

TOPIC

21

Electromagnetism

Objectives

Candidates should be able to:

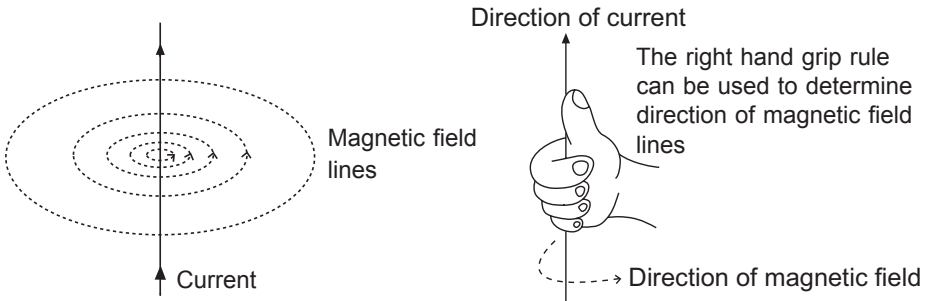
- (a) draw the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and/or direction of the current
- (b) describe the application of the magnetic effect of a current in a circuit breaker
- (c) describe experiments to show the force on a current-carrying conductor, and on a beam of charged particles, in a magnetic field, including the effect of reversing
 - (i) the current
 - (ii) the direction of the field
- (d) deduce the relative directions of force, field and current when any two of these quantities are at right angles to each other using Fleming's left-hand rule
- (e) describe the field patterns between currents in parallel conductors and relate these to the forces which exist between the conductors (excluding the Earth's field)
- (f) explain how a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by increasing
 - (i) the number of turns on the coil
 - (ii) the current
- (g) discuss how this turning effect is used in the action of an electric motor
- (h) describe the action of a split-ring commutator in a two-pole, single-coil motor and the effect of winding the coil on to a soft-iron cylinder

NOTES.....

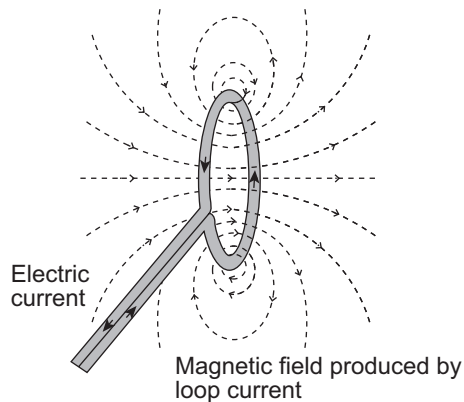
21.1 Magnetic Effect of a Current

1. A current-carrying wire will produce a magnetic field around it. The pattern of the field lines depends on how the wire is shaped.

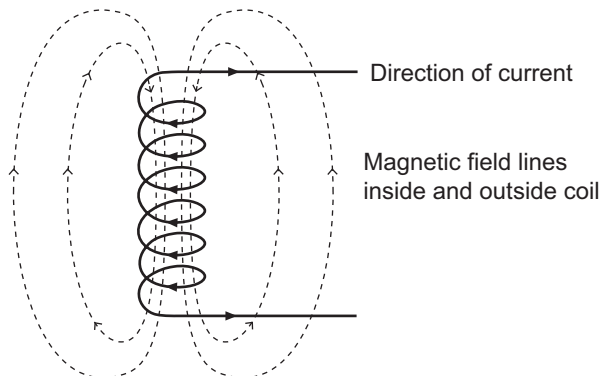
2. For a straight wire, the field lines form concentric circles around the wire as shown (note direction of arrows on field lines):



3. A higher current will result in a stronger magnetic field around the wire.
4. The field pattern of a single turn of circular wire carrying current is as shown:

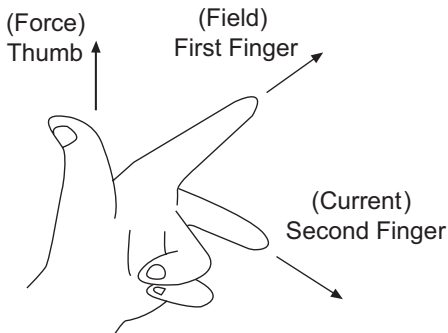


5. A solenoid's magnetic field pattern is as shown:



21.2 Force on a Current-carrying Conductor

1. When a current carrying wire is placed in a magnetic field, it will experience a magnetic force.
2. The direction of the force can be found using Fleming's Left Hand Rule:



Thumb: Direction of force

First Finger: Direction of field

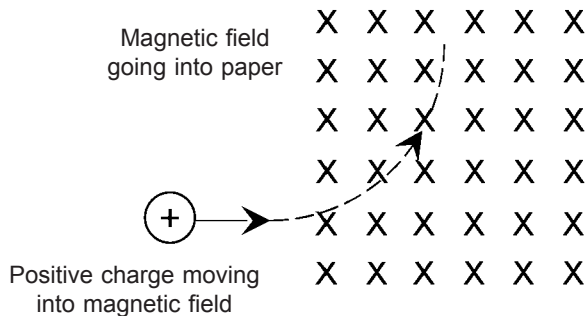
Second Finger: Direction of current in wire

Note: The three fingers must be held at 90° to each other.

3. For a positive charge moving in space, it will behave like a current-carrying wire.
4. For a negative charge, the direction of the current will be **opposite** to its direction of travel.

Example 21.1

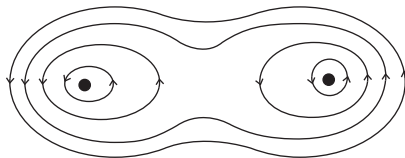
For a positive charge moving into a magnetic field as shown, it will experience a force to its left; hence its path is curved.



5. Force between two current-carrying wires.

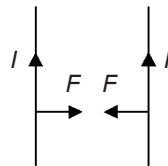
When two wires are carrying current, they will experience mutual forces of attraction or repulsion because each of them will produce a magnetic field which will affect the other. If the currents flow in the same direction, the wires will attract each other; if the currents flow in opposite directions, the wires will repel.

1. Currents in same direction

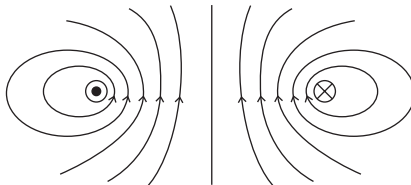


● Current coming out of paper

Notice that the field lines are only crowded outside and not in the middle? That is because the field lines cancel out in the middle of the wires. Hence there is an attractive force pulling the two wires together.

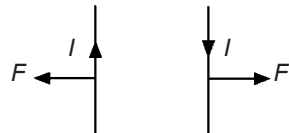


2. Currents in opposite directions



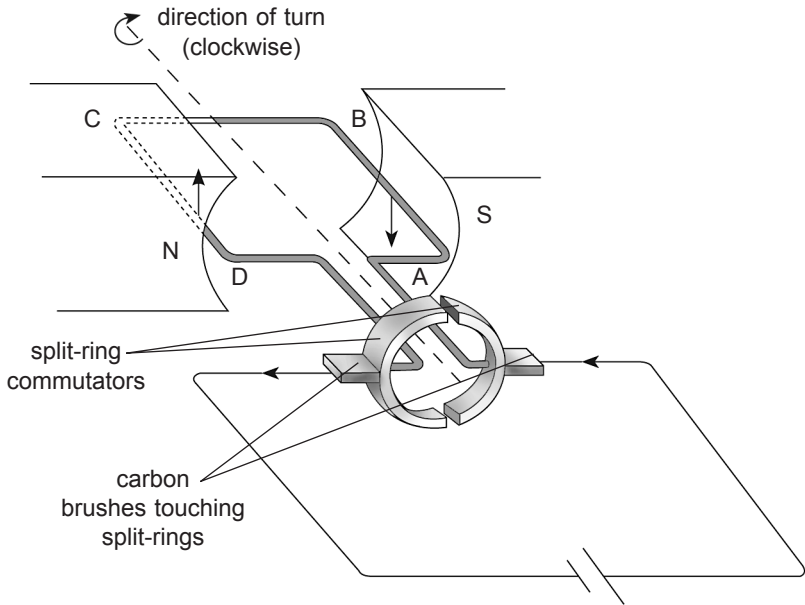
● Current coming out of paper
⊗ Current going into paper

Notice that the field lines are crowded between the wires. Crowded field lines exert a force sideways against each other. Hence there is a repulsive force pushing the wires apart.



21.3 D.C. Motor

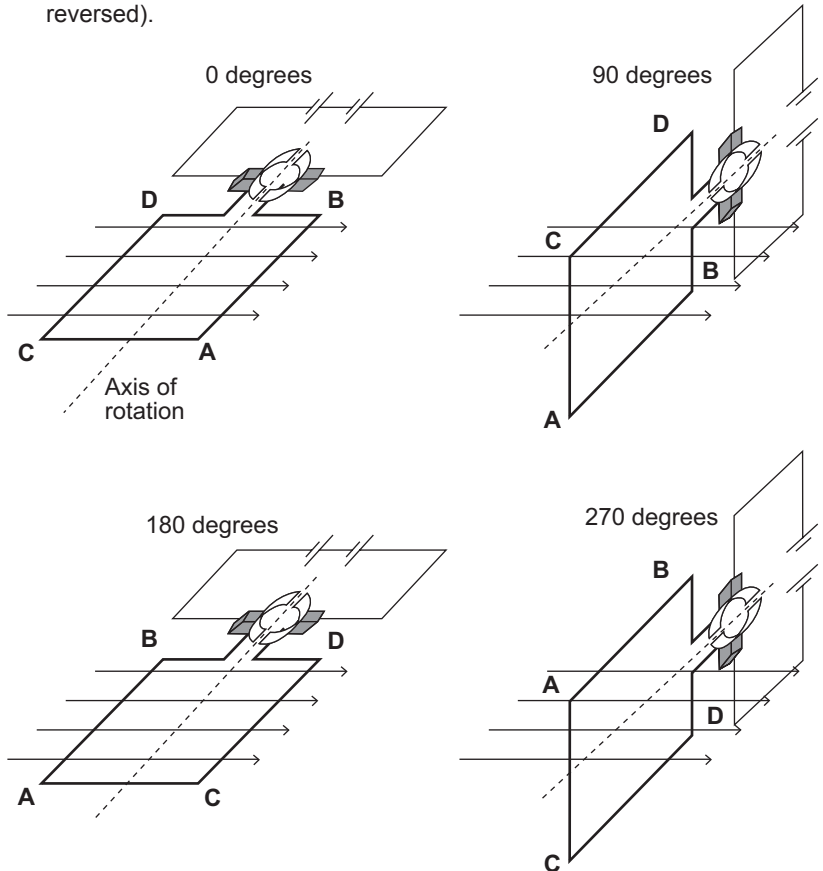
1. The behaviour of a current-carrying conductor in a magnetic field can be applied in electric motors which convert electrical energy into kinetic energy (i.e. fans).
2. The electric motor makes use of the principle that a current carrying coil will experience a turning effect inside a magnetic field.



3.	Features	Role
	Split-ring commutator	The split in the ring allows direction of current to be reversed in the coil to allow the coil to always rotate in one direction.
	Carbon brushes	Carbon (graphite) can conduct electricity and is also a lubricant. It allows the commutator to turn smoothly with minimal friction.

4. Stages of operation
 - (a) The carbon brushes make a connection with the coil every 180° turn for current to flow through the coil. In the 0° diagram, the brushes are in contact with the voltage source.
 - (b) Current through wire segment C-D interacts with the magnetic field resulting in an upward force (left hand rule). Similarly, current that flows through segment A-B produces a downward force. Both forces are of equal magnitude, but opposite directions (currents in different direction). Thus a turning effect about the axis in the middle of the coil is created.

- (c) In the 90° and 270° diagrams, the brushes are not in contact with the voltage source and no force is produced. In these two positions, the rotational kinetic energy of the coil keeps it spinning until the brushes regain contact.
- (d) In the 180° diagram, the same thing occurs, but the force on **A-B** is upwards and force on **C-D** is downwards (direction of currents has reversed).



5. The strength of the turning effect can be increased by:
- Increasing strength of magnetic field (use stronger magnets).
 - Increasing number of turns of wires in the coil.
 - Increasing the area of the coil (Area **ABDC**).
 - Increasing the current.
 - Adding a soft iron core around which the wires are coiled.