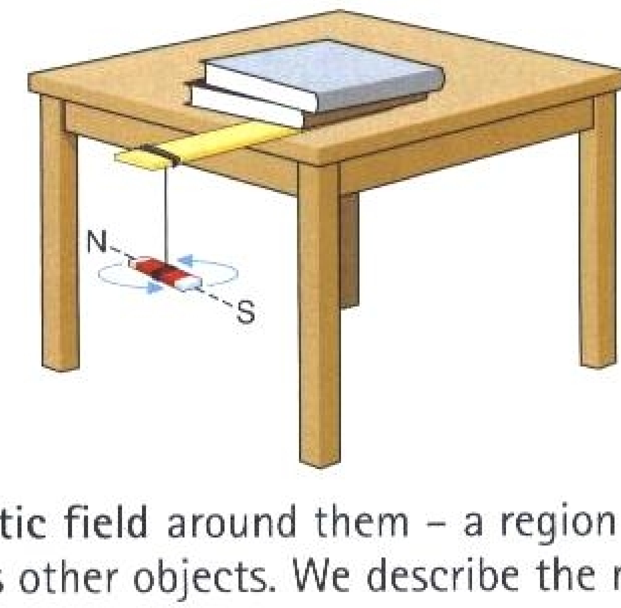
Alloys are made by melting different metallic elements (iron, aluminium, copper, tungsten, etc.) together. The resulting metal is known as a **ferrous** metal if it contains a lot of iron, and as a **non-ferrous** metal if it does not. Nickel and brass (copper + tin) are examples of non-ferrous metals.

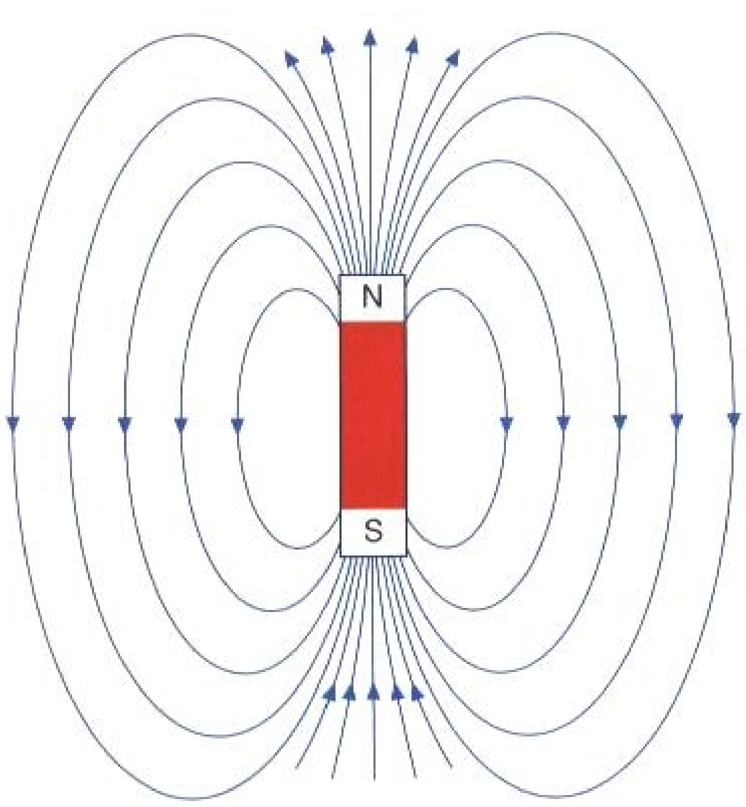
In the past all magnetic materials were ferrous, but this is no longer true, and the strongest magnets may not contain any iron at all, for example, samarium-cobalt (SmCo), often used in headphones.

When we refer to 'magnetically hard' and 'magnetically soft' materials we are not referring to their physical hardness. You may have seen rubberised magnetic strips used on notice boards. These strips are permanent magnets, but are physically soft.

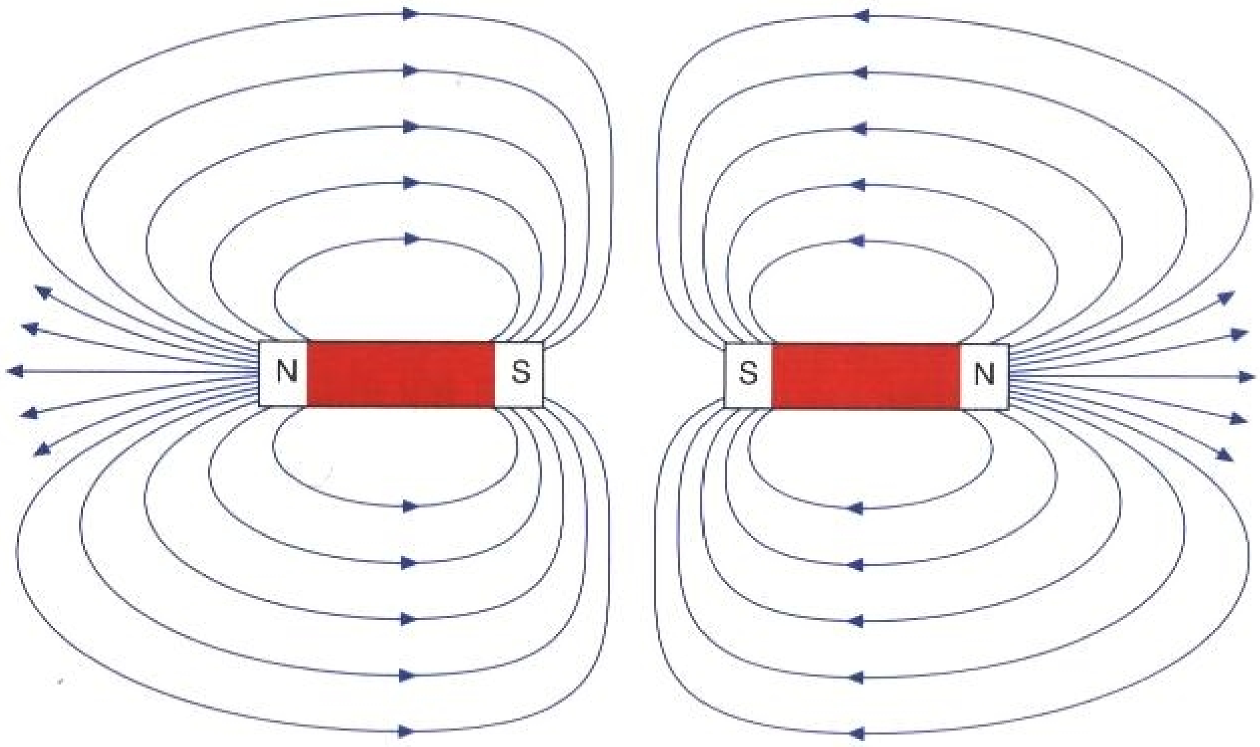
If a permanent magnet is suspended and allowed to swing, it will line up approximately north–south. Because of this, the two ends of a magnet (which are the most strongly magnetic parts) are called the north pole and the south pole, often labelled N and S. (Strictly, they are called the north-seeking pole and the south-seeking pole.)

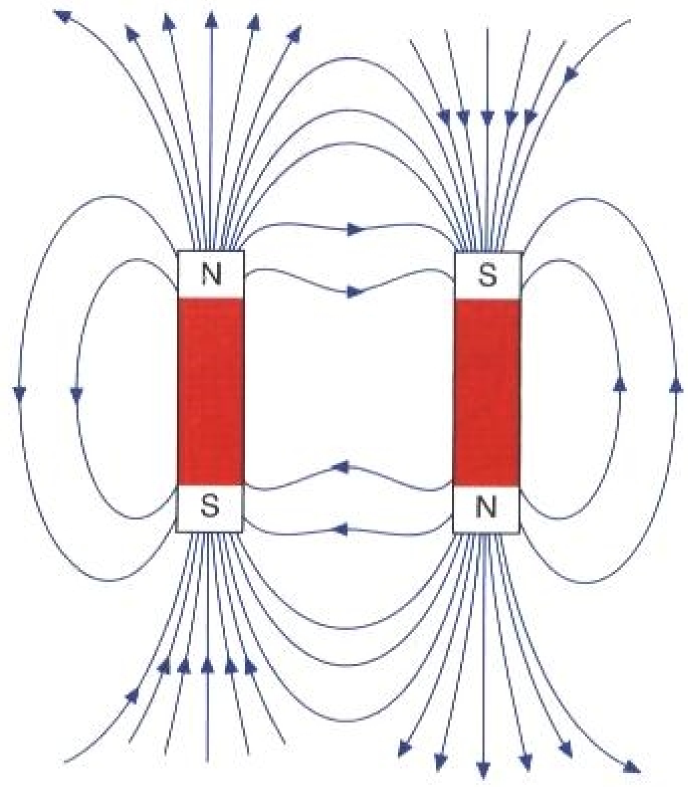
If two north poles from different magnets are brought together, there will be a **repulsion** between them. The same happens if two south poles are brought together. However, if a north pole and a south pole are brought together, there will be an **attraction**.





Magnets have a **magnetic field** around them – a region of space where their magnetism affects other objects. We describe the magnetic field using **magnetic field lines**. These lines show the path that the north pole of a magnet would take: heading away from a north pole and ending up at a south pole. The more concentrated the field lines are, the stronger the magnetic effect.



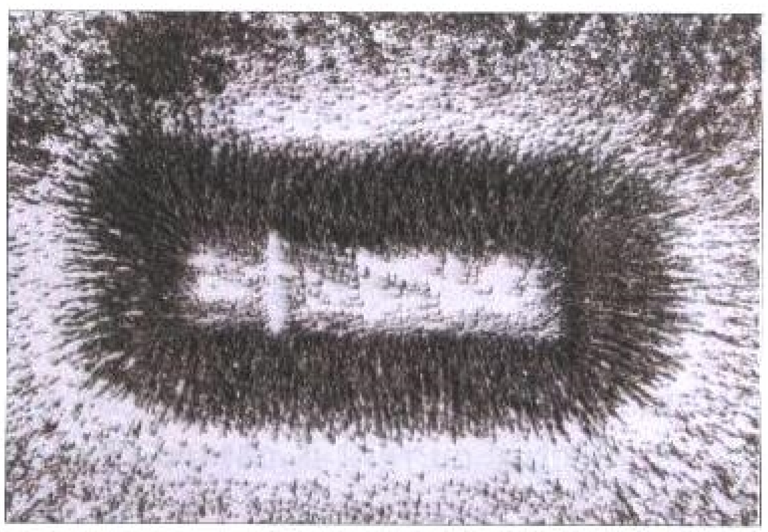


The magnetic field around a pair of bar magnets depends on the orientation of the magnets.

AN EXPERIMENT TO SHOW THE FIELD LINES AROUND A BAR MAGNET

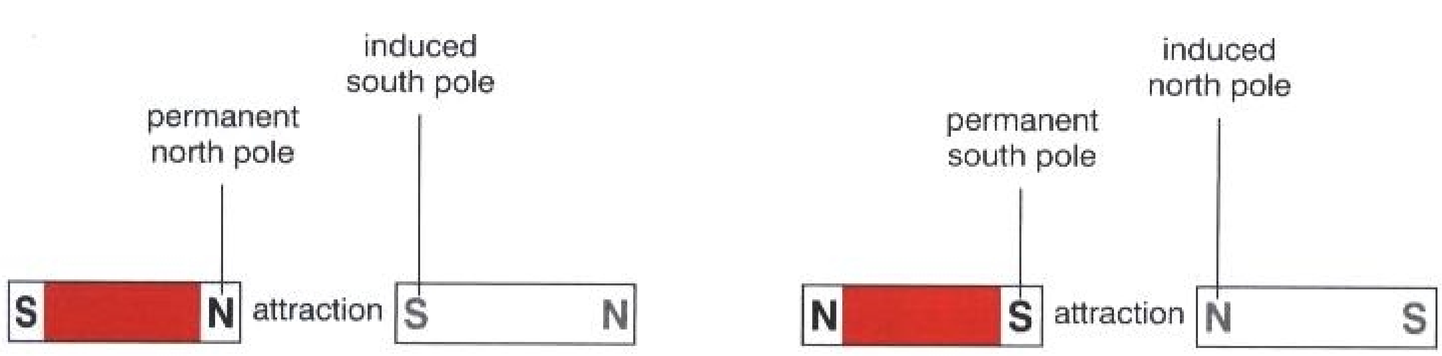
To show the field lines, place a bar magnet under a thin sheet of plastic, and sprinkle iron filings on to the top of the plastic. The iron filings will arrange themselves into strings of filings along the field lines.

It is also possible to follow the path of the field lines by placing a small compass (known as a plotting compass) on the plastic in place of the iron filings. If you move the compass in the direction that its north pole is pointing, then it will follow a field line.

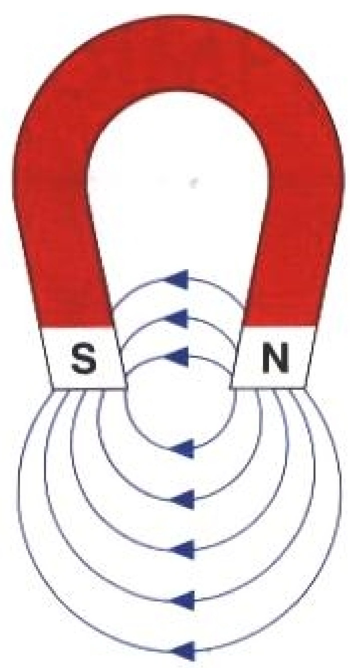


The iron filings show the field lines around a bar magnet.

If a soft magnetic material is brought near to a magnet it will be attracted. It has had magnetism **induced** in it, it has become **magnetised**. When the magnet is taken away, the material loses its magnetism again. Note that the magnet will continue to attract the soft magnetic material even if the material is turned round. This is the opposite behaviour to two magnets, as two magnets will repel each other in certain orientations. This simple method enables you to work out whether you are holding two magnets or one magnet and one piece of soft magnetic material.



The pole of a permanent magnet always induces the opposite pole in an unmagnetised piece of magnetic material. So an induced magnet is always attracted to a permanent magnet.



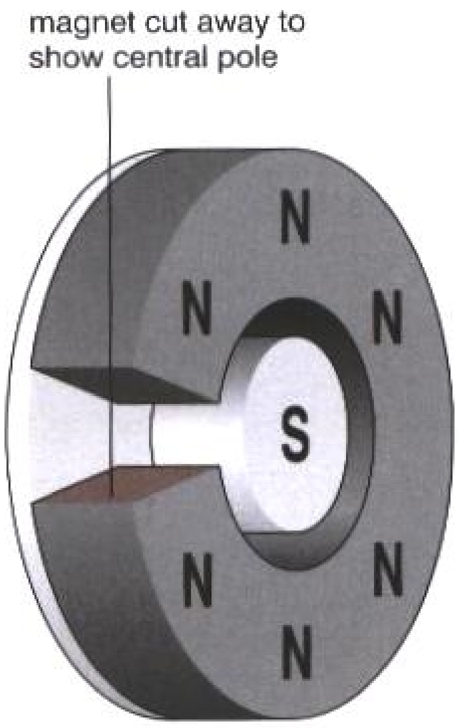
Horseshoe magnet.

TYPES OF MAGNET

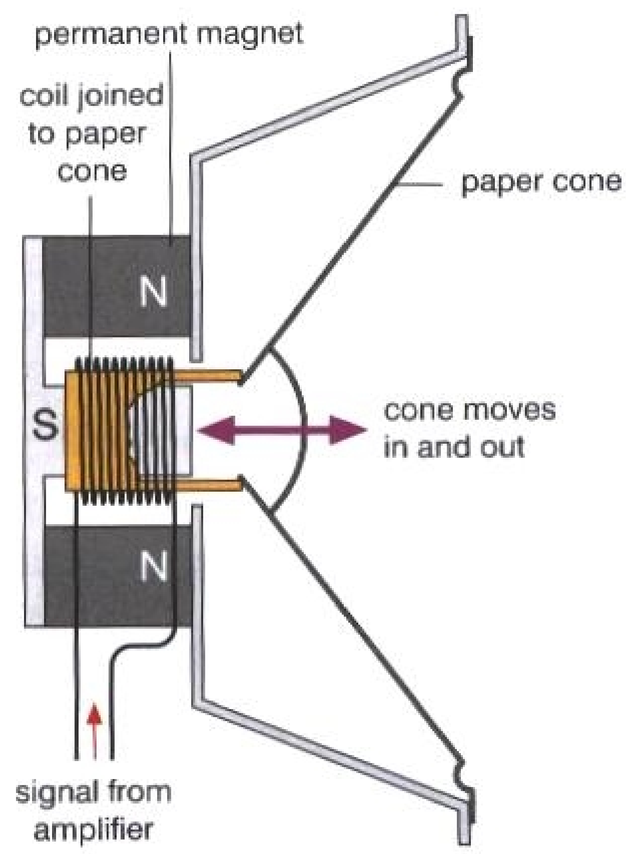
Bar magnets, as shown on page 109, are used in compasses.

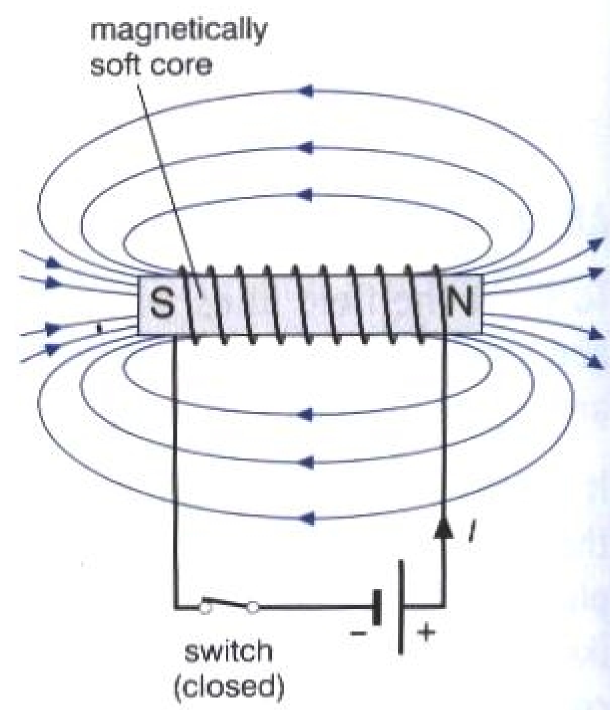
Horseshoe magnets bring the N and S poles close together, and this gives a strong magnetic field between the poles. They are used to lift heavy weights. With older magnetic materials it is necessary to place a 'keeper' across the poles when the magnet is stored to prevent the loss of magnetism.

The magnet used in a loudspeaker is very similar to the horseshoe magnet. The central pillar is made of one pole, and on the other side of a small gap, the opposite pole surrounds it. The coil of the loudspeaker moves in this gap.



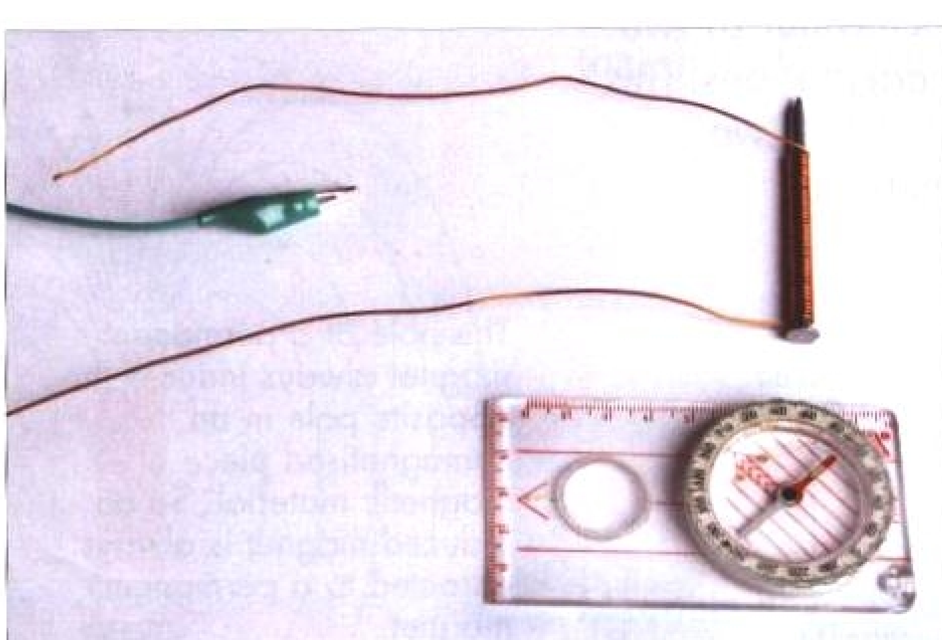
Magnet in a loudspeaker.



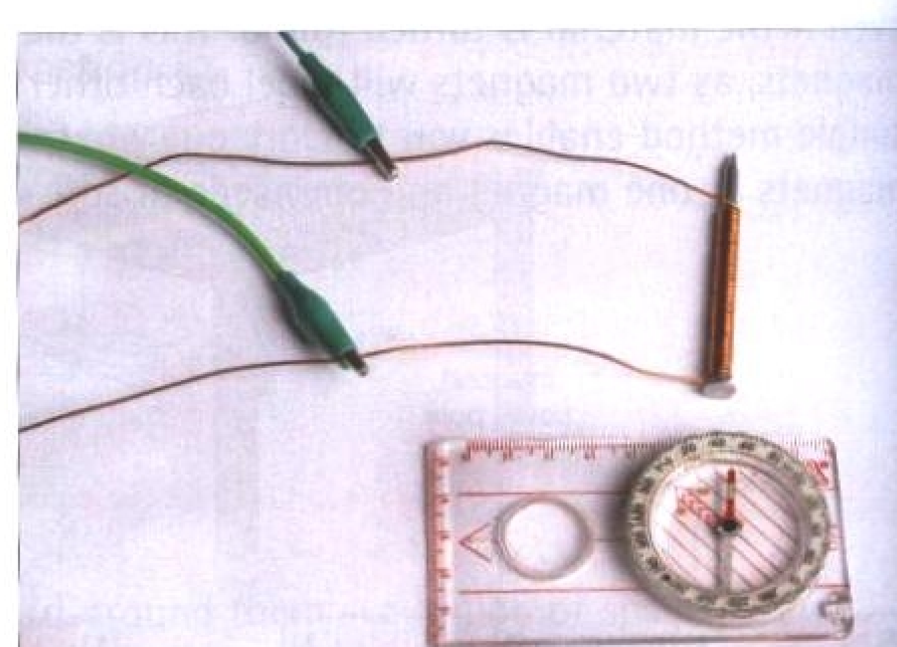


Electromagnet.

Electromagnets are made out of a coil of wire (often called a solenoid). When an electric current is passed through the coil, a magnet is formed with the N pole at one end of the coil and the S pole at the other end. If the coil is wrapped around a magnetically soft core, then when the coil is magnetised, it magnetises the core as well, and a very much stronger magnetic field is made. When the current is switched off, the coil loses its magnetism, so the core does as well.



No current is flowing through the coil, and the compass points to the north.



The electric current has magnetised the coil, and the coil has magnetised the soft iron core. The compass has lined itself up to the magnetic field.

METHODS OF MAGNETISATION

Permanent magnets are usually magnetised by putting them into a coil of wire and passing a large direct current of electricity through the coil for a moment. Very high currents are used, and special equipment must be used to make the method safe.

With some modern alloys, the magnetic field is applied to the molten alloy at very high temperature, and then the alloy is allowed to solidify while remaining in the magnetic field.

Steel can be magnetised to a certain degree by placing the bar N→S and hammering it. Ships become magnetised in this way during manufacture, as the hammering allows the Earth's field to magnetise them slightly.

METHODS OF DEMAGNETISATION

The only method of demagnetisation that is guaranteed to work is to heat the magnet. All magnets have a temperature (called the Curie temperature) at which they lose their magnetism. This temperature ranges from less than 100 °C to over 500 °C. When the magnet is cooled down, some of the magnetism may return.

Many magnets can be demagnetised by placing them in a coil of wire connected to an alternating electric current (a.c.) source. The current is switched on and while the a.c. current is flowing, the object is slowly taken out of the coil. In this way the object is magnetised in the opposite direction each time the current reverses, but as it is removed from the coil the amount of magnetisation is reduced each time.

Hammering or even dropping a powerful magnet may cause the loss of some of its magnetisation.

REVIEW QUESTIONS

Q1 What is the difference between a magnetically hard material and a magnetically soft material? Give an example of each.

Q2 Ranjit has a piece of metal that he thinks is a magnet. He holds it near another magnet and it is attracted. Ranjit says this proves his metal is a magnet. Explain why Ranjit is wrong.

Q3 Sketch the magnetic field pattern for a single bar magnet. How would the diagram change if the magnet were made stronger?

More questions on the CD ROM

Examination questions are on page 156.