A-LEVEL PHYSICS • EXERCISE SHEET

20.4 Magnetic fields due to currents

Name: ______________ Class: __________ Date: ____________ **Total: 22 marks**

KEY WORDS solenoid 螺线管 • iron core 铁芯 • coil 线圈 • current 电流 • magnetic field 磁场

Objective

Build the skills to answer exam questions on **magnetic fields due to currents** and the force between currents.

You must be able to:

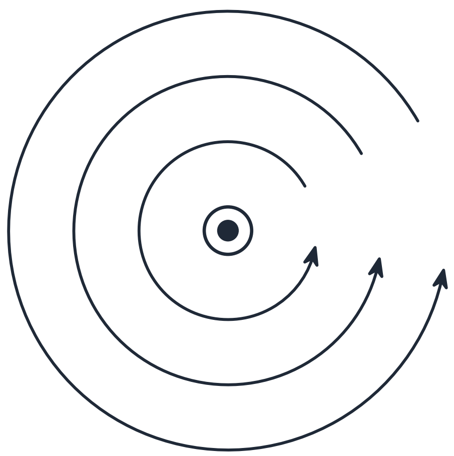
- sketch the field of a straight wire, a coil and a **solenoid**
- explain the **force between parallel currents**

1 Worked examples

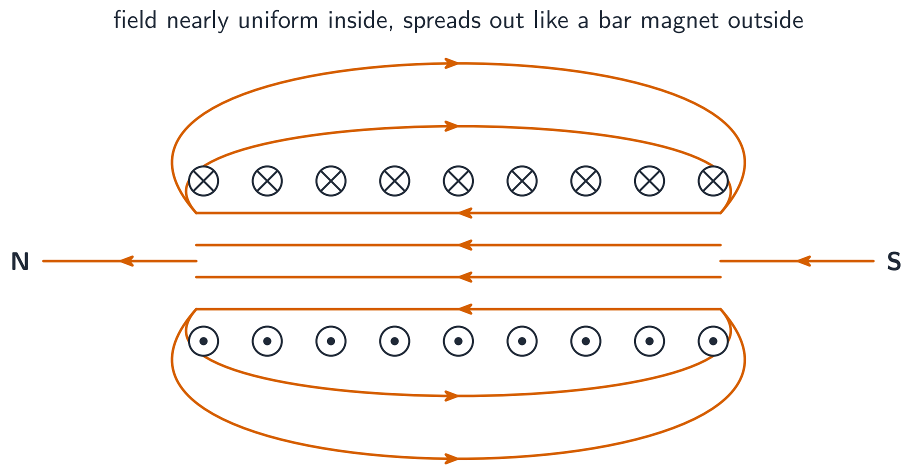
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Field around a wire

A current in a long straight wire makes **concentric circular** field lines (use the **right-hand grip rule**):



current out of page



The magnetic field of a solenoid

A **solenoid** makes a field like a bar magnet (uniform inside); adding a **ferrous (iron) core** makes it much stronger.

■ Force between parallel currents

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

- currents in the **same** direction → **attract**;
- currents in **opposite** directions → **repel**.

2 Practice

Now apply the methods above.

2.1 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**. [3]

2.2 State **one** way to make a **solenoid's** field stronger. [1]

2.3 State whether two parallel currents in the **same** direction attract or repel. [1]

3 Exam-style questions

3.1 Two parallel wires carry currents in the **same** direction. They: [1]

- **A** attract
- **B** repel
- **C** feel no force
- **D** rotate

3.2 Sketch the magnetic field pattern around a long straight current-carrying wire. [2]

3.3 Explain why two **antiparallel** currents (opposite directions) **repel**. [2]

3.4 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. [2]

(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. [3]

(c) **State** two ways of increasing the flux density inside the solenoid **without** changing its current. [2]

(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. [3]

(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. [2]

Solutions

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

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

2.3 They **attract**.

3.1 A — attract.

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

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

3.4 (a) The field inside is **uniform**: straight lines parallel to the axis, evenly spaced, running from the south end to the north end **inside** the solenoid.
(b) At least three **concentric circles** centred on the wire, spaced further apart as the distance grows, with arrows **anticlockwise** for a current out of the page.
(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.
(d) Flux through one turn $= BA = 6.0 \times 10^{-3} \times 1.8 \times 10^{-4} = 1.08 \times 10^{-6}$ Wb; flux **linkage** $= N\Phi = 50 \times 1.08 \times 10^{-6} = 5.4 \times 10^{-5}$ Wb.
(e) $\varepsilon = \dfrac{\Delta(N\Phi)}{\Delta t} = \dfrac{5.4 \times 10^{-5}}{0.020} = 2.7 \times 10^{-3}$ V. (The linkage falls to zero, so the whole of it is the change.)