

Exercise walk-through

Magnetic Fields of Current-Carrying Wires and the Biot-Savart Law ■ 12.3

eXercise

You must be able to

- state the **Biot-Savart law** 毕奥-萨伐尔定律, $d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$
- calculate the field of a **long straight wire**, $B = \frac{\mu_0 I}{2\pi r}$
- find the field at the **centre of a circular loop**, $B = \frac{\mu_0 I}{2R}$
- use the **right-hand rule** for field direction

Method — The Biot-Savart law

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$ gives the field of a small current element; integrate over the wire for the total field ($\mu_0 = 4\pi \times 10^{-7}$).

Method — Standard results

- Long straight wire: $B = \frac{\mu_0 I}{2\pi r}$.
- Centre of a circular loop of radius R : $B = \frac{\mu_0 I}{2R}$.

Method — Direction

Curl the right hand around the wire with the thumb along the current; the fingers give the field direction.

Practice 2.1 ■ 2 marks

Find the field 0.050 m from a long wire carrying 8.0 A ($\mu_0 = 4\pi \times 10^{-7}$).

Solution 2.1

Method: The Biot-Savart law

Worked steps

$$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(8.0)}{2\pi(0.050)} = 3.2 \times 10^{-5} \text{ T} \quad \text{M1} \quad \text{A1}.$$

Practice 2.2 ■ 1 mark

State the rule used to find the direction of the field around a straight wire.

Solution 2.2

Method: Direction

Worked steps

the right-hand rule (grip rule) **B1**.

Practice 2.3 ■ 1 mark

Write the field at the centre of a circular loop of radius R carrying current I .

Solution 2.3

Method: Standard results

Worked steps

$$B = \frac{\mu_0 I}{2R} \quad \text{B1}.$$

Exam-style 3.1 ■ 1 mark

The magnetic field of a long straight wire is

A $\frac{\mu_0 I}{2\pi r}$

B $\frac{\mu_0 I}{2R}$

C $\mu_0 nI$

D BIl

Solution 3.1

Method: Standard results

A $\frac{\mu_0 I}{2\pi r}$



B $\frac{\mu_0 I}{2R}$

C $\mu_0 nI$

D BIL

Worked steps

A.

Exam-style 3.2 ■ 1 mark

The Biot-Savart law gives the field of a

A current element

B point charge

C capacitor

D resistor

Solution 3.2

Method: The Biot-Savart law

A current element



B point charge

C capacitor

D resistor

Worked steps

A.

Exam-style 3.3 ■ 2 marks

A circular loop of radius 0.10 m carries 5.0 A ($\mu_0 = 4\pi \times 10^{-7}$).

- (a) Find the magnetic field at its centre.
- (b) State how the field changes if the current is doubled.

Solution 3.3

Method: Standard results

Worked steps

$$(a) B = \frac{\mu_0 I}{2R} = \frac{(4\pi \times 10^{-7})(5.0)}{2(0.10)} = 3.1 \times 10^{-5} \text{ T} \quad \text{M1 A1. (b) it doubles } (B \propto I) \quad \text{B1}.$$