

Exercise walk-through

12.3

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

AP Physics C: Electricity and Magnetism

Magnetic fields

A **magnetic field** $\vec{B}$ has field lines in **closed loops** – there are **no monopoles**. Materials differ by how their **atomic dipoles** align:

- **ferromagnetic** – an external field aligns whole **magnetic domains**, and the alignment **survives** the field being removed – a permanent magnet; align strongly, stay (iron)
- **paramagnetic** – align weakly
- **diamagnetic** – weakly oppose



Aurora magnetism

The magnetic field, and why there are no monopoles

magnetic field

$\vec{B}$

a **vector field**

surrounding magnets, moving charges and currents; it sets the force on any *moving* charge

field lines

run out of the north pole and into the south *outside* the magnet, and continue through it – they always **close on themselves**

Gauss's law for B

$\oint \vec{B} \cdot d\vec{A} = 0$ through *any* closed surface – as many lines leave as enter

what that means

no isolated **magnetic monopole**

has ever been found; cut a magnet in half and you get two magnets

a compass

a small **magnetic dipole**
cal field

that lines up **tangent** to the lo-

Compare with electric flux, which equals $Q_{\text{enc}}/\epsilon_0$ and is non-zero. The **zero** on the right is the whole difference between the two fields.

Exercises 2.1-2.3

2.1 Find the field 0.050 m from a long wire carrying 8.0 A ($\mu_0 = 4\pi \times 10^{-7}$). [2]

2.2 State the rule used to find the direction of the field around a straight wire. [1]

2.3 Write the field at the centre of a circular loop of radius R carrying current I . [1]

Exercises 2.1-2.3

2.1 Find the field 0.050 m from a long wire carrying 8.0 A ($\mu_0 = 4\pi \times 10^{-7}$). [2]

2.1

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

2.2 State the rule used to find the direction of the field around a straight wire. [1]

2.2

- the right-hand rule (grip rule)
-

2.3 Write the field at the centre of a circular loop of radius R carrying current I . [1]

2.3

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

Exercise 3.1

3.1 The magnetic field of a long straight wire is

[1]

☐

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

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

C $\mu_0 n I$

D BIL

Exercise 3.1

3.1 The magnetic field of a long straight wire is

[1]

- ☐ **A** $\frac{\mu_0 I}{2\pi r}$
- B** $\frac{\mu_0 I}{2R}$
- C** $\mu_0 n I$
- D** BIL

3.1 A

• $\frac{\mu_0 I}{2\pi r}$.

Exercise 3.2

3.2 The Biot-Savart law gives the field of a

[1]

☐

A current element

B point charge

C capacitor

D resistor

Exercise 3.2

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[1]

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A current element

B point charge

C capacitor

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3.2 A

- current element.

Exercise 3.3 (a)

3.3 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.

[2]

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(a) Find the magnetic field at its centre.

[2]

(a)

- $$B = \frac{\mu_0 I}{2R} = \frac{(4\pi \times 10^{-7})(5.0)}{2(0.10)} = 3.1 \times 10^{-5} \text{ T}$$

Exercise 3.3 (b)

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

(b) State how the field changes if the current is doubled.

[1]

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(b) State how the field changes if the current is doubled.

[1]

(b)

- it doubles ($B \propto I$)