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GRADE 10 / SCIENCE

Chapter 12

Magnetic Effects of Electric Current



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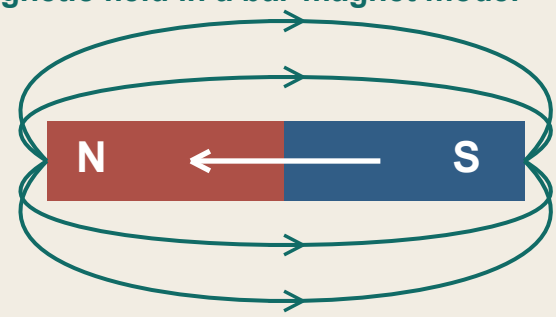
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Magnetic Effects of Electric Current

Magnetic fields and compasses

A small compass turns to align with the local magnetic field. Its north-seeking end indicates the field direction when other fields are negligible.

Direction of the magnetic field in a bar-magnet model



Outside: N to S. Inside: S to N.

Outside and inside

Outside a bar magnet, field lines run from N to S. Inside the magnet they return from S to N, forming continuous loops.

Field strength

On a consistently drawn field map, more closely spaced lines represent a stronger field. Lines do not cross at a point with a well-defined field direction.

WORKED EXAMPLE

Place a compass just beyond the north pole on the magnet's axis. Which way does its north tip point?

Away from the north pole, along the outward field there. Near the south pole, an outside field points towards the magnet.

SELF-CHECK

Do field lines end where the drawing stops?

No. The drawing shows a limited region. The magnetic field continues beyond its edges.

Field around a current

Look straight at the end of a long current-carrying wire. The magnetic field forms circles around the wire in planes perpendicular to the wire.



Circular field pattern | Compass detects direction | Current needs a closed path



Right thumb → conventional current • Curled fingers → magnetic field

End-on view of a straight wire

Dot • towards you

Point the right thumb out of the page. The fingers curl anticlockwise as viewed by you. At the top of the circle the field points left.

Cross • away from you

Point the right thumb into the page. The fingers curl clockwise. At the top of the circle the field points right.

Distance

For a long straight wire at fixed current, field strength decreases as 1/r. Doubling the distance halves the field strength.

Current

At a fixed distance the field strength is proportional to current. Reversing the current reverses circulation.

WORKED EXAMPLE

At 2 cm from a long wire the field is 40 μT. What is it at 4 cm for the same current?

$B_2 = B_1 \times r_1/r_2 = 40 \times 2/4 = 20$ μT. The field direction continues to follow the right-hand rule.

SELF-CHECK

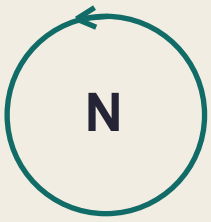
On the right side of a wire carrying current towards you, which way does the field point?

Upwards on the page. Follow the anticlockwise tangent at the right edge of the circle.

Magnetic Effects of Electric Current

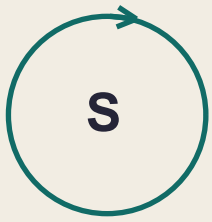
Loops and solenoids

The field near the centre of a current loop points along the loop's axis. Many turns reinforce one another inside a long solenoid.



Anticlockwise

North • field towards you



Clockwise

South • field away from you

Choose a viewpoint

Face one end of the coil. Anticlockwise conventional current makes that end north. Clockwise current makes that end south.

Field strength

For an ideal long air-core solenoid, $B \approx \mu_0(N/\ell)I$. Here N/ℓ is turns per metre. The field is nearly uniform far from the ends. A suitable iron core can strengthen it.

WORKED EXAMPLE

A long air-core coil has 600 turns over 0.30 m and carries 0.50 A. Estimate its internal field.

$N/\ell = 2{,}000\ m^{-1}$. $B \approx (4\pi \times 10^{-7}) \times 2{,}000 \times 0.50 = 1.26 \times 10^{-3}$ T, or 1.26 mT.

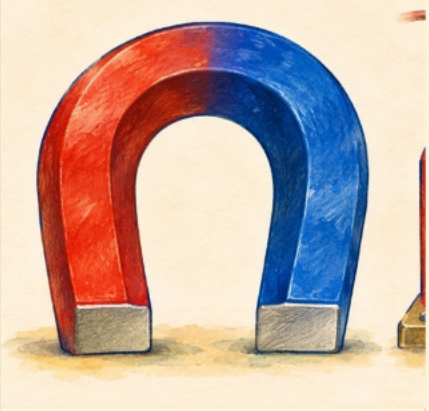
SELF-CHECK

A second air-core coil has 400 turns over 0.20 m and carries 0.25 A. Current is clockwise viewed from the right. What is its field and north end?

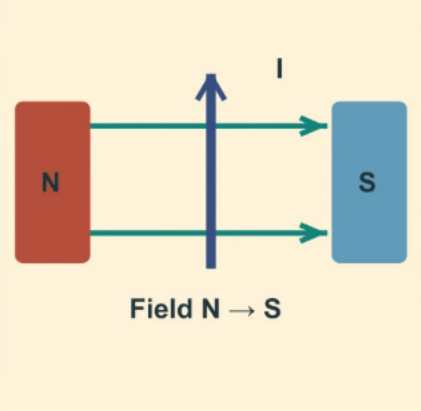
$B \approx (4\pi \times 10^{-7}) \times 2{,}000 \times 0.25 = 6.28 \times 10^{-4}$ T. The right face is south, so the left face is north.

Force on a conductor

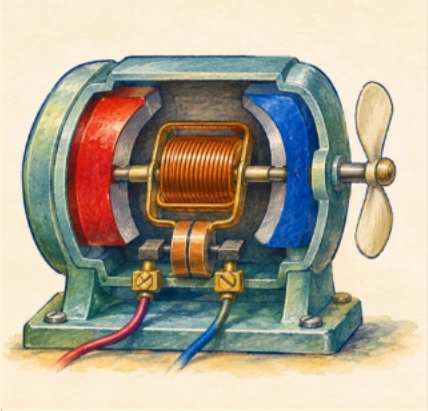
A current-carrying wire in an external magnetic field can feel a force. A non-zero magnetic force is perpendicular to both current and field.



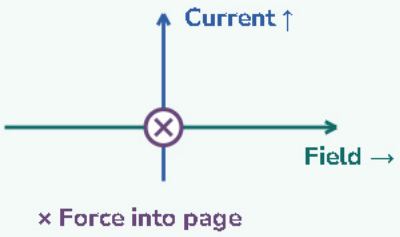
Magnetic poles



Wire perpendicular to field



Motor application



Force magnitude $F = BIL \sin\theta$ •
Perpendicular wire: $F = BIL$
Current upwards, field to the right

First finger

Fleming's left-hand rule: point the first finger along the external magnetic field, from the N pole towards the S pole in the gap.

Middle finger

Point it along conventional current. With the three digits mutually perpendicular, the thumb gives the force direction.

Angle and length

L is the length of straight wire inside the uniform field. θ is the angle between the current and the magnetic field. Force is greatest at 90° and zero at 0° or 180°.

Reversals

Reversing the current alone reverses the force. Reversing both the current and the field leaves the force direction unchanged.

WORKED EXAMPLE

A 0.20 m wire carries 5.0 A upwards in a uniform 0.40 T field to the right. Find the force.

The directions are perpendicular. $F = 0.40 \times 5.0 \times 0.20 = 0.40$ N. Fleming's rule gives a force into the page.

SELF-CHECK

A 0.50 m wire carries 2.0 A downwards in a 0.30 T field to the right. Find size and direction.

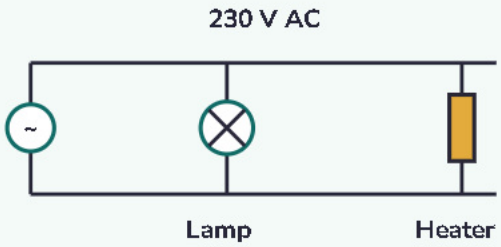
$F = 0.30 \times 2.0 \times 0.50 = 0.30$ N. The force points out of the page.

Domestic electrical safety

Household appliances use parallel branches. Each branch has the full supply voltage, while the main circuit carries the sum of the branch currents.



Lighting load	Heating load	Overcurrent protection



For a resistive load: $I = P/V$ • Parallel branch currents add.

Each load is connected across the same 230 V supply.

Overload	Several appliances together can draw more current than the circuit is designed to carry. Wires can overheat.
Short circuit	An unintended low-resistance path can cause a very large current. A fuse or circuit breaker provides overcurrent protection.
Earthing	A protective earth connection provides a low-impedance fault path for exposed metal parts and helps suitable protection disconnect the supply.
What the rating tells you	Comparing load current with a breaker rating checks one condition only. It cannot establish the safety of wiring, insulation or earthing.

WORKED EXAMPLE

A 60 W lamp and a 75 W resistive load share a 230 V supply. Compare their total current with 5 A.

Total power = 135 W. Current = 135/230 ≈ 0.59 A, below 5 A. This checks the stated load only.

SELF-CHECK

A 1,500 W heater and a 100 W lamp use 230 V on a 10 A circuit. Assume resistive loads. Find the total.

$I = (1{,}500 + 100)/230 \approx 6.96$ A. This operating current is below the 10 A rating.

ONE LAST CHALLENGE

What flips when current reverses?

A compass sits beside a straight wire. Reverse the current while keeping its size the same. What happens to the wire's magnetic field?



THE REVEAL

Same strength. Opposite direction.

At the same distance the field strength stays the same. Reverse your right thumb and your fingers curl the other way.

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