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:

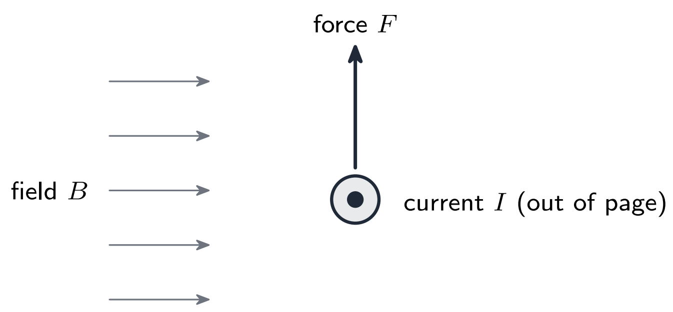
- use $F = BIL\sin\theta$ and **Fleming's left-hand rule**
- define **magnetic flux density**

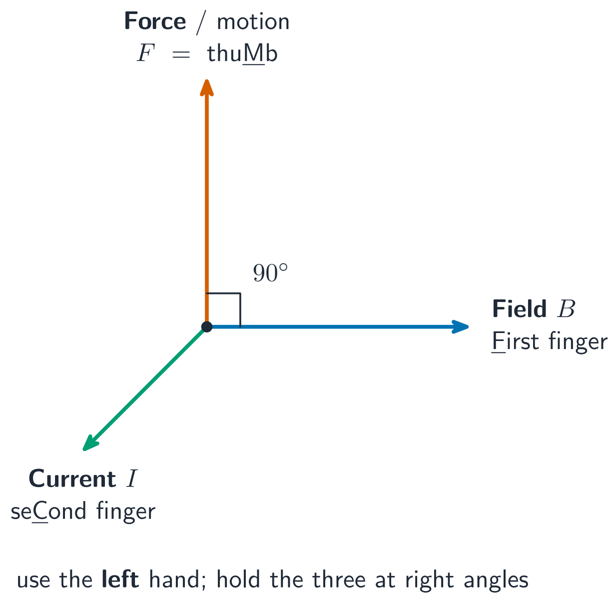
1 Worked examples

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

2.1 F = force, B = flux density, I = current, L = length, θ = angle between wire and field.

2.2 $F = BIL = 0.50 \times 3.0 \times 0.20 = 0.30$ 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 — at 90° to the field.

3.2 $F = BIL = 0.30 \times 4.0 \times 0.15 = 0.18$ N.

3.3 The force is **zero** ($\sin 0° = 0$).

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) $F = mg = 1.6 \times 10^{-3} \times 9.81 = 1.6 \times 10^{-2}$ N.
(c) $F = BIL$, so $B = \dfrac{F}{IL} = \dfrac{1.57 \times 10^{-2}}{2.4 \times 0.080} = 8.2 \times 10^{-2}$ 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.