A-LEVEL PHYSICS • EXERCISE SHEET

20.2 Force on a current-carrying conductor

Name: ______________ Class: _________ Date: ___________ **Total: 23 marks**

KEY WORDS magnetic flux density 磁通密度 • magnetic flux 磁通量 • fleming's left-hand rule 弗莱明左手定则 • magnetic field 磁场 • tesla 特斯拉

Objective

Build the skills to answer exam questions on the **force on a current-carrying conductor**.

You must be able to:

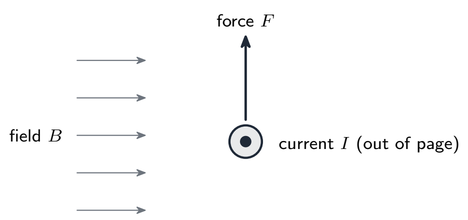
- use $F = BIL\sin\theta$ and **Fleming's left-hand rule**
- define **magnetic flux density**

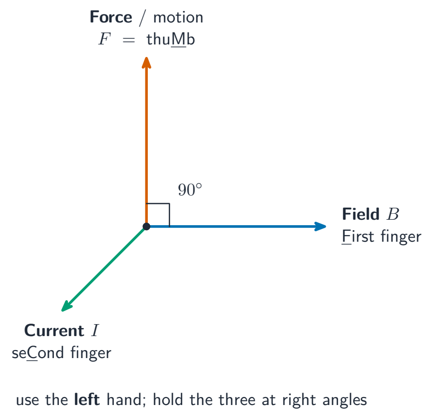
1 Worked examples

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.

■ The motor effect

A current in a wire in a magnetic field feels a force, perpendicular to both:





Fleming left-hand rule for the motor force

$$F = BIL\sin\theta,$$

where θ is the angle between wire and field. The force is **maximum** at 90° ($F = BIL$) and **zero** when the wire is along the field. **Fleming's left-hand rule:** thuMb = Motion/force, First finger = Field, seCond finger = Current.

Magnetic flux density B is defined as the **force per unit current per unit length** on a wire at right angles to the field (unit: **tesla**, T).

Worked example. 0.20 m wire, 3.0 A, $B = 0.50$ T at 90°: $F = BIL = 0.50 \times 3.0 \times 0.20 = 0.30$ N.

2 Practice

Now apply the methods above.

2.1 Write $F = BIL\sin\theta$ and state what each symbol means. [2]

2.2 A 0.20 m wire carries 3.0 A at right angles to a 0.50 T field. Find the **force**. [2]

2.3 Define **magnetic flux density**. [1]

2.4 State the three quantities in **Fleming's left-hand rule**. [1]

3 Exam-style questions

3.1 The force on a current-carrying wire is **maximum** when the wire is: [1]

- **A** parallel to the field
- **B** at 45° to the field
- **C** at 90° to the field
- **D** removed from the field

3.2 A wire of length 0.15 m carries 4.0 A at right angles to a 0.30 T field. Calculate the **force**. [2]

3.3 State what happens to the force when the wire is **parallel** to the field. [1]

3.4 A wire carries current **out of the page** in a field pointing **to the right**. Use Fleming's left-hand rule to find the **direction of the force**. [2]

3.5 A straight horizontal wire of length 8.0 cm lies on a top-pan balance, at right angles to a uniform horizontal magnetic field. When a current of 2.4 A passes through the wire, the balance reading **increases** by 1.6 g.

(a) **Explain** why the balance reading changes when the current is switched on. [2]

(b) **Determine** the force on the wire. [2]

(c) **Determine** the magnetic flux density of the field. [2]

(d) **State** what happens to the balance reading if (i) the current is reversed, and (ii) the wire is turned so that it lies **along** the field. [2]

(e) The current is now increased in steps and the change in balance reading recorded each time. **State** what a graph of the change in reading against current would look like, and **explain** how its gradient could be used to find the flux density. [3]

Solutions

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

2.1

- $F = BIL\sin\theta$
- F = force, B = flux density, I = current, L = length, θ = angle between wire and field

2.2

- $F = BIL$

$$F = (0.50\ \mathrm{T})(3.0\ \mathrm{A})(0.20\ \mathrm{m}) = \mathbf{0.30}\ \mathrm{N}$$

2.3

- the **force per unit current per unit length** on a wire placed at **right angles** to the field

2.4

- **force (motion)**, **field**, **current**

3.1 C

- F is maximum when the wire is **at** 90° **to the field**

3.2

- $F = BIL$

$$F = (0.30\ \mathrm{T})(4.0\ \mathrm{A})(0.15\ \mathrm{m}) = \mathbf{0.18}\ \mathrm{N}$$

3.3

- the force is **zero** ($\sin 0^\circ = 0$)

3.4

- first finger = field (right), second finger = current (out of page)
- the thumb points **upwards**, so the force is **upward**

3.5

(a) the current-carrying wire in a magnetic field experiences a force $F = BIL$

- by Newton's third law the wire pushes back on the magnet with an equal and opposite force, and here that push is **downwards** on the balance, so the reading rises

(b) $F = mg$

$$F = (1.6\times10^{-3}\ \mathrm{kg})(9.81\ \mathrm{m\ s^{-2}}) = \mathbf{1.6\times10^{-2}}\ \mathrm{N}$$

(c) $F = BIL$, so $B = F/(IL)$

$$B = \frac{1.57\times10^{-2}\ \mathrm{N}}{(2.4\ \mathrm{A})(0.080\ \mathrm{m})} = \mathbf{8.2\times10^{-2}}\ \mathrm{T}$$

(d) (i) the force reverses, so the reading **decreases** by the same 1.6 g instead

(ii) with the wire **along** the field the force is **zero** ($\theta = 0$ in $F = BIL\sin\theta$), so the reading returns to its original value

(e) a **straight line through the origin**

- because $F \propto I$ when B and L are fixed
- the gradient of force against current is BL, so dividing the gradient by the length L gives the flux density B