A-LEVEL PHYSICS • EXERCISE SHEET

20.1 Concept of a magnetic field

Name: ____________ Class: ________ Date: __________ **Total: 20 marks**

KEY WORDS magnetic field 磁场 • field line 场线 • force 力 • bar magnet 条形磁铁 • permanent magnet 永磁体

Objective

Build the skills to answer exam questions on the **magnetic field** — its sources and field lines.

You must be able to:

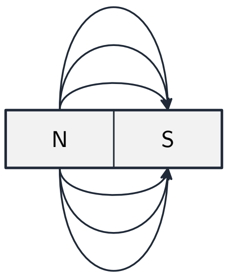
- state what produces a magnetic field
- represent a magnetic field with **field lines**

1 Worked examples

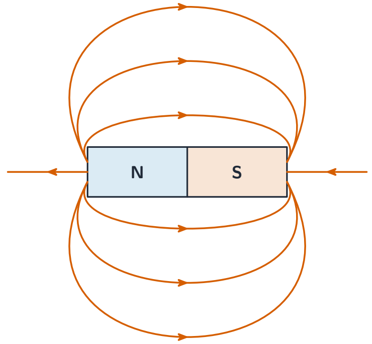
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Magnetic fields

A **magnetic field** is a region where a moving charge or current feels a force. It is produced by **moving charges (currents)** or **permanent magnets**.



field lines run from **N** to **S** outside the magnet



The field of a bar magnet

- field lines run **N to S** outside a magnet (closed loops);
- they **never cross**; **closer lines** → **stronger field**.

2 Practice

Now apply the methods above.

2.1 State **two** things that can produce a magnetic field. [1]

2.2 State the direction of the field lines **outside** a bar magnet. [1]

2.3 State what **closer** field lines indicate. [1]

3 Exam-style questions

3.1 Magnetic field lines **outside** a bar magnet point from: [1]

- **A** S to N
- **B** N to S
- **C** N to N
- **D** nowhere

3.2 Sketch the magnetic field lines around a bar magnet. [2]

3.3 State **two** ways a magnetic field can be produced. [2]

3.4 A long, straight vertical wire carries a current of 5.0 A **into** the page. A second parallel wire, 0.040 m away, carries 3.0 A in the **same** direction. The flux density produced by the first wire at the position of the second is 2.5×10^{-5} T.

(a) **State** what is meant by a **magnetic field**. [2]

(b) In the space below, **draw** four field lines to represent the magnetic field around the first wire, and **mark** the direction of the field. [3]

(c) **Calculate** the magnetic force per unit length exerted on the second wire. [2]

(d) **State**, with a reason, the direction of that force. [2]

(e) The flux density produced by the **second** wire at the position of the first is 1.5×10^{-5} T. **Determine** the force per unit length on the first wire, and **explain** your reasoning. [3]

Solutions

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

2.1

- **moving charges (currents)** and **permanent magnets**

2.2

- from **N to S**

2.3

- a **stronger** magnetic field

3.1 B

- outside a magnet, field lines run **N to S**

3.2

- curved lines from **N to S** outside the magnet
- closer together near the **poles**

3.3

- a **current** (moving charges) in a wire
- a **permanent magnet**

3.4

(a) a region in which a **force** is experienced by a moving charge, a current-carrying conductor or a magnetic pole

(b) four **concentric circles** centred on the wire

- drawn with the spacing **increasing** with distance, because the field weakens as $1/r$
- arrows **clockwise**, from the right-hand grip rule with the current into the page

(c) $F/L = BI$

$$\frac{F}{L} = (2.5 \times 10^{-5}\ \mathrm{T})(3.0\ \mathrm{A}) = \mathbf{7.5 \times 10^{-5}}\ \mathrm{N\ m^{-1}}$$

(d) the force is **towards** the first wire, i.e. the two wires **attract**

- currents in the same direction attract; applying the left-hand rule with the field of one wire and the current in the other gives a force pointing along the line joining them

(e) by **Newton's third law** the forces on the two wires are equal in magnitude and opposite in direction

- so the force per unit length on the first wire is also 7.5×10^{-5} N m^{-1}
- check: $BI = (1.5 \times 10^{-5}\ \mathrm{T})(5.0\ \mathrm{A}) = 7.5 \times 10^{-5}\ \mathrm{N\ m^{-1}}$ — a smaller field acting on a larger current gives the same product