Electricity and Magnetism: Physics Narrative 07

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This is the ‘Physics Narrative’ for this episode, that explains the physics for teachers. To develop your expertise in the episode, work with the ‘Teaching and Learning Issues’ and the ‘Teaching Approaches’. Navigate to any part of the topic using the Topic Menu, or use the tabs below to stay within this episode..

Electromagnets at work

What do electric bells, scrap-yard cranes and the central-locking in automobiles have in common? They all work using magnets, but not the permanent magnets of door catches and pupils' toys. The bells, cranes and car locks are based on electromagnets.

What is an electromagnet?

All electromagnets work on the principle that an electric current in a wire produces a magnetic field. In fact it is remarkably straightforward to make an electromagnet. Simply coil a length of wire round a piece of iron, such as a long iron nail, and pass an electric current through the wire. When there is a current in the wire a magnetic field is created and the iron becomes magnetised.

Linking electrical current to magnetism

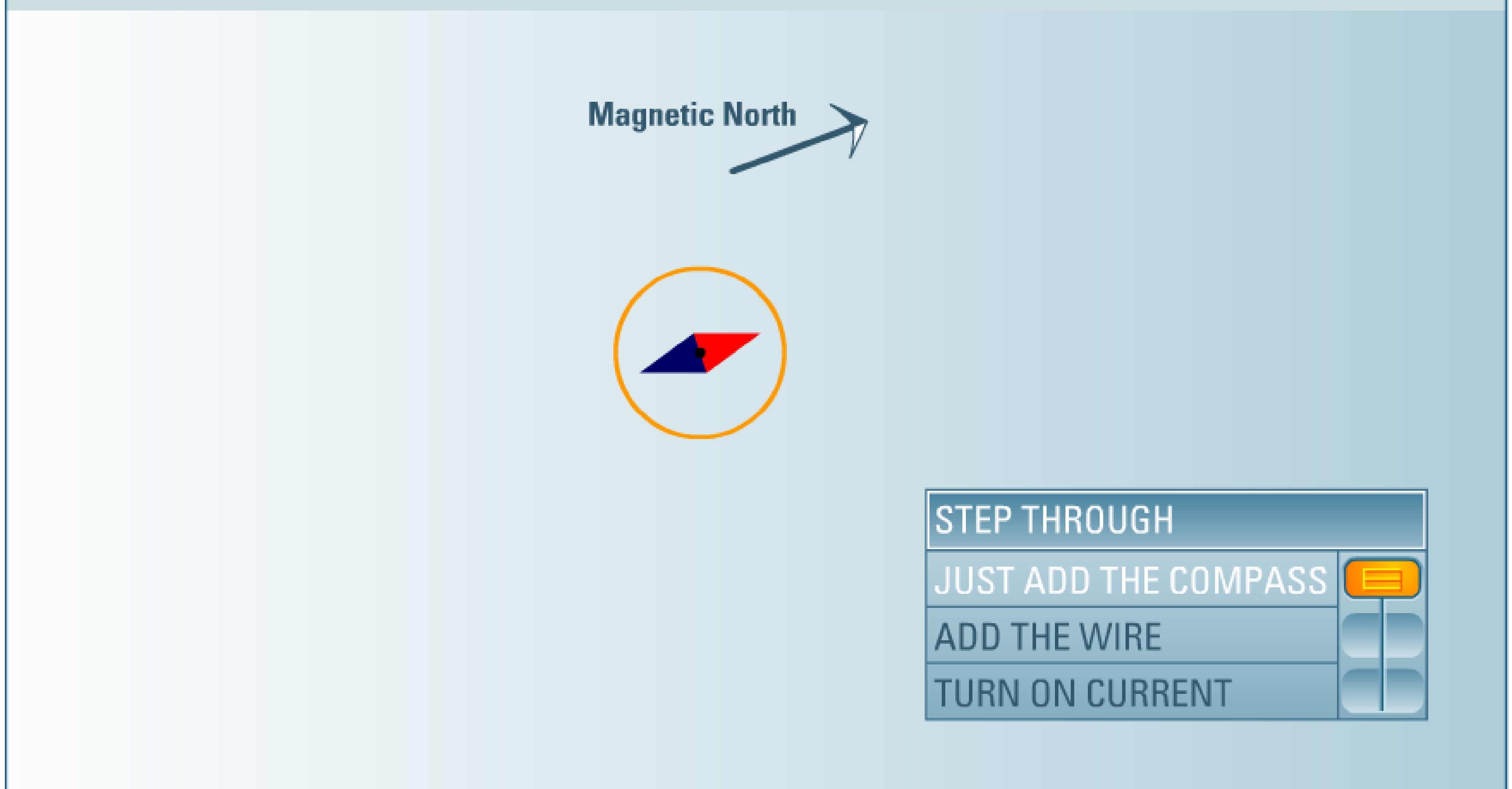
The connection between electric currents and magnetic fields was first demonstrated in 1820 by a Danish scientist named Hans Christian Oersted. Oersted showed that a compass needle (a small pivoted magnet) moves whenever an electric current passes through a nearby wire.

This simple demonstration can be replicated in the classroom to great effect, making the link from electricity to magnetism:

- Everyone knows that wires connected to batteries are "about electricity".
- Everyone knows that compass needles are "about magnetism".
- Switch on the electric current and the compass needle moves.
- You have witnessed, at first hand, the link between electricity and magnetism!

Oersted's experiment

Use the stepper to show the effect to look for when you try it for yourself.



Ampere's thinking

An early view of the connection between electric currents and magnetism.

The French scientist, Andre-Marie Ampere, considered that the phenomenon of magnetic fields being produced by electric currents is a fundamental feature of magnetism. In fact, he suggested that all magnetism, including that associated with permanent magnets, is due to electric currents. But how can electric currents be responsible for the behaviour of permanent magnets, when there seems to be no electric current?

Ampere's reasoning went something like this:

A permanent magnetic effect in a piece of iron/steel is due to the circulation of electric charges (imagine the motion of electrons around the nucleus of each atom). These moving charges constitute a minute electric current and so all magnetic effects are ultimately due to electric currents.

The magnetic fields produced by electric currents

Current through a long straight wire

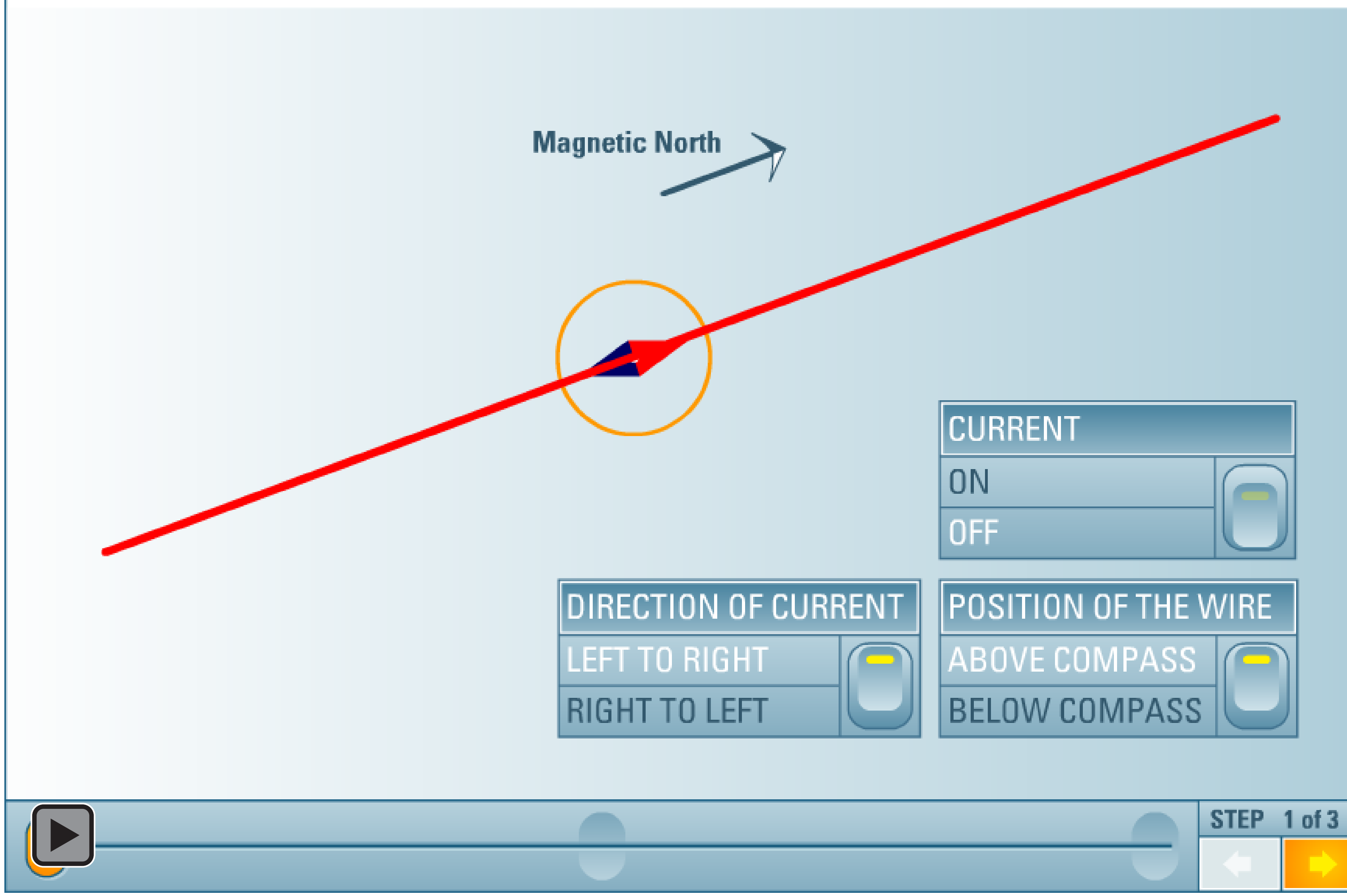
As Oersted found out, when there is an electric current in a long straight wire a magnetic field is created around it. But what is the shape of that field?

A clue is given by the fact that when a compass is placed above the wire and the electric current switched on, the needle deflects at right angles to the wire. When the compass is placed below the wire, and the electric current switched on, the needle deflects in the opposite direction.

In fact, the field around the wire is circular in shape; the needles of the plotting compasses form a continuous loop around the wire. These circles stretch out along the wire, forming cylinders.

The field around a long wire

Use the switches to explore the effect of the wire on the compasses.



The magnetic fields produced by electric currents

Current through a solenoid

If an electric current is passed through a long coil of wire (which physicists call a solenoid) a magnetic field is produced which is the same shape as that of a bar magnet.

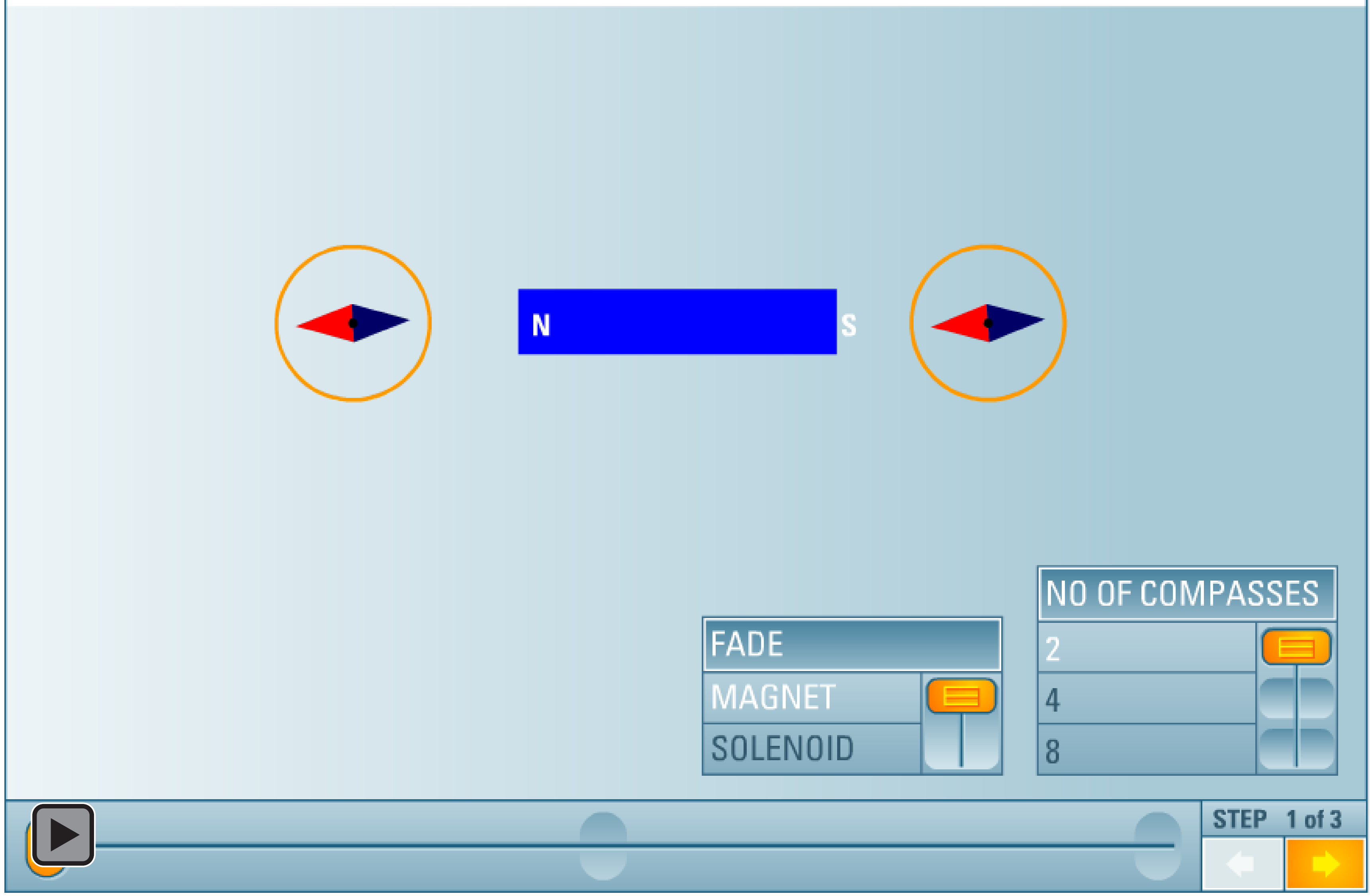
How is it that the bar magnet field shape is produced around the solenoid?

We can answer this question by starting from first principles and remembering the field around the long straight wire and now imagining the wire is coiled up. Adding the field due to all of the coils of wire amounts to a field shape exactly the same as that of a bar magnet.

This level of detail in thinking about magnetic fields is not part of the 11-14 science curriculum, but it is helpful to have these more advanced ideas in mind when teaching the basic principles of magnetic fields.

The magnetic field of a solenoid

Use the slider and stepper to see the similarities to the field of a bar magnet.



Electromagnets in everyday use

Why might we want to use an electromagnet rather than a permanent bar magnet? There are two obvious advantages to using electromagnets.

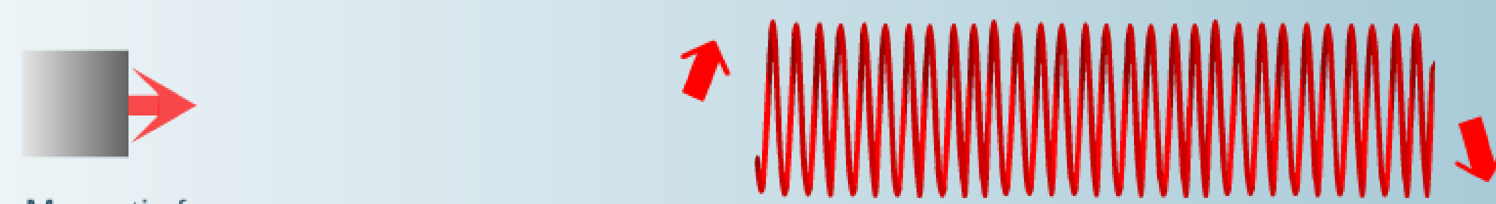
Firstly they can be switched on and off. Complete an electric circuit and a current passes to produce a magnetic field. Switch off the current and the magnetism disappears (provided the iron forms a temporary magnet).

Also their magnetic strength can be changed. The strength of the magnetic field around the solenoid can be increased by:

- increasing the number of coils (or turns) of wire
- increasing the electric current through the coil
- placing a magnetic material inside the solenoid coil

The strength of an electromagnet

Use the steppers to explore the factors.



Magnetic force exerted by solenoid on iron

SET THE CURRENT
2 AMPERE
4 AMPERE
6 AMPERE

SET THE NUMBER OF TURNS
30
60
90

SET THE CORE
AIR
IRON

Electromagnets in everyday use

Electric bells

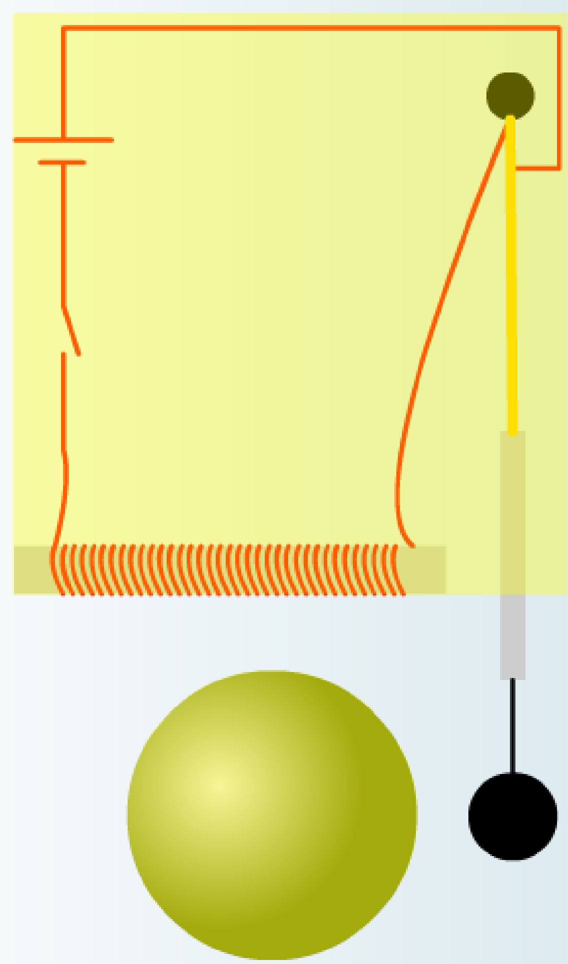
Electric door bells are "make and break" devices which work via an electromagnet. There is one electric circuit containing two switches. One is a conventional push-button switch. The second is has two parts, a spring and an electromagnet. The alternating action of the spring and the electromagnet makes and breaks the circuit for as long as the push-button switch is pressed. Here are the steps:

- Pushing the door bell button acts to complete or "make" an electric circuit allowing a current through the coil of the electromagnet.
- The electromagnet attracts an iron striker, which moves across to hit the bell, making one ring.
- As the striker moves across, it "breaks" the circuit, thereby switching off the electromagnet so allowing the striker to spring back to it original position.
- As the striker returns to its original position it makes the circuit once more and the cycle continues, with the bell ringing until the door bell button is released.

Practice the explanation with the commentary turned off.

The bell

Use the stepper to identify the parts of the bell, and the switch to see or hide the commentary.



COMMENTARY ON OFF

STEP 1 of 11

Electromagnets in everyday use

Scrap-yard magnets

Car scrap-yards use huge electromagnets to lift heaps of crumpled iron and steel. Switch off the current and the object crashes to the ground.

Electromagnets in everyday use

Electromagnetic relays

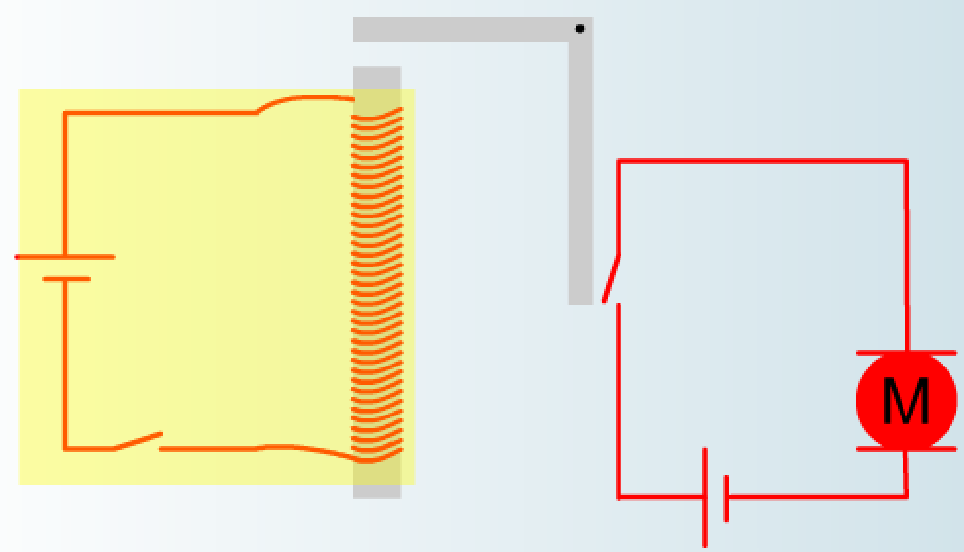
An electromagnetic relay consists of two circuits. The first circuit contains a simple electromagnet which requires a relatively small current to make it work. When the switch is closed, there is an electric current through the coil of wire and the iron rocker arm is attracted to the electromagnet. The arm rotates about the pivot and closes a switch to complete the second circuit and the motor starts up. When the switch in the first circuit is opened the electromagnet releases the rocker arm and the switch springs open again. The motor circuit is now broken.

The basic idea behind a relay is that a circuit with a small electric current is used to control a second circuit through which there is a much bigger electric current. The second circuit might, for example, contain a powerful electric motor or very bright lights. One common use of relays is to operate the starter motor of a car. Here a small electric current is activated by the ignition switch to complete the starter motor circuit which allows a very big electric current through the car starter motor.

Practice the explanation with the commentary turned off.

The relay

Use the stepper to identify the parts of the relay, and use the switch to see or hide the commentary.



COMMENTARY
ON
OFF

STEP 1 of 12

Electromagnets in everyday use

Electric motors

In the home, by far the most common use of electromagnets is in electric motors. Think of all of those bits of electrical equipment with some kind of electric motor: vacuum cleaners, refridgerators, washing machines, tumble driers, food blenders, fan ovens, microwaves, dish-washers, hair driers.

The list is a long one, and when you start thinking more widely about electric motors in cars, lawn-mowers and a whole host of industrial applications, it becomes obvious that this application of electromagnets is extensive and extremely important to our daily lives. The question of how electric motors work builds on the basics of magnetism introduced here, and is usually worked on in later years. The interactive shows how it builds on what you already know.

Building up a motor

Step through to see how the motor is built up. Use the switches to explore the diagram.