

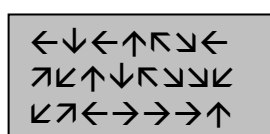
How Do Things Move Without Contact?

Reference: Heinemann Physics 12 4th Edition Chapters 1 – 3 Pages 1 – 106

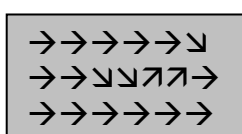
Physics with Synno – Move Without Contact – Lesson 6

M.1 Why are Magnets “Magnetic”?

Ferromagnetic materials (usually iron) contain many small dipoles or domains. When these dipoles and domains are aligned within the material, a magnetic effect is achieved. A random arrangement of these domains means that the material does not exhibit magnetic properties.



Unmagnetised



Magnetised

Although all atoms have spinning electrons, only a small number of materials are ferromagnetic, and not all pieces of iron are magnets. Groups of around a billion atoms form domains. In un-magnetised materials, the directions of the domains are random and so their fields all cancel out.

M.1.1 All Magnets Have Two Poles

All magnets have two ends or faces called poles. One pole is called the North Pole and the other the South Pole. Like poles will repel and unlike poles will attract each other. The North-seeking pole, commonly called the North Pole, on a magnet will point towards the Earth's North Pole.

Because magnets always have two poles they are called **dipolar**. When a magnet is broken, two new poles appear at the broken ends as shown below. It is not possible to form a magnetic monopole.



The properties of magnets are very similar to the forces between electrical charges, where

- like charges repel and opposite charges attract
- the force of attraction or repulsion increases as the distance between the charges decreases

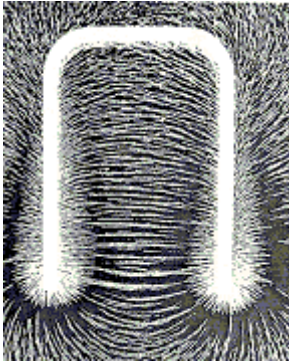
This is one reason why there was thought to be a connection between electricity and magnetism.

M.2 Magnetic Fields

Video: Magnetic Field Viewer Demonstration

A magnet will exert a force on a nearby object that is either a magnet or a particular metal. We classify this magnetic force as a non-contact field force.

The strength and direction of the force depends on where the object is placed. We can predict and measure the direction and size of forces around a magnet.

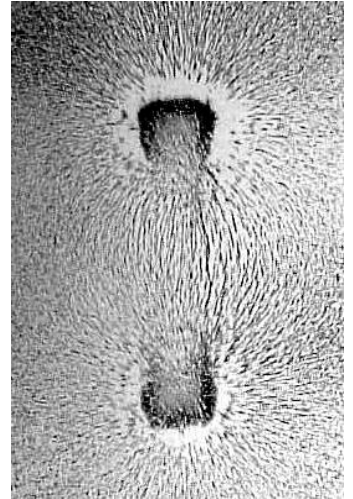


The set of forces surrounding a magnet is called the magnetic field.

The shape of the field can be found by using iron filings that line up with the direction of the field at each point.

The strength of the magnetic field decreases with the distance from the magnet.

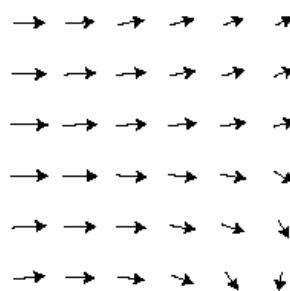
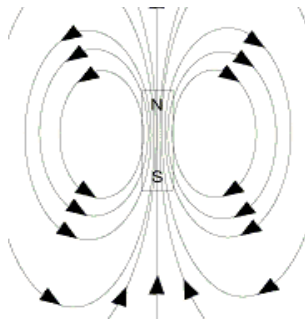
Magnetic fields are vectors.



M.2.1 What are field lines?

Video: Magnetic lines of force demonstration

The wind patterns in a certain area of the ocean could be charted in a “sea of arrows” representation like this: Each arrow represents both the wind’s strength and its direction at a certain point.



Magnetic field strength lines are similar to these wind strength lines

Field lines are drawn around the magnet to the right.

Field lines show the direction of the force at any point on an imaginary single north pole that is placed near the magnet.

An imaginary north pole will experience

- a downward force when placed directly left or right of the magnet
- an upward force when placed directly above or below the magnet

Field lines always are drawn **from North to South.**

M.2.2 Magnetic Field Strength

The symbol **B** is given to the magnetic field strength

Its unit is the Tesla (T).

It is a vector quantity, therefore

It has both magnitude and direction.

Two or more magnetic fields need to be added as vectors.

Permanent magnets typically have $\mathbf{B} = 10^{-3}$ to 1T.

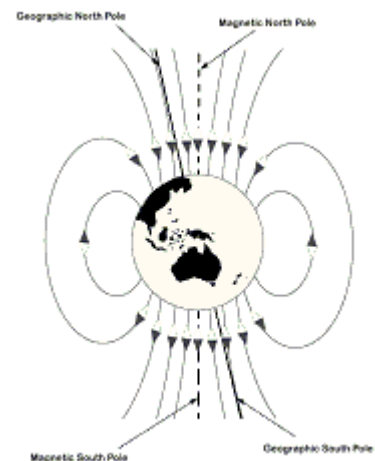
Remember, magnetic field lines start at the north poles and travel through space to the south poles.

Magnets tend to point in the direction of the magnetic field.

(The North pole points in the direction of the field, the South pole in the opposite direction.)

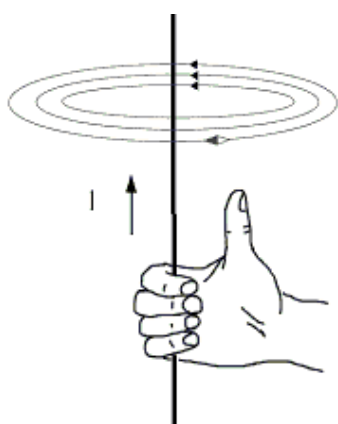
What about the Earth?

The earth's magnetic field $\sim 5 \times 10^{-5}\text{T}$.



M.2.3 Magnetic Fields around Wires

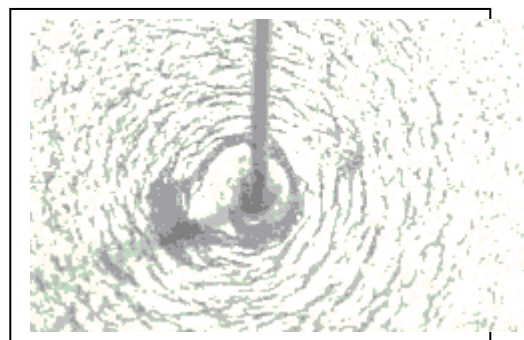
Video: Magnetic Field Around a Current Carrying Wire



A conductor carrying an electric current is always surrounded by a magnetic field.

That's right: every current-carrying wire becomes a magnet!

Electromagnetism is a temporary effect caused by the flow of electric current and it disappears when the current flow is stopped.



The magnetic field lines due to the current in a straight wire are concentric circles with the wire at the centre. The direction of the magnetic field can be found using the right-hand screw (grip) rule.

The wire is gripped with the **right** hand so that the thumb lines up with the direction of current flow. The direction of the magnetic field is given by the curl of the fingers.

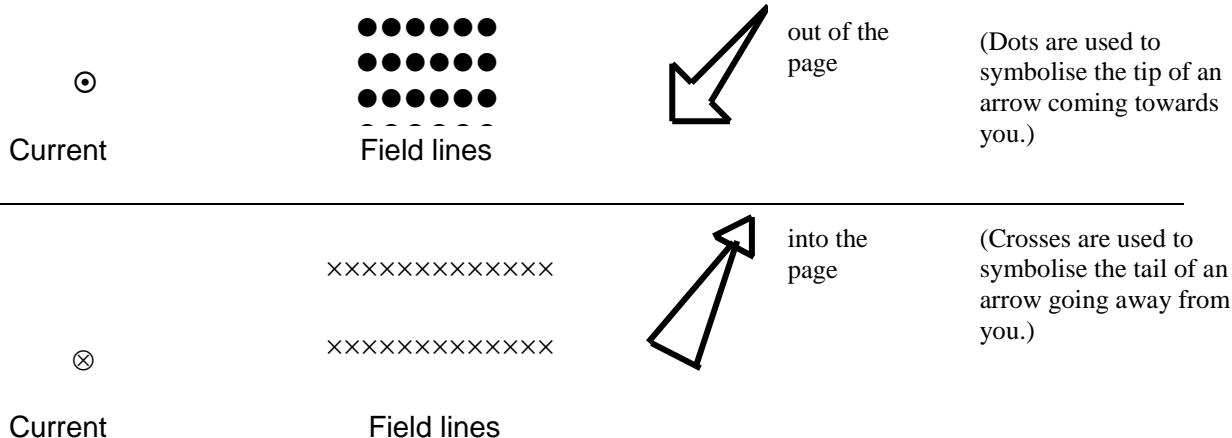


The strength of the magnetic field caused by the current is given by $B = \frac{kI}{r}$ (k is a constant).

M.2.4 Drawing 3D Direction

Remember: the direction of the current is the direction of positively charged particles. When the electrons are moving in one direction the conventional current is in the opposite direction.

To represent three dimensional situations on a two dimensional page, use the following convention.

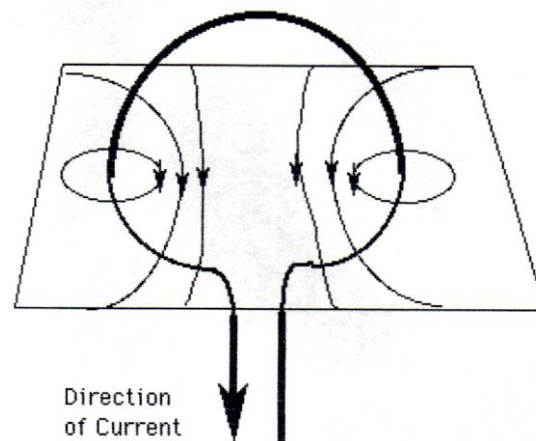


M.2.5

Magnetic Field of a Coil

Video: Magnetic Field of a Coil of Wire

If we have a single coil of wire, a magnetic field is set up. The direction of this magnetic field can be worked out using the Right Hand Grip Rule.



M.2.6

Magnetic Field of a Solenoid

A solenoid is simply a coil of wire that has many turns in the coil. The direction of the magnetic field can be worked out using Synnot's right hand rule for solenoids which says wrap your fingers around the coil in the direction of the current and your thumb points to North. In fact the magnetic field pattern around a solenoid is the same as that around a bar magnet.

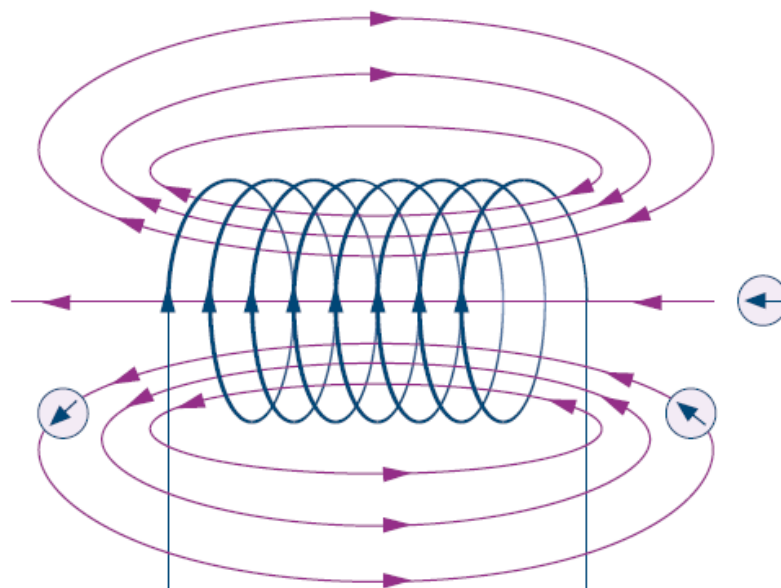
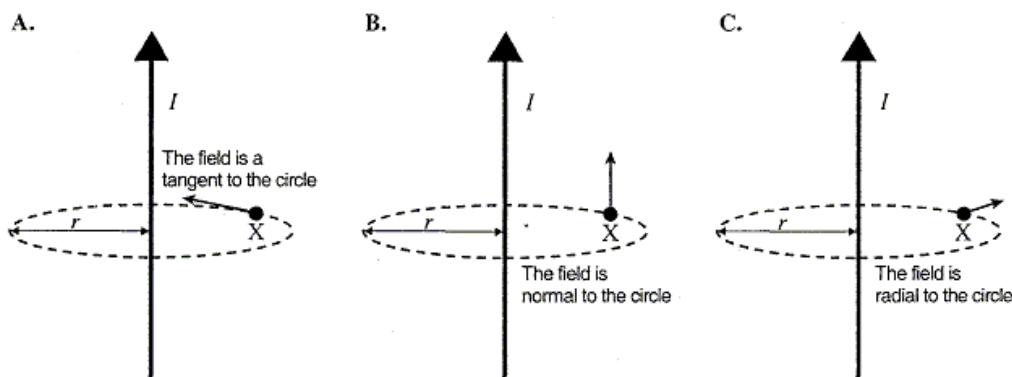


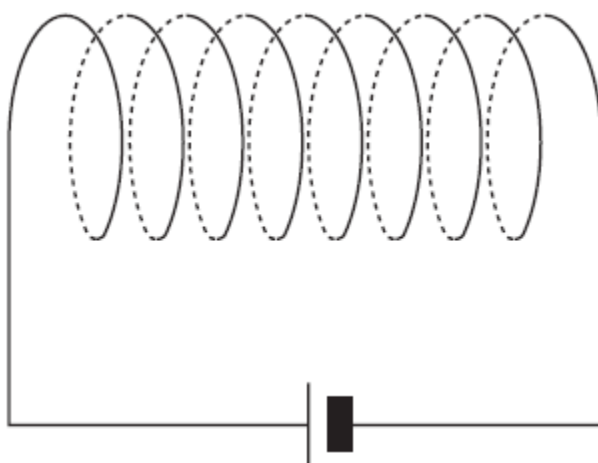
FIGURE 2.3.17 This solenoid has an effective 'north' end at the left and a 'south' end at the right. The compass points in the direction of the field lines.

Example 1 2000 Question 2

Which **one** of the diagrams (A-C) best indicates the **direction** of the magnetic field at point X, a distance r from the lightning stroke? The direction of the current I is shown. The field at X is shown as an arrow.



The figure below shows a solenoid powered by a battery.



Example 2 (2006 Question 1)

Complete the diagram above by sketching **five** magnetic field lines created by the solenoid. Make sure that you clearly show the direction of the field, including both inside and outside the solenoid.