# Exercise walk-through

## Force on a current-carrying conductor ▪ 20.2

eXercise

# You must be able to

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

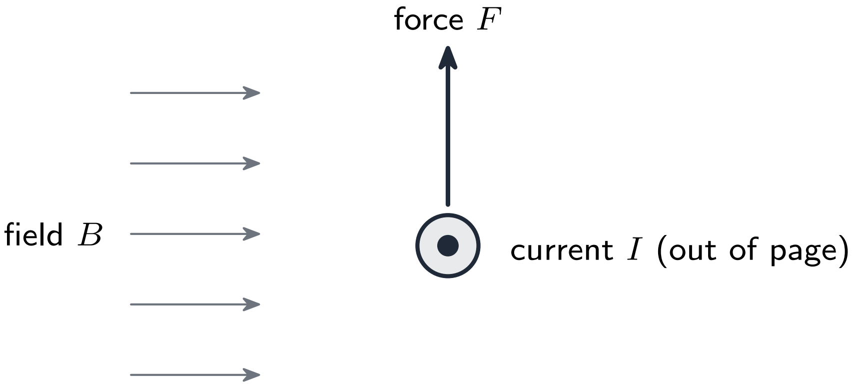
# Method — The motor effect

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

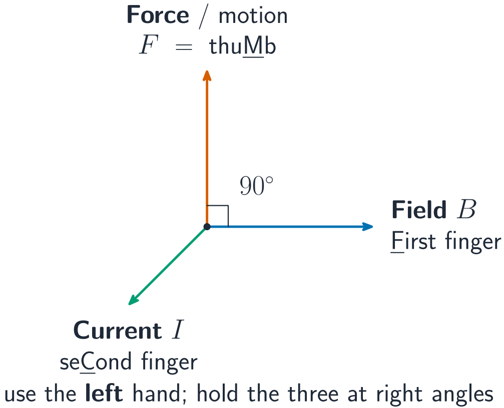
$$F = BIL\sin\theta,$$

where $\theta$ 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.

# Method — The motor effect



# Method — The motor effect




*Fleming left-hand rule for the motor force*

# Practice 2.1 ▪ 2 marks

Write $F = BIL\sin\theta$ and state what each symbol means.

# Solution 2.1

**Worked steps**

$F$ = force, $B$ = flux density, $I$ = current, $L$ = length, $\theta$ = angle between wire and field **B1** **B1** *for the equation, for the symbols.*

# Practice 2.2 ▪ 2 marks

A $0.20$ m wire carries $3.0$ A at right angles to a $0.50$ T field. Find the **force**.

# Solution 2.2

Method: The motor effect

**Worked steps**

$F = BIL = 0.50 \times 3.0 \times 0.20 = 0.30$ N M1 A1.

# Practice 2.3 ▪ 1 mark

Define **magnetic flux density**.

# Solution 2.3

Method: The motor effect

**Worked steps**

The **force per unit current per unit length** on a wire placed at **right angles** to the field **B1**.

# Practice 2.4 ▪ 1 mark

State the three quantities in **Fleming's left-hand rule**.

# Solution 2.4

Method: The motor effect

## Worked steps

**Force (motion)**, **field**, **current** B1.

# Exam-style 3.1 ▪ 1 mark

The force on a current-carrying wire is **maximum** when the wire is:

**A** parallel to the field

**B** at $45°$ to the field

**C** at $90°$ to the field

**D** removed from the field

# Solution 3.1

Method: The motor effect

**A** parallel to the field

**B** at $45°$ to the field

**C** at $90°$ to the field ✓

**D** removed from the field

**Worked steps**

**C** — at $90°$ to the field.

# Exam-style 3.2 ▪ 2 marks

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

# Solution 3.2

Method: The motor effect

**Worked steps**

$F = BIL = 0.30 \times 4.0 \times 0.15 = 0.18$ N **M1** **A1**.

# Exam-style 3.3 ▪ 1 mark

State what happens to the force when the wire is **parallel** to the field.

# Solution 3.3

Method: The motor effect

**Worked steps**

The force is **zero** $(\sin 0° = 0)$ **B1**.

# Exam-style 3.4 ▪ 2 marks

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**.

# Solution 3.4

Method: The motor effect

**Worked steps**

First finger = field (right), second finger = current (out of page); the thumb points **upwards**, so the force is **upward** B1 B1.

# Exam-style 3.5 ▪ 2 marks

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.

(b) **Determine** the force on the wire.

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

(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.

(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.

# Solution 3.5

Method: The motor effect

## Worked steps

(a) The current-carrying wire in a magnetic field experiences a force $F = BIL$ **B1**; 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 **B1**.
(b) $F = mg = 1.6 \times 10^{-3} \times 9.81$ **M1** $= 1.6 \times 10^{-2}$ N **A1**.
(c) $F = BIL$, so $B = \dfrac{F}{IL} = \dfrac{1.57 \times 10^{-2}}{2.4 \times 0.080}$ **M1** $= 8.2 \times 10^{-2}$ T **A1**.
(d) (i) The force reverses, so the reading **decreases** by the same $1.6$ g instead **B1**.
(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 **B1**.

# Solution 3.5

(e) A **straight line through the origin** B1, because $F \propto I$ when $B$ and $L$ are fixed B1. The gradient of force against current is $BL$, so dividing the gradient by the length $L$ gives the flux density $B$ B1.