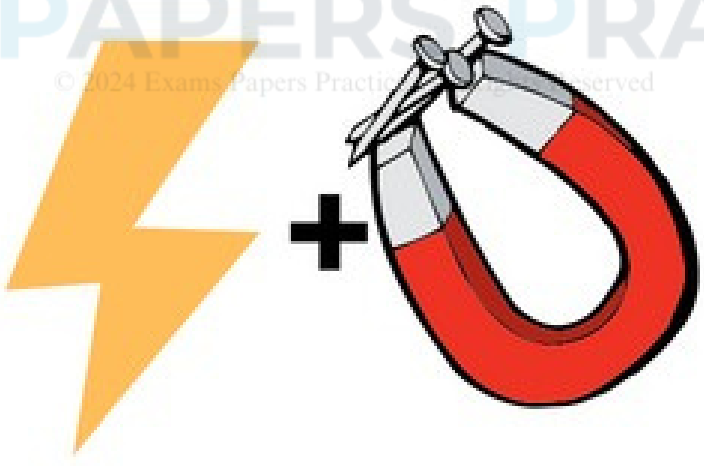
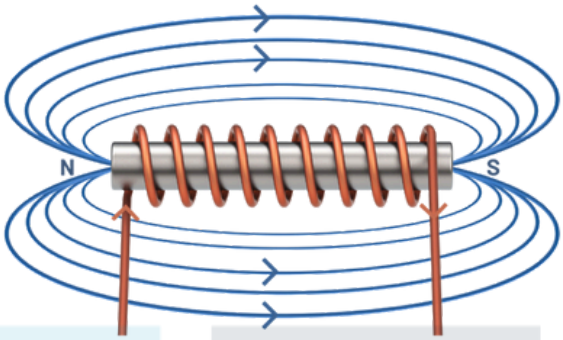
Chapter 20

Electromagnetic Force



20.1 The magnetic effect of current

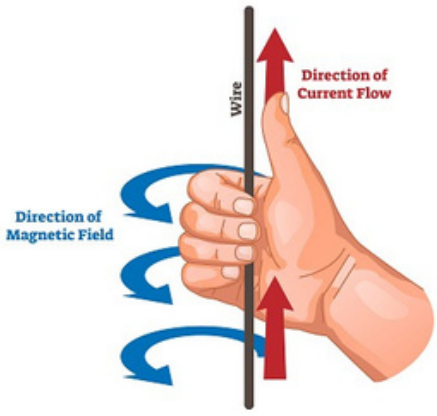
1. In chapter 16, we learned that the flow of current results in a magnetic field around the solenoid.



2. If you uncoil a solenoid, it becomes a straight wire. When current flows through this wire, it generates a magnetic field around it.

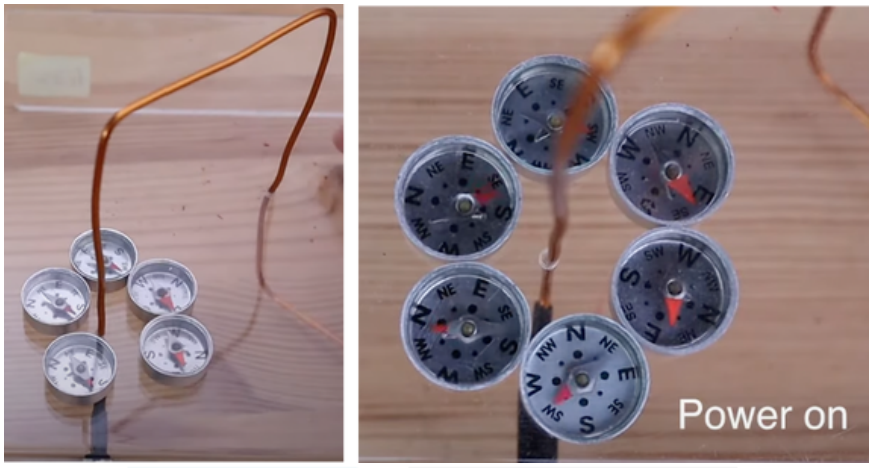
3. Winding the wire into a coil is a way of concentrating the magnetic field.

Right-hand grip rule



The right-hand grip rule helps determine the direction of the magnetic field around a current-carrying conductor, where the thumb points in the direction of the current and the curled fingers indicate the direction of the magnetic field lines.

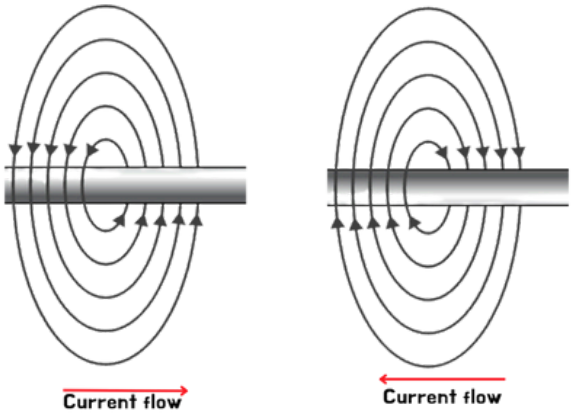
Experiment to investigate the field around a straight wire carrying current



- Arrange plotting compasses around the wire.
- Turn on the power supply and observe the direction in which the plotting compasses point.

Characteristics of the magnetic field produced by the current in the wire

- Further from the wire, the circular field lines are spaced farther apart, indicating a weaker magnetic field.
- If the current increases, the magnetic field strengthens, causing the field lines to be closer together.
- When the current's direction is reversed, the direction of the magnetic field lines also reverses.



Characteristics of the magnetic field produced by the solenoid

- The field lines are densely packed at the poles of the electromagnet.
- Inside the coil, the field lines are parallel, indicating a uniform magnetic field.
- The polarity of the electromagnet reverses when the direction of the current is reversed.

Electromagnetic in action – the relay

1. How it works:
   - When switch A is closed, a small current flows through the coil of the electromagnet.
   - The electromagnet attracts the iron armature. As the armature moves, it pushes the two contacts at B together, thereby completing the second circuit.
   - Note that there is no electrical connection between the two circuits.
2. A relay is used to allow a small current to switch a larger current on and off.

20.2 Force on a current-carrying conductor

1. We know that there is a magnetic field around an electric current.
2. The magnetic field can be attracted or repelled by another magnetic field to produce movement. This is called the motor effect.

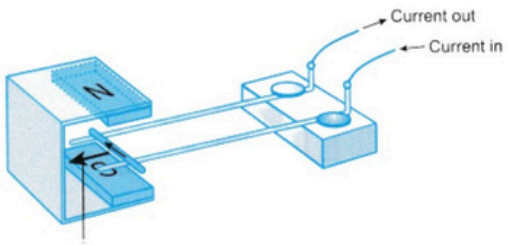
Definition:

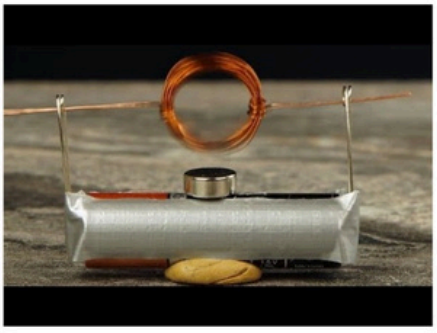
> The motor effect is the phenomenon where a current-carrying conductor experiences a force when placed in a magnetic field, causing it to move.

3. How an electric motor work?
    - An electric motor consists of a coil with a current flowing through it within a magnetic field.
    - It doesn't necessarily have to be a coil; as long as current flows to intersect the magnetic field lines, it works.
    - The motor rotates because the interaction between the magnetic fields generates a force that causes movement.
4. Application of motor effect
    a. Loudspeaker

Experiments to observe the force:

1. Catapult field
2. Rotating coil



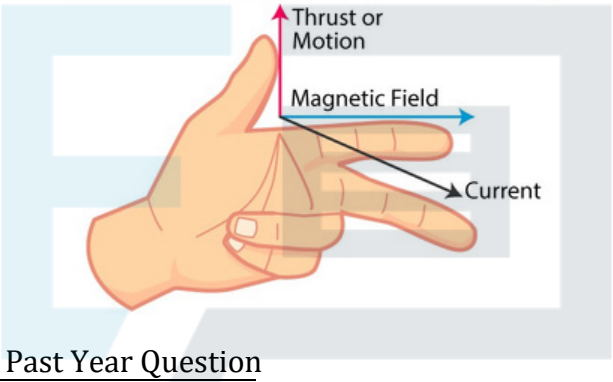


Fleming's left-hand rule

1. Definition

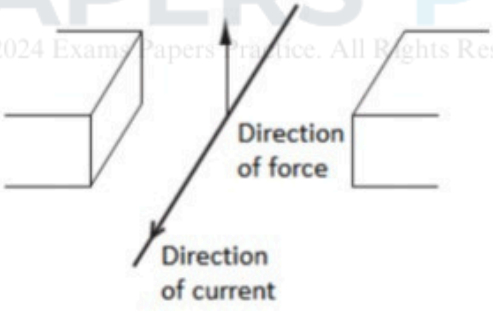
> Fleming's left-hand rule is a mnemonic used to predict the direction of the force experienced by a current-carrying conductor in a magnetic field, where the thumb represents the direction of the force, the first finger indicates the direction of the magnetic field, and the second finger shows the direction of the current.

2. Diagram



Worked Example 2 – Past Year Question

A current-carrying wire is placed between two magnetic poles as shown in the diagram below. It experiences an upwards force.

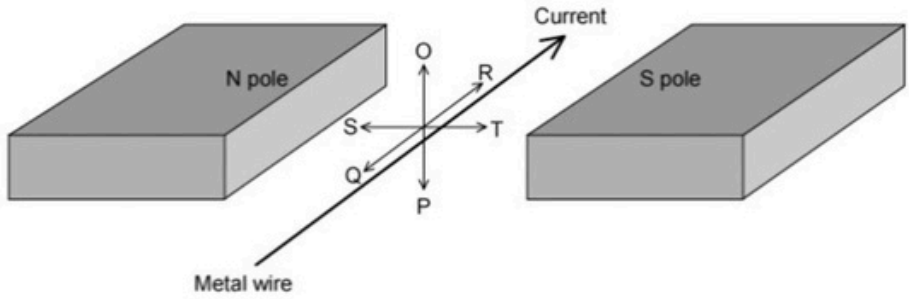


What is the orientation of the magnetic poles?

	left magnet	right magnet
A	N	N
B	S	N
C	N	S
D	S	S

Worked Example 3 – Past Year Question

A current-carrying wire is placed into a magnetic field as shown in the diagram. The wire experiences a force.



In which direction is the force?

A OP

B PO

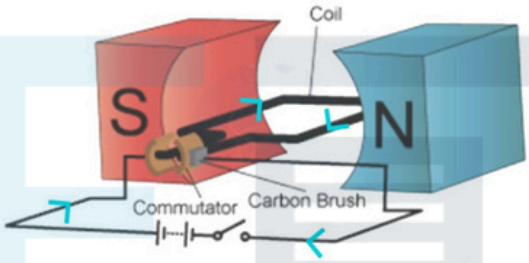
C ST

D QR

20.3 Electric motor

1. The movement produced in the motor effect experiment (Catapult field) is not very practical. The conductor moves out of the field, and the effect ceases.
2. A motor is specifically engineered to harness the motor effect to generate rotational motion.

How is turning effect produced?



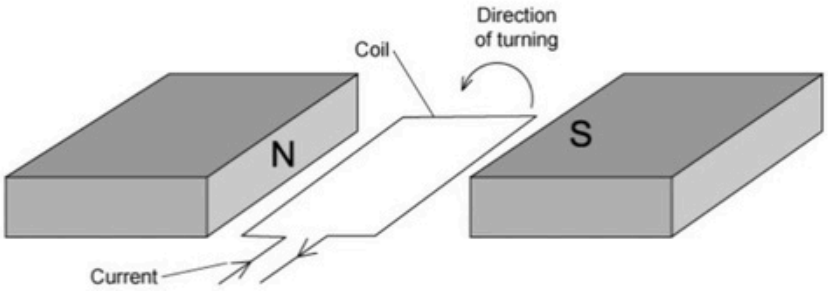
1. Only the two longer sides of the coil experience a force.
2. Using Fleming's left-hand rule:
    a. The force on the left side will be upward.
    b. The force on the right side will be downward.
3. This creates a turning effect, causing clockwise rotation in our case.
4. When the coil is in a vertical position, there is no turning effect. Momentum from the coil's rotation carries it further around.
5. As the coil's momentum carries it around, wires AB and CD exchange positions.
6. Consequently, current always enters from the right and flows counterclockwise around the coil, ensuring the motor continues to rotate in the same direction.

How to increase the turning effect:

1. Increase the number of turns of wire in the coil
2. Increase the current
3. Increase the strength of the magnetic field

Worked Example 4 – Past Year Question

A simple DC electric motor is shown in the diagram.



Which of the following changes would make the coil turn more quickly?

A Reducing the strength of the magnetic field.

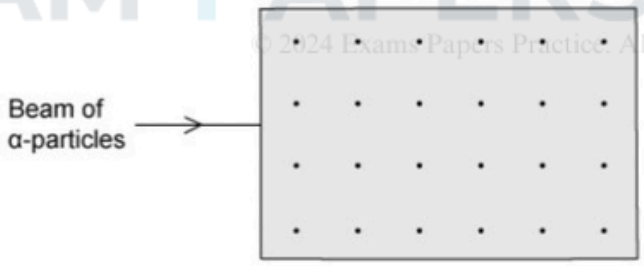
B Reversing the direction of the current AND swapping the magnetic poles

C Swapping the magnetic poles.

D Increasing the current in the coil.

Worked Example 5 – Past Year Question

A magnetic field can be represented by the diagram shown below. The dots represent magnetic field lines coming out of the page:



A beam of alpha particles is directed through the field as shown above. Alpha particles, being charged, will be deflected by the field. In which direction will they be deflected?

A Upwards

B Downwards

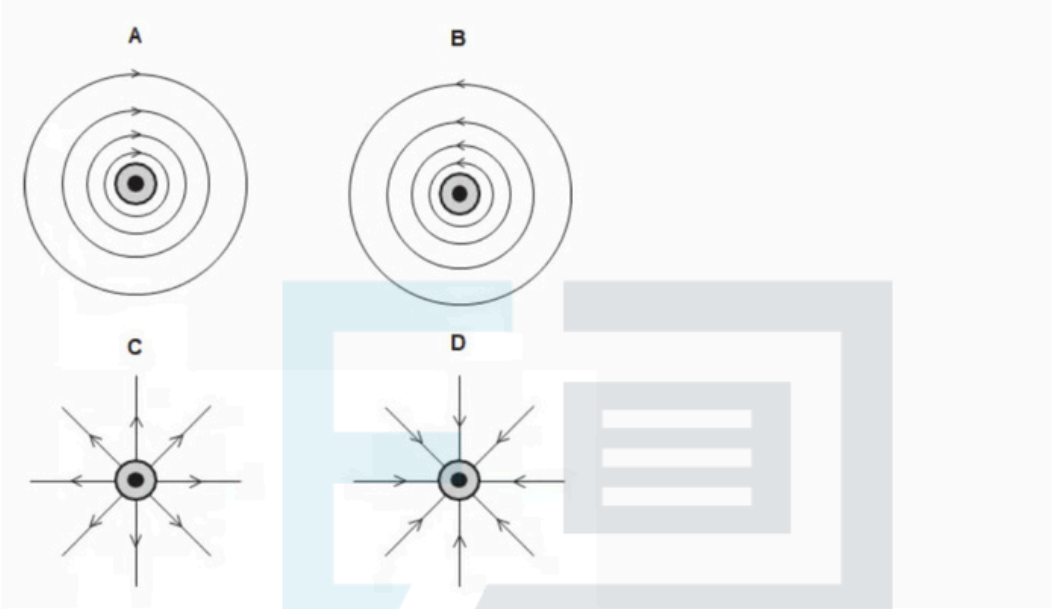
C Into the page

D Out of the page

Worked Example 6 – Past Year Question

Four students are asked to draw the magnetic field pattern of a current-carrying wire. The wire is carrying the current out of the page.

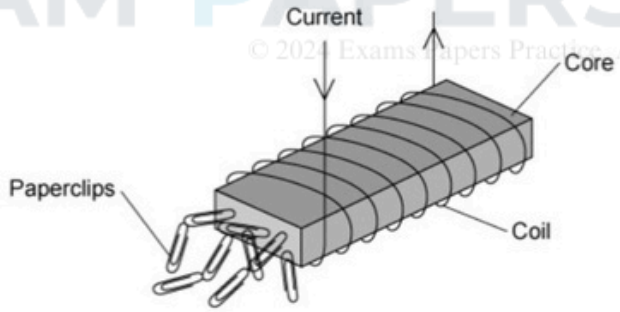
The diagrams they draw are shown below.



Which is correct?

Worked Example 7 – Past Year Question

The diagram below shows an electromagnet. A student wants to find out how strong the magnetic field is by counting the number of metal pins it can pick up.



The experiment is repeated but the current in the coil is doubled. What would happen to the number of pins attracted to the electromagnet?

A More pins would be attracted.

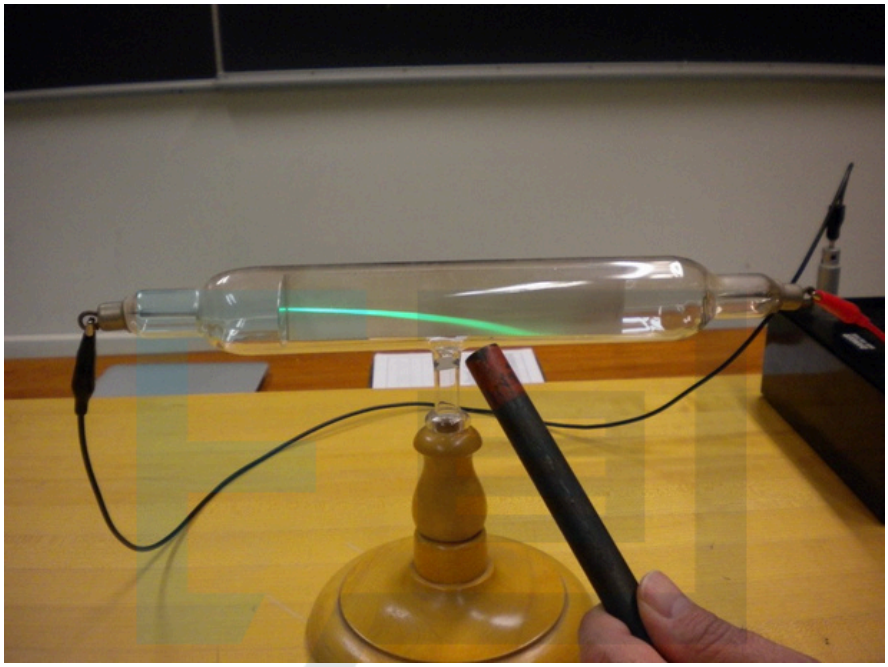
B Some pins would fall off.

C The number of pins would stay the same.

D No pins would be attracted.

20.4 Beams of charged particles and magnetic fields

1. A magnetic field can indeed be utilized to deflect a beam of electrons or any other electrically charged particles.
2. This can be demonstrated in the laboratory using a vacuum tube.

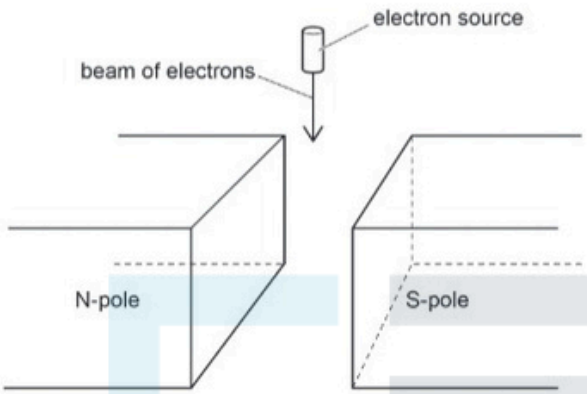


- In the setup described, an electron beam travels from left to right within a vacuum tube.
- A magnet positioned near the beam generates a magnetic field that interacts with the beam's own magnetic field due to its current flow. This interaction produces a force that deflects the electron beam.
- Reversing the polarity of the magnet will reverse the direction of the deflection..

Worked Example 8 – Past Year Questions

An electron source produces a narrow beam of electrons that all travel at the same speed.

The electron source is placed in a vacuum and the beam of electrons travels vertically downwards. The diagram shows the beam of electrons before it passes between the N-pole and the S-pole of a magnet.



(a) Describe what is meant by the direction of a magnetic field. State the direction of the magnetic field between the two poles in the diagram.

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..... [1]

(b) Describe and explain what happens to the beam of electrons in the magnetic field between the poles of the magnet in the diagram.

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..... [3]

[Total: 4]

Question	Answer	Marks
1(a)	the direction of the force on a N-pole **AND** left to right / N to S	**1**
1(b)	beam deflects (1) beam deflects into the page (1) moving electrons / charges constitute a current **OR** left-hand rule **OR** moving electrons / current in a magnetic field experiences a force (1)	**3**

Worked Example 9 – Past Year Questions

The diagram represents a current in a wire. The current is into the plane of the paper.

(a) Draw the pattern of the magnetic field produced around the wire. Show clearly the direction of the magnetic field.

[2]

(b) The direction of the current in the wire is reversed. The magnitude of the current is unchanged.

State the effect that reversing the current has on the magnetic field produced.

Question

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..... [1]

[Total: 3]

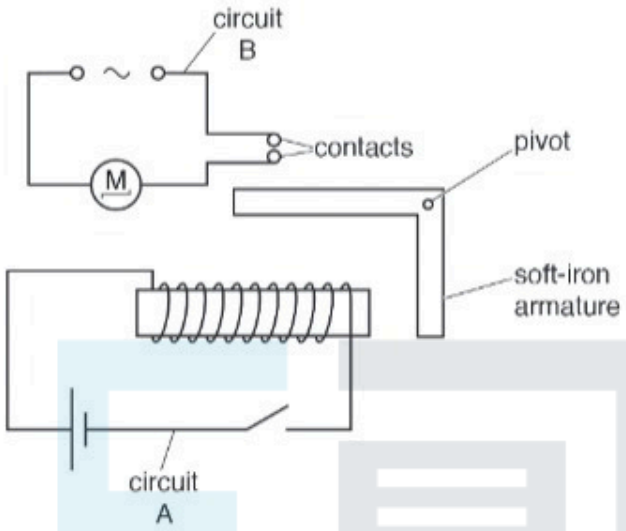
Mark scheme

Question	Answer	Marks
1(a)	at least 3 concentric circles (1) closer together near the wire **AND** clockwise arrow (1)	**2**
1(b)	arrows **or** field reverses / is in opposite direction	**1**

Worked Example 10 – Past Year Questions

The diagram shows a relay.

Question



Circuit A contains a switch that operates the motor in circuit B when it is closed.

The soft-iron armature is replaced with a steel armature. The switch in circuit A is closed.

Explain what happens when the switch in circuit A is then opened.

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..... [2]

[Total: 2]

1	current in circuit B does not stop when switch in circuit A is opened (1) steel remains magnetised when there is no current in the coil (1)	2