Exercise walk-through

Magnetic fields due to currents ▪ 20.4

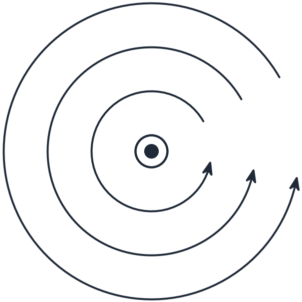
eXercise

You must be able to

- sketch the field of a straight wire, a coil and a **solenoid**
- explain the **force between parallel currents**

Method — Field around a wire

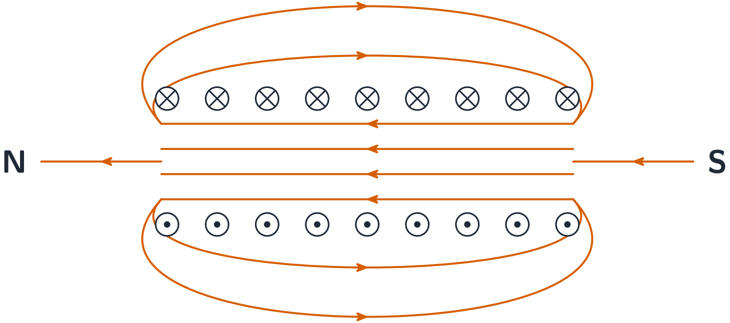
A current in a long straight wire makes **concentric circular** field lines (use the **right-hand grip rule**):
A **solenoid** makes a field like a bar magnet (uniform inside); adding a **ferrous (iron) core** makes it much stronger.



current out of page

Method — Field around a wire

field nearly uniform inside, spreads out like a bar magnet outside



The magnetic field of a solenoid

Method — Force between parallel currents

Each wire sits in the other's field. By Fleming's left-hand rule:

- currents in the **same** direction $\rightarrow$ **attract**;
- currents in **opposite** directions $\rightarrow$ **repel**.

Practice 2.1 ▪ 3 marks

A long straight wire carries a current **into** the page. In the space below, sketch the magnetic field pattern in the plane of the page, marking the **direction** of the field. State what happens to the pattern when the current is **reversed**.

Solution 2.1

Method: Field around a wire

Worked steps

Concentric circles centred on the wire, drawn further apart as the distance grows B1, with arrows **clockwise** when the current goes into the page (right-hand grip rule) B1. Reversing the current keeps the same circles but reverses every arrow, to anticlockwise B1.

Practice 2.2 ▪ 1 mark

State **one** way to make a **solenoid's** field stronger.

Solution 2.2

Method: Field around a wire

Worked steps

Any one: add a **ferrous/iron core**; increase the **current**; increase the **number of turns** B1.

Practice 2.3 ▪ 1 mark

State whether two parallel currents in the **same** direction attract or repel.

Solution 2.3

Method: Force between parallel currents

Worked steps

They **attract** **B1**.

Exam-style 3.1 ▪ 1 mark

Two parallel wires carry currents in the **same** direction. They:

A attract

B repel

C feel no force

D rotate

Solution 3.1

Method: Force between parallel currents

A attract ✓

B repel

C feel no force

D rotate

Worked steps

A — attract.

Exam-style 3.2 ▪ 2 marks

Sketch the magnetic field pattern around a long straight current-carrying wire.

Solution 3.2

Method: Field around a wire

Worked steps

Concentric circles centred on the wire B1; closer together near the wire, with a direction (arrow) shown B1.

Exam-style 3.3 ▪ 2 marks

Explain why two **antiparallel** currents (opposite directions) **repel**.

Solution 3.3

Method: Force between parallel currents

Worked steps

Each wire lies in the other's magnetic field and feels a force ($F = BIL$) B1; for opposite-direction currents Fleming's left-hand rule gives forces pushing the wires **apart** (repulsion) B1.

Exam-style 3.4 ▪ 2 marks

A long solenoid of length 0.35 m has 700 turns and carries a current of 2.4 A. A long straight wire runs parallel to its axis some distance away.

(a) **State** the shape of the magnetic field **inside** a long solenoid, away from its ends.

(b) In the space below, **draw** the field pattern of a long straight wire carrying a current **out of** the page, showing at least three field lines and their direction.

(c) **State** two ways of increasing the flux density inside the solenoid **without** changing its current.

(d) A small coil of 50 turns and cross-sectional area 1.8×10^{-4} m^2 is placed at the centre of the solenoid, with its plane perpendicular to the axis. The flux density there is 6.0×10^{-3} T. **Determine** the magnetic flux linkage of the small coil.

(e) The current in the solenoid is switched off, falling to zero in 0.020 s. **Determine** the average e.m.f. induced in the small coil.

Solution 3.4

Method: Field around a wire

Worked steps

(a) The field inside is **uniform**: straight lines parallel to the axis, evenly spaced B1, running from the south end to the north end **inside** the solenoid B1.
(b) At least three **concentric circles** centred on the wire B1, spaced further apart as the distance grows B1, with arrows **anticlockwise** for a current out of the page B1.
(c) Any two: increase the **number of turns per unit length**; insert a **soft-iron core**; wind the turns closer together over a shorter length B1 B1.
(d) Flux through one turn $= BA = 6.0 \times 10^{-3} \times 1.8 \times 10^{-4} = 1.08 \times 10^{-6}$ Wb M1 M1; flux **linkage** $= N\Phi = 50 \times 1.08 \times 10^{-6} = 5.4 \times 10^{-5}$ Wb A1.

Solution 3.4

(e) $\varepsilon = \dfrac{\Delta(N\Phi)}{\Delta t} = \dfrac{5.4 \times 10^{-5}}{0.020}$ M1 $= 2.7 \times 10^{-3}$ V A1. (The linkage falls to zero, so the whole of it is the change.)