Electric motors (HT only)

6.7.2.3 · Physics · revision notes

A coil of wire carrying a current in a magnetic field tends to rotate: this is the basis of an electric motor. You need to explain, using the motor effect and Fleming's left-hand rule, why the coil turns, which way it turns and how it keeps turning. Higher tier only. Expect 'explain' questions from 2 marks up to 6-mark extended answers, usually with a diagram of a simple d.c. motor.

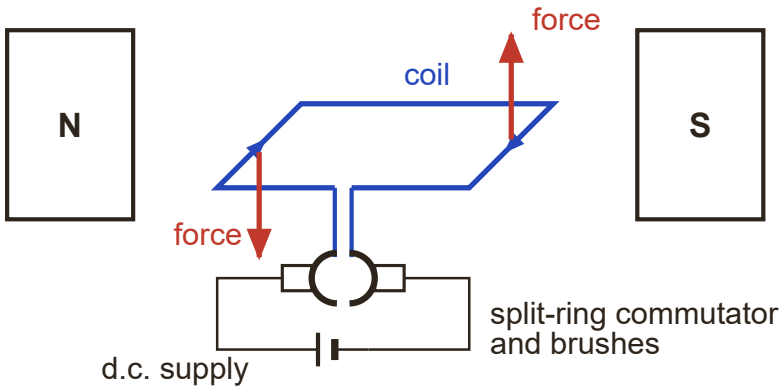
Key facts

- Coil carrying a current in a magnetic field → rotates (the basis of an electric motor)
- Direction of rotation: Fleming's left-hand rule on each side
- Brushes: make contact with the spinning commutator
- Faster: bigger current, stronger magnet, more turns
- Current in opposite directions in the two sides → forces in opposite directions → rotation
- Split-ring commutator: reverses the current in the coil every half turn
- Reverse the rotation: reverse the current or reverse the field

Notes

Why the coil turns

- A simple d.c. motor has a rectangular coil of wire on an axle, between the poles of a magnet.
- The current goes one way along one side of the coil and the **opposite way** along the other side.
- By the motor effect, each side has a force on it. The forces are in **opposite directions** (one up, one down), on opposite sides of the axle, so the coil **rotates**.



Opposite currents in the two sides give opposite forces (red), so the coil turns.

- Use Fleming's left-hand rule on each side to find the direction of rotation.
- A side of the coil that is parallel to the field lines (e.g. the short end side when the coil is horizontal) has no force on it.

Keeping it turning: the split-ring commutator Grade 7+ only

- Without a commutator, the coil would only turn until it was vertical. Past that point the forces would push it back, so it would rock and then stop instead of spinning.
- The **split-ring commutator** is a ring split into two halves, one joined to each end of the coil. Two **brushes** press against it to carry the current in and out.
- Every half turn, the commutator swaps which end of the coil is connected to each brush. This **reverses the current in the coil**.
- So the side of the coil nearer the north pole always has current in the same direction, and the coil keeps turning the same way.
- When the coil is vertical, the brushes touch the gaps in the commutator, so there is no current, no force and no turning effect. The coil's momentum carries it past this point, which is when the current reverses. Grade 8+ only

Changing the motor

- To **reverse** the direction of rotation: reverse the current (swap the connections to the supply) or reverse the magnetic field (swap the poles).
- To make it turn **faster** (bigger forces): increase the current, use a stronger magnet, or use more turns of wire on the coil.

How to answer each type of question

Explain why the coil of a motor rotates

2 to 3 marks | **Grade 6**

1. Say each side of the coil is a current-carrying wire in a magnetic field, so it has a force on it (motor effect).
2. Say the current is in opposite directions in the two sides.
3. So the forces are in opposite directions, and the coil turns.

Example. A simple electric motor has a rectangular coil between the poles of a magnet. The coil is horizontal and there is a current in it.
Explain why the coil starts to rotate. [3 marks]

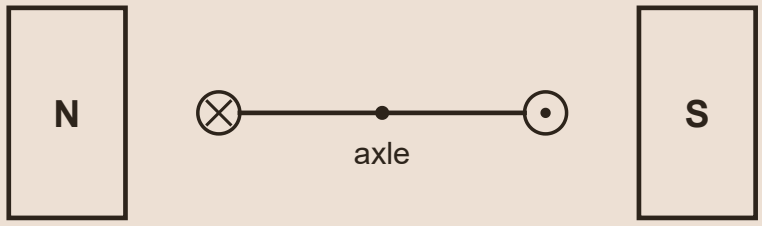
Model answer. Each side of the coil is a current-carrying conductor in a magnetic field, so it has a force on it (the motor effect) (1). The current is in opposite directions in the two sides (1), so the forces are in opposite directions (one up, one down), which makes the coil turn (1).

Use Fleming's left-hand rule to find the direction of rotation

2 to 3 marks | **Grade 6**

1. Mark the field direction from N to S.
2. Use the left-hand rule on one side of the coil to find its force, then on the other side (it will be opposite).
3. Decide whether this turns the coil clockwise or anticlockwise.

Example. A motor coil is viewed from one end of its axle. The coil is horizontal. The north pole of the magnet is on the left and the south pole is on the right. The current is into the page in the left-hand side of the coil, and out of the page in the right-hand side.



Explain which way the coil starts to turn. [3 marks]

Model answer. The field is from left to right (N to S) (1). By Fleming's left-hand rule, the force on the left-hand side is downwards and the force on the right-hand side is upwards (1). So the coil turns anticlockwise (1).

State how to change the speed or direction of a motor

1 to 3 marks | Grade 6

1. Faster: bigger current, stronger magnet, more turns on the coil.
2. Opposite direction: reverse the current, or reverse the magnetic field. Not both.

Example. (a) Give two changes that would make a simple d.c. motor spin faster. [2 marks]
(b) State one change that would make the motor spin in the opposite direction. [1 mark]

Model answer.

(a) Any two, 1 mark each: increase the current (or the potential difference); use a stronger magnet; use a coil with more turns.

(b) Reverse the current (swap the connections) or reverse the magnetic field (swap the poles) (1).

6-mark: explain how a d.c. motor keeps turning

6 marks | Grade 8

1. Start with the motor effect: each side of the coil has a force on it.
2. Explain why the forces are opposite and make the coil turn.
3. Explain what the split-ring commutator does and when (every half turn).
4. Link it back: so the coil keeps turning in the same direction.
5. Write in full sentences and in a logical order: the whole answer is marked for its quality, not just point by point.

Example. A simple d.c. motor has a coil between the poles of a magnet. The coil is connected to a d.c. supply through a split-ring commutator and brushes.
Explain how the motor produces continuous rotation in one direction. [6 marks]

Model answer. A top-level answer includes most of these points in a logical order: there is a current in the coil, which is in the magnetic field of the magnet; each side of the coil at right angles to the field has a force on it (the motor effect); the current is in opposite directions in the two sides, so the forces are in opposite directions (Fleming's left-hand rule); the forces act on opposite sides of the axle, so the coil turns; when the coil is vertical there is no turning effect, but its momentum carries it on; the split-ring commutator reverses the current in the coil every half turn; so the forces keep turning the coil the same way.

Don’t lose marks

- Saying the commutator reverses the direction of rotation: it keeps the rotation in the same direction by reversing the current.
- Saying the commutator reverses the current every full turn: it is every half turn.
- Saying the magnet 'attracts' the coil: the force is the motor effect on the current in the coil.
- Forgetting that the currents in the two sides of the coil are in opposite directions.
- Writing 'a bigger magnet' instead of 'a stronger magnet'.

More tips

Memory tricks

- A motor is two motor-effect wires side by side: opposite currents, opposite forces, rotation.
- The commutator swaps the connections every half turn: think 'commute = switch'.
- Faster motor: more Current, more Magnet strength, more turns.

Exam technique

- Use the key phrases: 'motor effect', 'current in opposite directions', 'forces in opposite directions', 'rotates' and 'every half turn'.
- If a diagram shows the current, state the direction of rotation (clockwise or anticlockwise) and say you used Fleming's left-hand rule.
- Refer to 'the coil', 'the current' and 'the magnetic field' rather than 'it'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 — **State that a coil carrying current rotates**
A coil of wire carrying a current in a magnetic field tends to rotate.

Grade 5 — **Explain why the coil's sides feel opposite forces**
The current is in opposite directions in the two sides, so the forces on them are in opposite directions.

Grade 6 — **Describe how to reverse or speed up motors**
Reverse the current or the field to reverse it; increase the current, field strength or number of turns to speed it up.

Grade 6 — **Find which way a motor coil turns**
Use Fleming's left-hand rule on each side of the coil to find the forces, then decide clockwise or anticlockwise.

Grade 7 — **Explain the role of the split-ring commutator**
It reverses the current in the coil every half turn, so the coil keeps turning in the same direction.

Grade 8 — **Explain why the coil keeps turning past vertical**
When the coil is vertical the forces give no turning effect, but its momentum carries it past, just as the commutator reverses the current.

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