Electromagnetism

Uses of electromagnetism

- Electric bell
- Relay to allow one circuit to operate another
- Loudspeakers and telephone earpiece
- For removing metal (ferrous) splinters from your eyes
- In scrap yards for lifting metals
- Recording heads in tape recorders, floppy discs and hard discs
- Electric motors
- Electric analogue meters
- Deflector coils in CRT televisions
- Locking devices for safes
- Nuclear accelerators

When a current flows through a wire a magnetic field is produced around the wire. This field is called and electromagnetic field and the device produced is called an electromagnet. If the wire is wrapped round into a coil the magnetic field is stronger.

It is very easy to detect the magnetic field by putting a compass needle near a wire. When a current is passed through the wire the compass needle will turn. The greater the current in the wire the more the compass needle moved. This experiment was first done by a man called Oersted in 1819 who made the discovery by accident.

You can find the direction of the magnetic field produced by a wire by putting a small compass near the wire (Figure 1).

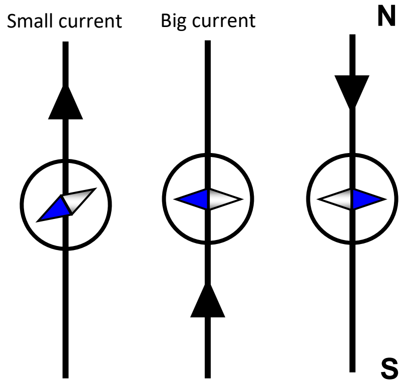


Figure 1

The direction of the magnetic field produced depends on the direction of the current and the shape of the field depends on the arrangement of the wires.

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

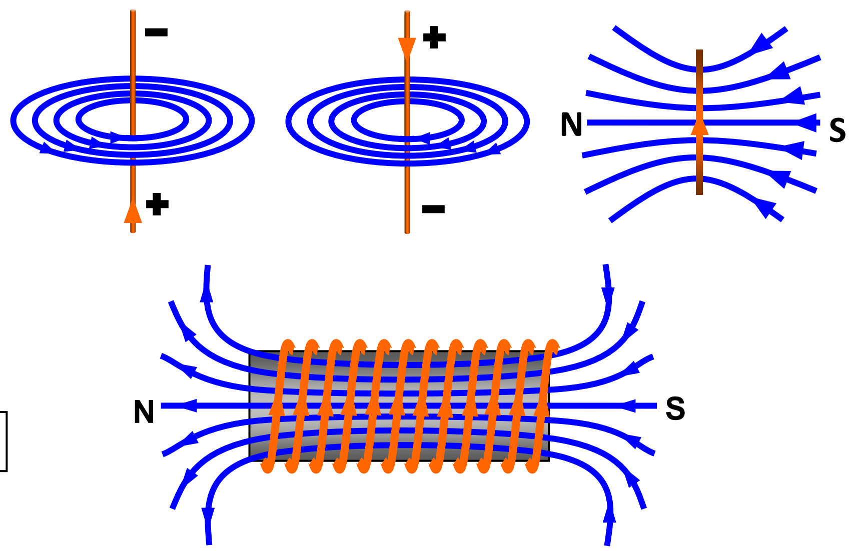


Figure 2

Electromagnets

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

You can use a small compass to test the polarity of an electromagnet. The following diagrams show the result of doing this for different current directions, different shaped cores and different ways of winding the wire round the core.

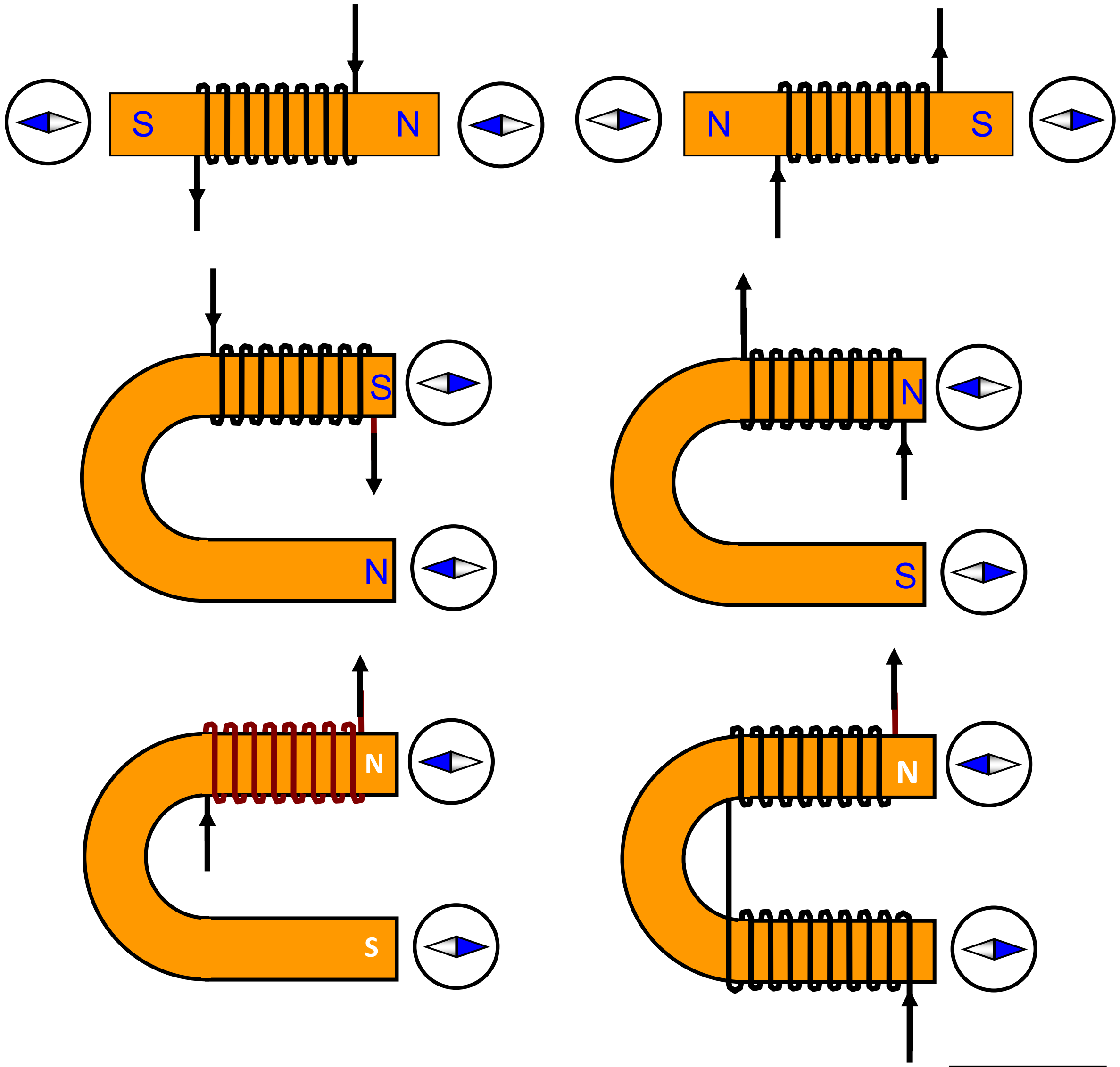
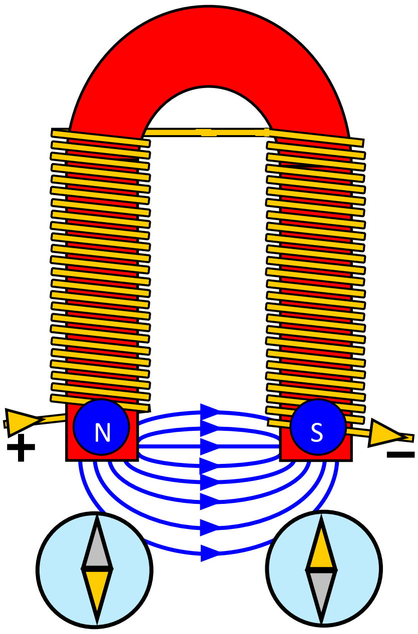


Figure 3

Electromagnet – strength and polarity



The diagram shows a U shaped electromagnet. You can see that the lines of magnetic field are closer between the poles and so the field is stronger there. Notice the way in which the wire is wound round the core of the electromagnet to give two opposite poles at the two ends of the U. This is one of the most useful forms of electromagnet.

Making an electromagnet stronger
An electromagnet be made stronger by:
(a) more coils
(b) more current
(c) coils closer together
(d) putting an iron core in the centre of the coil
(e) bending the poles of the magnet closer together to make a U shaped magnet

Polarity of an electromagnet
There are some simple rules to help you find out which end of an electromagnet is north and which is south.
(a) Direction of the current round the ends of the coil of wire (Physicists call a straight coil of wire a solenoid). Look at the ends of the coil from the outside; the direction of the current follows the direction of the letters N and S for north and south (see Figure 1).

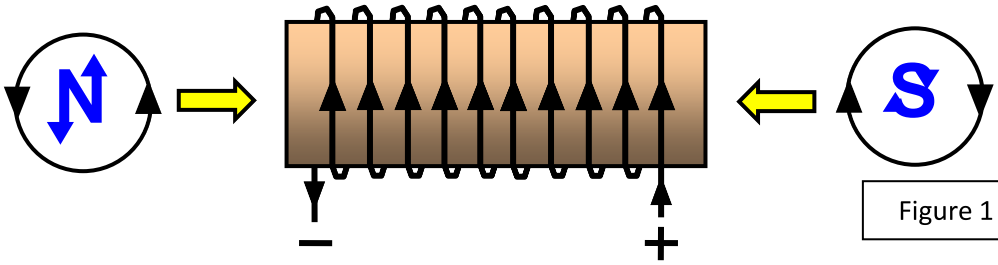


Figure 1

(b) the right hand grip rule
(i) for a solenoid
If you imagine gripping the solenoid with your right hand so that your fingers follow the direction of the current then your thumb will point towards the NORTH end of the electromagnet (see Figure 2).

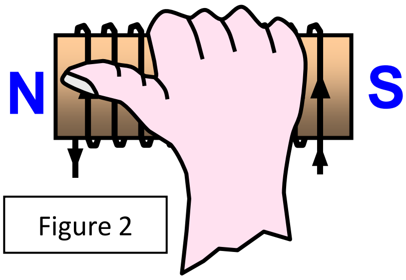


Figure 2

(ii) for a straight wire
If you imagine griping the wire with your right hand with your thumb in the direction of the current then your fingers will show the direction of the magnetic field round the wire pointing from NORTH to SOUTH.
(See Figure 3)

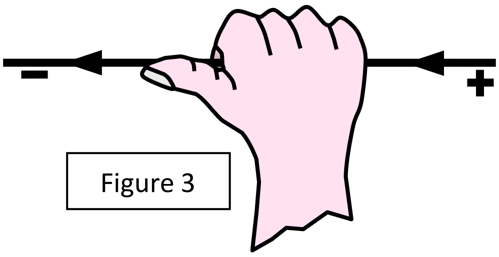
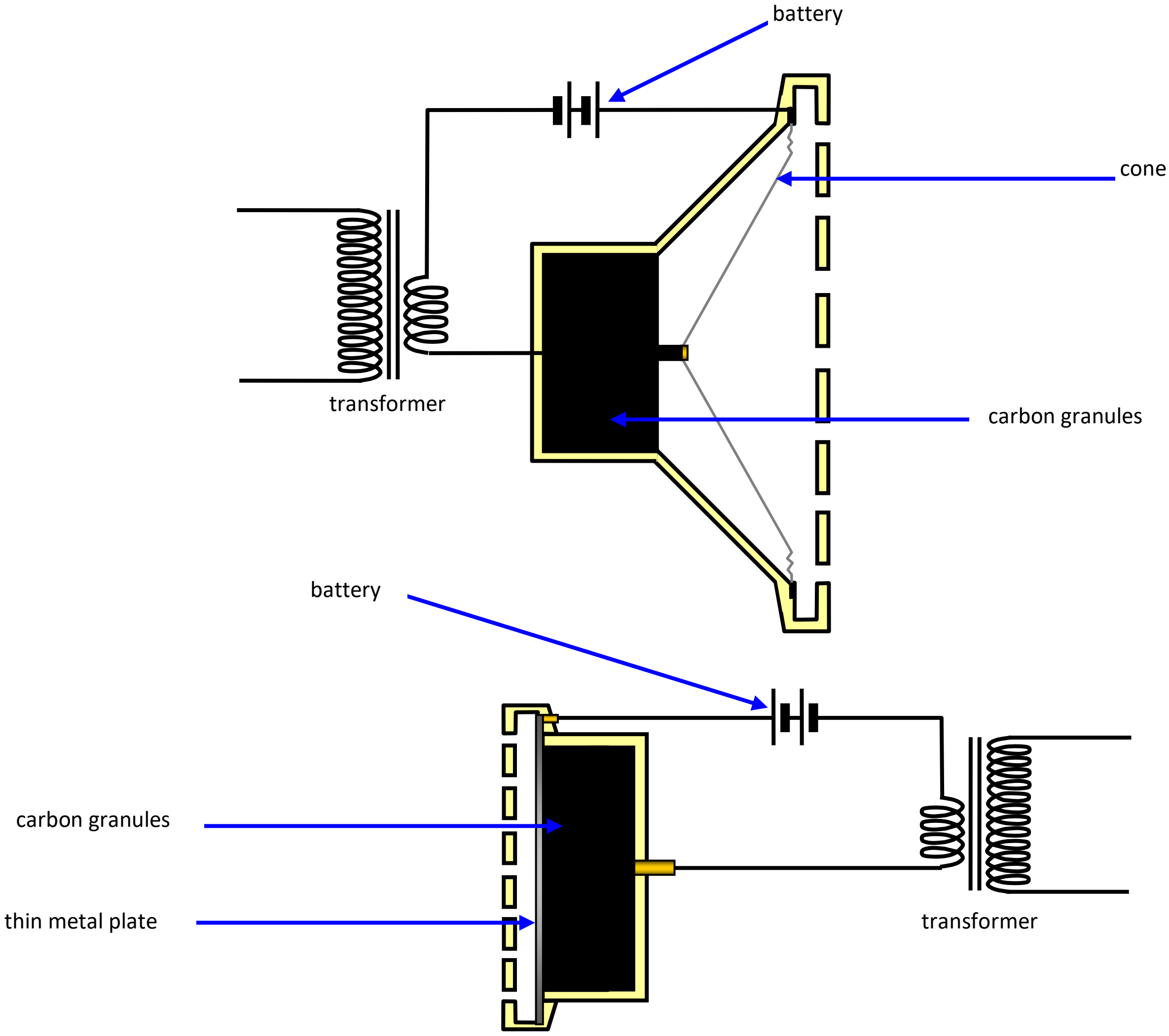


Figure 3

The carbon granule microphone

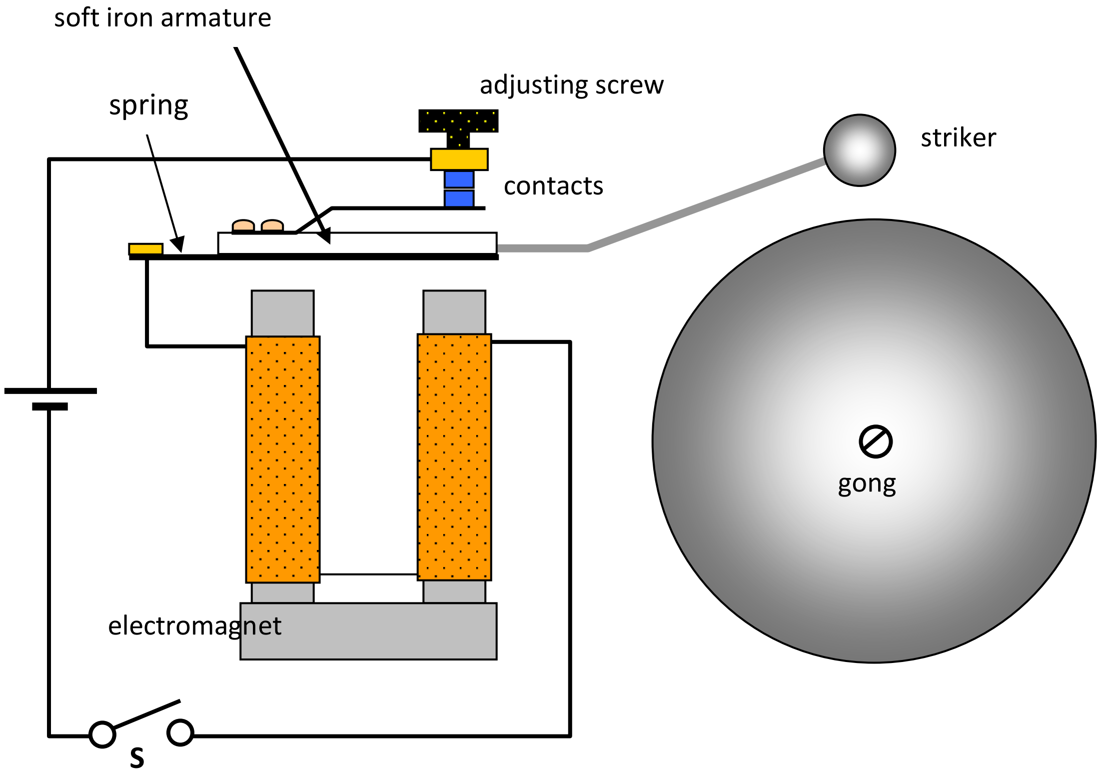
The carbon granule microphone works because of the change in resistance of a volume of carbon granules as they are compressed and then released. When they are squashed there is better electrical contact and their resistance goes down – when the pressure on them is reduced the resistance of the volume goes up.

Two diagrams of the carbon granule microphone are shown. In each one a battery passes a small current through the carbon granules. When a sound wave hits the front of the microphone (the cone in the first diagram) the pressure on the carbon granules changes in step with the sound wave. This causes the resistance of the granules to change and therefore the current through them also changes (the battery voltage stays the same). This changing current is fed to a transformer and the output goes to an amplifier and a loudspeaker.



The electric bell

A simple electric bell is shown in the diagram — it works like this. When the switch S is closed current flows round the circuit, through the electromagnet — along the spring — through the contacts — through the adjusting screw and back to the battery again.



The electromagnet therefore attracts the soft iron armature and the striker hits the gong once.

As soon as the armature is attracted the contacts are opened and so the current stops flowing.

This switches off the electromagnet, the spring pulls the armature away — the contacts meet again and so the current starts flowing again. This is repeated over and over again and so the bell rings.

Motion from electricity

In 1821 Michael Faraday found a way of producing motion from electricity. He found that if a wire carrying an electric current was placed in a magnetic field then there was a force on the wire; and if it could it moved. This happens because of the combined effects of the magnetic fields of the wire and the magnets.

This may not seem very important but this simple fact is the basis of all our electric motors. Just think of how many times you use an electric motor in the house or at school – none of them would have been possible without Faraday's discovery.

The effect can easily be demonstrated by the experiment shown below (Figure 1).

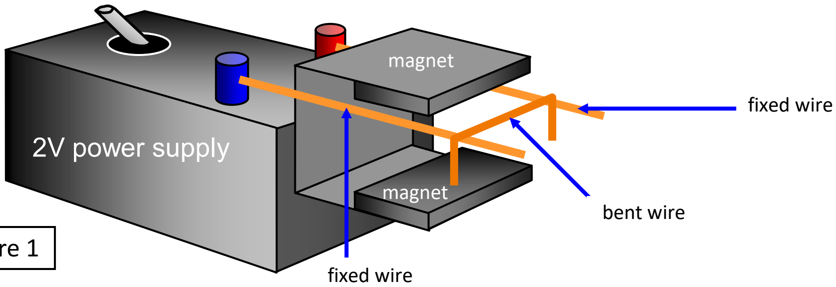


Figure 1

When a current is passed through the bent wire it moves along the two fixed wires between the poles of the magnets.
(Note : the magnets must be fixed to the metal yoke so that opposite poles face each other)

You will find that altering either the direction of the current or the direction of the magnetic field will change the direction of motion.

Figure 2 shows the arrangement clearly.

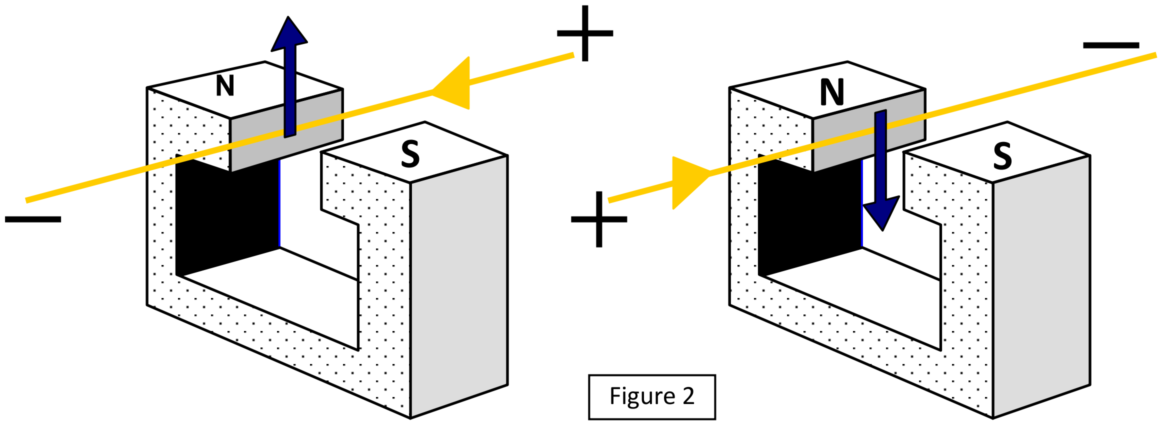


Figure 2

The maximum force occurs when the current and the field are at right-angles to each other and the motion is then at right angles to both the field and the current. The bigger the current and the stronger the magnetic field the greater the force on the wire and the faster it will move. Also the wire will 'feel' the biggest force if it is at right angles to the magnetic field and no force at all if it is parallel to the field.

Professor J .A. Fleming found a simple way of remembering the direction of motion using your left hand. It is called Fleming's Left Hand Rule. If the thumb, first finger and second finger of the left hand are placed at right angles to each other then:

The **F**irst finger gives the **F**ield (N to S)

The se**C**ond finds the **C**urrent (+ to -)

The thu**M**b shows the **M**otion.

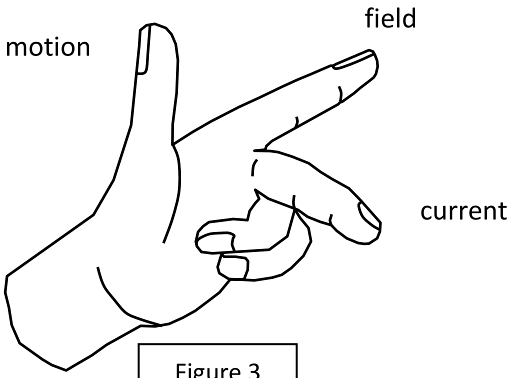


Figure 3

The catapult field

We will now look at the magnetic field that gives this motion; because of its shape it is called the **CATAPULT FIELD**.

The diagrams show the field of two flat magnets (i), the field of a wire (ii), and the result of putting the wire and magnets together (iii). It is this third field that is called the catapult field. You can see that the magnetic lines of force are close together near the wire so forcing it upwards. It is rather like the effect of a stretched rubber sheet on an object put on it.

(Think about the forces on a trampolinist when they are standing on a trampoline).

If the current direction is reversed the wire will be forced downwards.

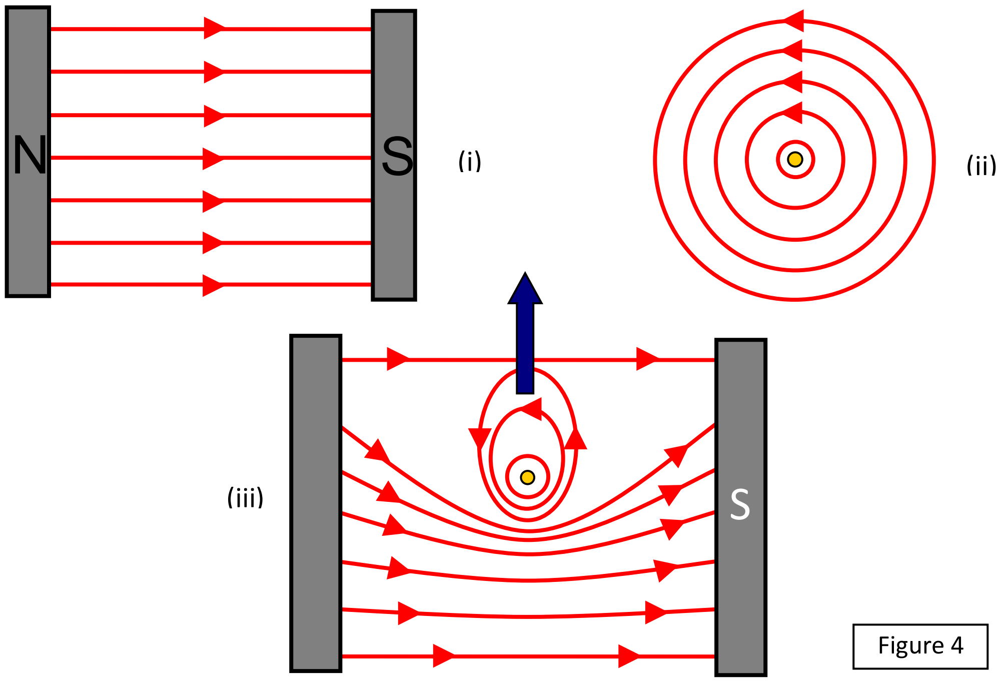


Figure 4

Force on a coil of wire in a magnetic field

If a current flows round a coil the way the current direction along one side of the coil will be opposite to that along the other side. Therefore, if the coil is placed in a magnetic field the forces on each side of the coil will be opposite to each other. (See figure 5)

This means that side of the coil will be pushed upwards and the other side pushed downwards and so the coil will twist. This rotation of the coil is the basis of all electric meters and motors.

With more turns of wire on the coil the twisting force will be greater.

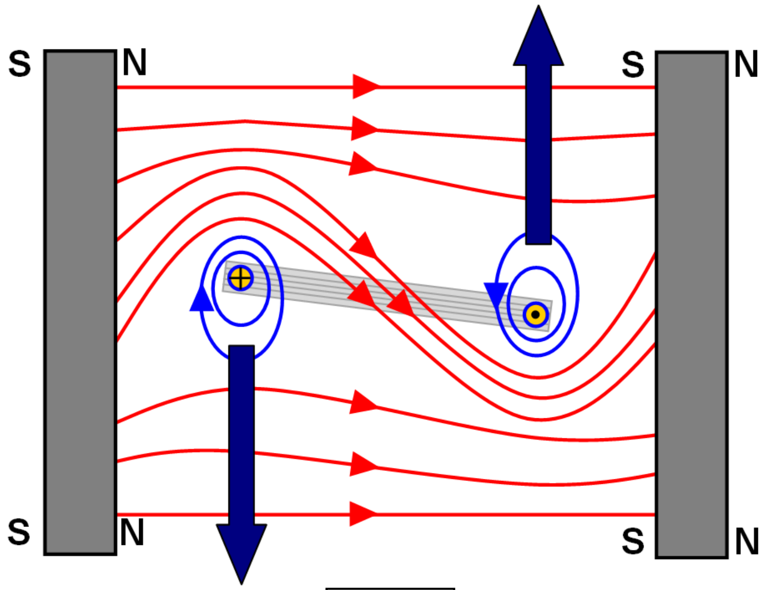


Figure 5

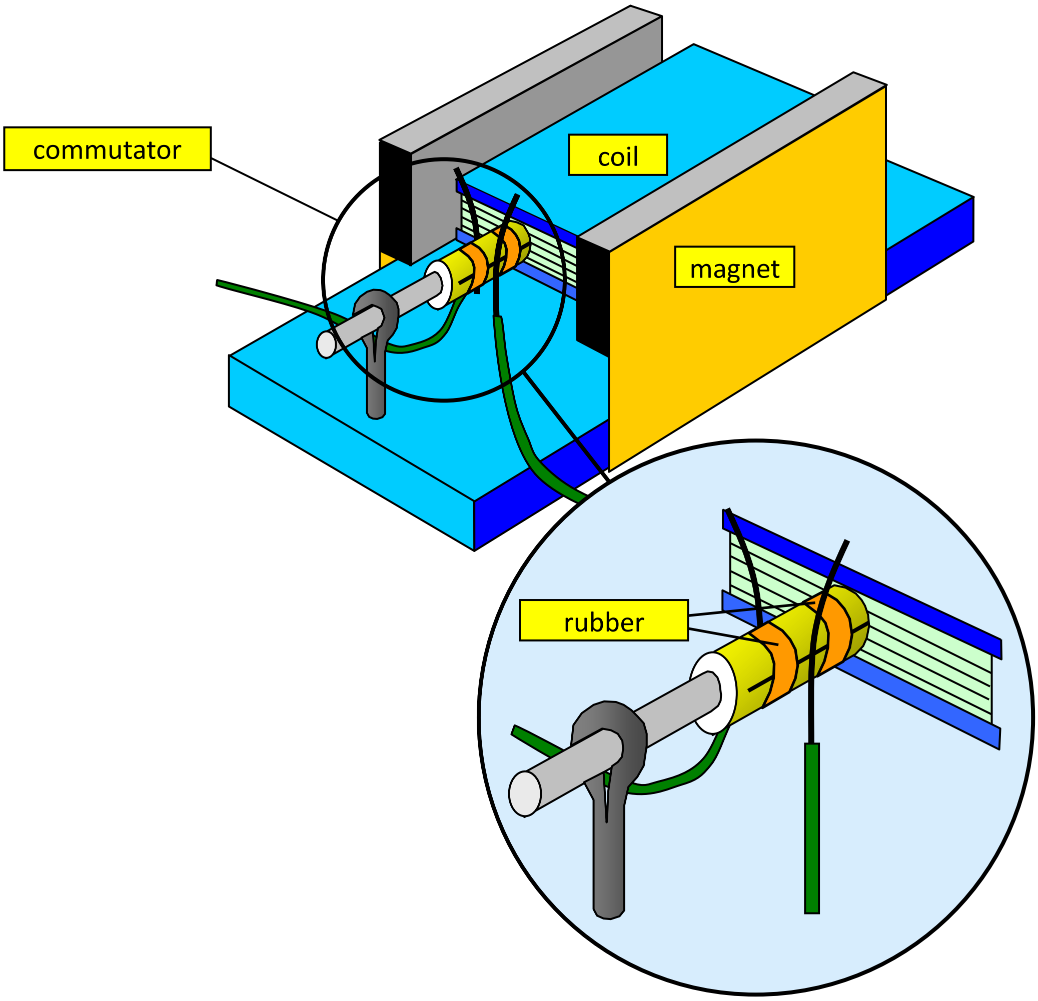
A simple electric motor

Electric motors play a very large part in our everyday lives. Perhaps you have made an electric motor like the one shown in the diagram. You will find electric motors in CD players, sewing machines, electric drills, washing machines, hair driers etc.

An electric motor like the one above needs three things to make it work:

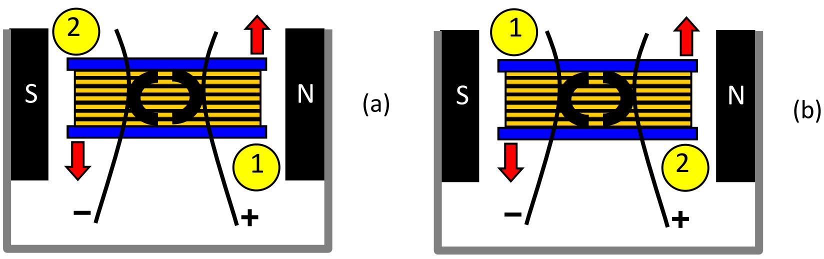
1 a magnetic field;
2 a coil of wire with a current flowing through it;
3 a means of getting this current in and out of the coil.

When a wire carrying a current is in a magnetic field there is a force on it at right angles to the field. (See the catapult field and Fleming's left hand rule.)



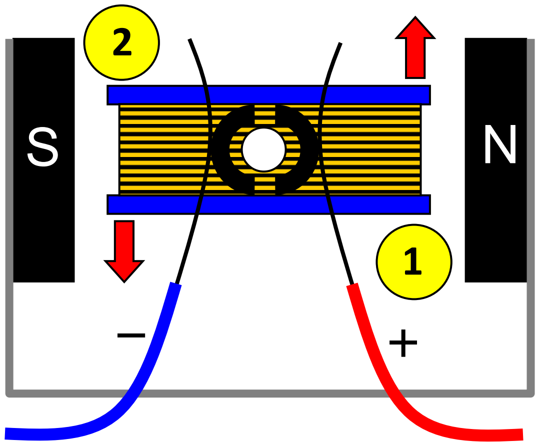
A coil in a magnetic field experiences an equal but opposite force on its two sides and so the coil twists.

If we start with the coil in the position shown in diagram (a) then there will be an upward force on side (1) of the coil and a downward force on side (2) of the coil. The coil will therefore start to twist in an anticlockwise direction.



The inertia of the coil and core keeps it turning until the input wires make contact with the ends of the coil again. This time the positive wire touches side (2) and the negative wire touches side (1).
Side (2) now moves up and side (1) moves down — the coil continues to turn in an anticlockwise direction. This process then continues and so the coil spins.

The electric motor works because if a wire carrying an electric current is in a magnetic field there is a force on the wire. This makes the wire move if it can.



The diagram shows the view of a simple electric motor looking from the end of the axle. (The end of the axle is the small white circle in the middle of the diagram).

When a current flows through the coil there is a force on the coil. The side marked 1 is forced upwards and the side marked 2 is forced downwards.

The coil turns in an ANTICLOCKWISE DIRECTION. The inertia of the coil keeps it turning between each contact with the input wires (+ and -).

To make the motor turn faster we can:
(a) increase the current
(b) replace the magnets with more powerful ones
(c) push the magnets closer to the coil
(d) put an iron centre piece into the coil (this concentrates the magnetic field through the coil)
(e) adding more sets of coils around the central core

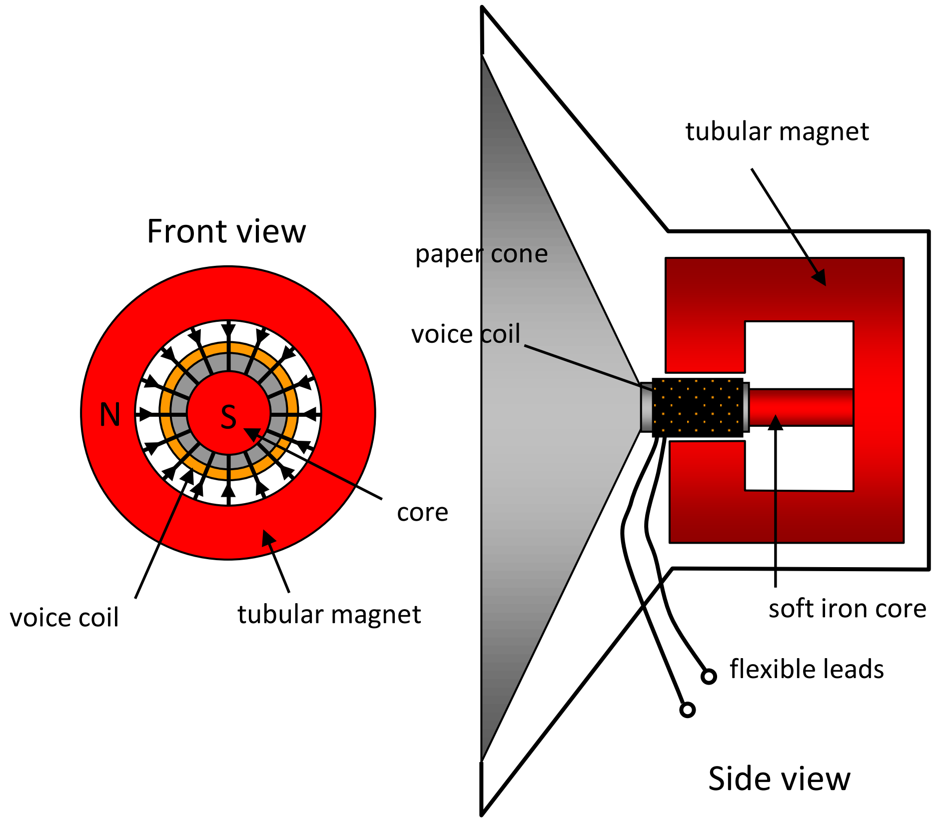
Changing the direction in which the motor turns
MAGNETS
If we change the magnets so that they face the other way (North on the left and south on the right) the motor will turn in the opposite direction (CLOCKWISE in this case).

CURRENT
If we change the direction of the current so that the wire on the right is negative and that on the left positive) the motor will turn in the opposite direction (CLOCKWISE in this case).

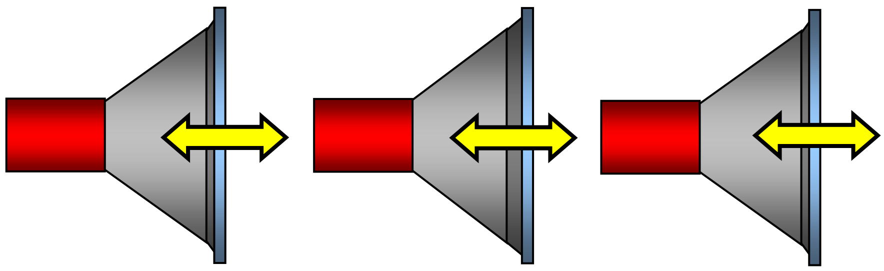
MAGNETS AND CURRENT
If we change BOTH the direction of the current AND the way the magnets are facing the motor will turn in the SAME direction as the original one (ANTICLOCKWISE in this case).

USING A.C.
Alternating current (a.c.) is current where the direction is changing all the time. It flows first one way and then the other. If our simple motor is connected to a.c. it will simply vibrate. It will start to turn one way and then immediately try and turn the other way as the current direction changes – result – vibration only.

The moving coil loudspeaker



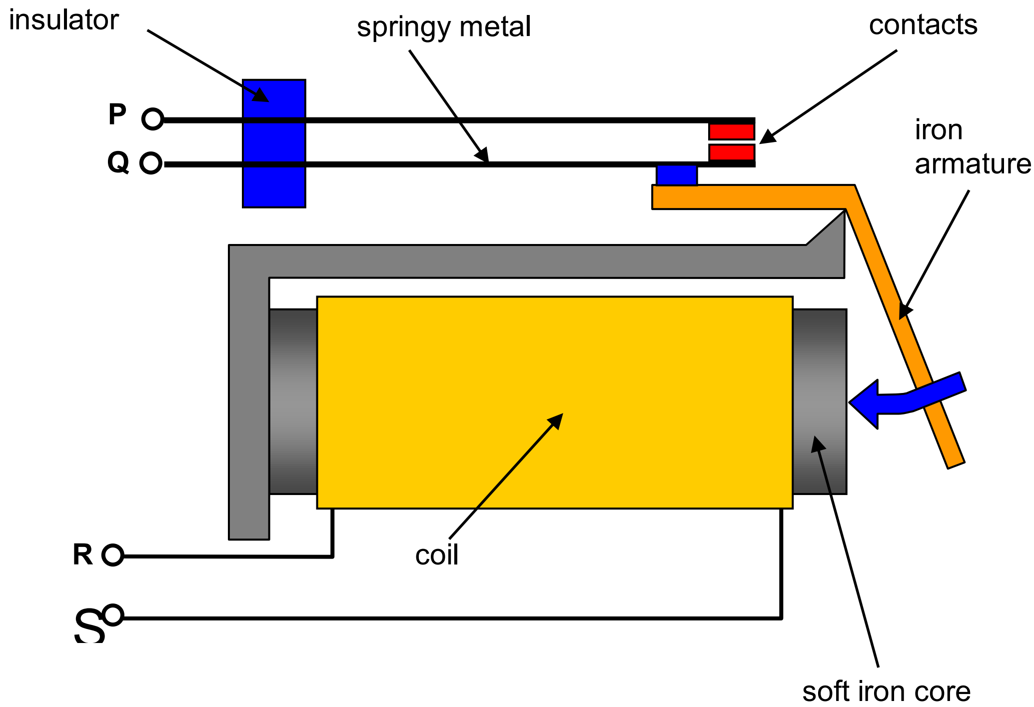
The current from the amplifier is fed to the voice coil which is wound round a paper former fixed to the speaker cone. This former fits over the core of a tubular magnet. The current in the coil makes it a magnet and so it is affected by the field of the speaker magnet. The force on the coil makes it move at right angles to the magnetic field – that is in and out of the paper in the first diagram. Since the signal is a.c. the force on the coil is changing and so it moves backwards and forwards, this in turn makes the speaker cone vibrate giving you the sound.



The paper cone is fixed to the frame of the speaker by a flexible section. As the current goes through the coil round the base of the speaker cone the cone is pulled either backwards or forwards. (See Force on a current in a magnetic field and Fleming's left hand rule). The bigger the current the more it moves, that is why you can see it in the large disco speakers when the sounds are large!

If the current changes, as it will from a sound source such as a microphone the cone is pulled backwards and forwards. The low notes will be of a lower frequency and so the cone will move backwards and forwards more slowly and so the movement is easier to see

The relay



A relay is a device that is used when we want one circuit to control another. This is especially useful when one circuit may have to carry a larger current than the control devices can take. A good example of this is the use of a computer (small current output) to control a stage lighting circuit (large current).

To switch on the relay a small current must flow in the circuit RS. When this happens the coil and soft iron core become an electromagnet. The iron armature is attracted to it - the contacts are closed and so the circuit PQ (large current) is made.