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:

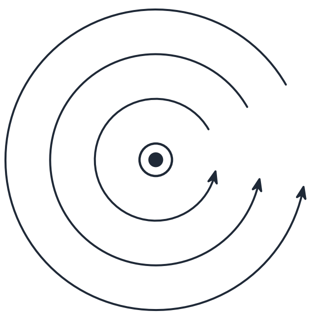
- sketch the field of a straight wire, a coil and a **solenoid**
- explain the **force between parallel currents**

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.

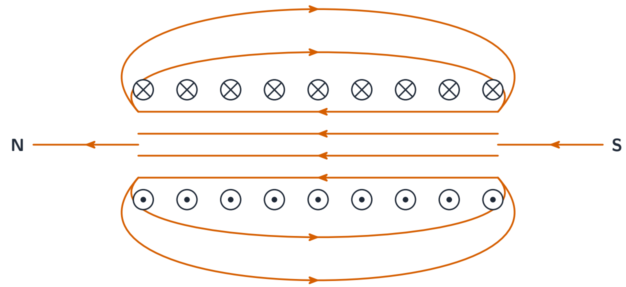
Field around a wire

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



current out of page

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



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

Each answer shows the steps, then the **result**.

2.1

- **concentric circles** centred on the wire, drawn further apart as the distance grows
- 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

- parallel currents in the same direction **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
- 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 $= BA$

$$\Phi = (6.0 \times 10^{-3}\ \mathrm{T})(1.8 \times 10^{-4}\ \mathrm{m}^2) = 1.08 \times 10^{-6}\ \mathrm{Wb}$$

- flux **linkage** $= N\Phi$

$$N\Phi = 50 \times 1.08 \times 10^{-6}\ \mathrm{Wb} = \mathbf{5.4 \times 10^{-5}}\ \mathrm{Wb}$$

(e) $\varepsilon = \Delta(N\Phi)/\Delta t$

$$\varepsilon = \frac{5.4 \times 10^{-5}\ \mathrm{Wb}}{0.020\ \mathrm{s}} = \mathbf{2.7 \times 10^{-3}}\ \mathrm{V}$$

- the linkage falls to zero, so the whole of it is the change