Unit 16 · Magnetic Fields

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 34

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

In $\varphi = BA\cos\theta$, θ is the angle between the field and the **normal** to the coil, not its plane. The plane is at 20° to the field, so the normal is at 70°: $N\varphi = 100 \times 0.2 \times 0.01 \times \cos 70° = \mathbf{0.068\ Wb}$. With the plane nearly along the field, few lines pass through, so the flux must be small.

MARKING SCHEME

- ✓ The error: θ is measured from the normal, not the plane.
- ✓ $\theta = 70°$.
- ✓ $N\varphi = 0.068$ Wb.

2 A real setting

ANSWER A · 4

i. $I = \dfrac{2\pi aB}{\mu_0} = \dfrac{0.02 \times 35 \times 10^{-6}}{2 \times 10^{-7}} = \mathbf{3.5\ A}$.

ii. The wire's field under it is east–west, at right angles to the Earth's northward field, and equal to it, so the needle points along their resultant: **45°** from north.

iii. **45° the other way** (to the other side of north): the wire's field reverses.

MARKING SCHEME

- ✓ $I = 2\pi aB/\mu_0$.
- ✓ $I = 3.5$ A.
- ✓ 45°, because the two equal fields are at right angles.
- ✓ Reversed: 45° to the other side.

3 Show that

MARKING SCHEME A · 3

- ✓ $Bqv = mv^2/r$ gives $r = mv/(qB)$.
- ✓ $T = 2\pi r/v = 2\pi m/(qB)$, with no v in it.
- ✓ $f = qB/(2\pi m)$.

4 Compare

ANSWER A · 4

i. $B = \dfrac{V_H net}{I} = \dfrac{6.0 \times 10^{-3} \times 2.0 \times 10^{22} \times 1.6 \times 10^{-19} \times 2.0 \times 10^{-4}}{0.020} = \mathbf{0.19\ T}$.

ii. $V_H = \dfrac{BI}{net} = \dfrac{0.192 \times 0.020}{10^{29} \times 1.6 \times 10^{-19} \times 2.0 \times 10^{-4}} = \mathbf{1.2 \times 10^{-9}\ V}$, five million times smaller.

iii. $V_H \propto 1/n$: a semiconductor has far fewer free carriers, so for the same current they drift much faster and the Hall voltage is large enough to measure easily.

MARKING SCHEME

- ✓ $B = V_H\, net/I$.
- ✓ $B = 0.19$ T.
- ✓ Copper: about 1.2×10^{-9} V.
- ✓ Few carriers (small n) give a large Hall voltage.

5 Predict, then explain

MARKING SCHEME U · 3

- ✓ They repel.
- ✓ The forces are equal (the formula has both currents; Newton's third law).
- ✓ 4.8×10^{-5} N per meter.

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6 Add the fields

ANSWER A · 4

i. Between unlike currents the two fields point the same way, so they add:

$B = 2 \times 10^{-7}\left(\frac{6}{0.05} + \frac{4}{0.05}\right) = \mathbf{4.0 \times 10^{-5}\ T}$.

ii. Outside the pair the two fields are opposite, and they can cancel only nearer the smaller current.

At x beyond the 4 A wire: $\frac{6}{x + 0.10} = \frac{4}{x}$, so $6x = 4x + 0.40$ and $\mathbf{x = 0.20\ m}$.

MARKING SCHEME

- ✓ Between the wires the fields add.
- ✓ $B = 4.0 \times 10^{-5}$ T.
- ✓ Outside they oppose, and cancel nearer the smaller current.
- ✓ $6/(x + 0.10) = 4/x$ gives $x = 0.20$ m.

7 Work backwards

ANSWER HA · 3

In one period T the proton goes $2\pi r$ round and p along, at speeds $v\sin\theta$ and $v\cos\theta$, so

$\tan\theta = \frac{2\pi r}{p} = \frac{2\pi \times 2.0}{10} = 1.26$: $\theta = \mathbf{51}^\circ$.

From $r = \frac{mv\sin\theta}{qB}$: $v\sin\theta = \frac{qBr}{m} = \frac{1.6 \times 10^{-19} \times 0.10 \times 0.020}{1.67 \times 10^{-27}} = 1.92 \times 10^5$ m/s, so $v = \frac{1.92 \times 10^5}{\sin 51.5^\circ} =$ $\mathbf{2.4 \times 10^5\ m/s}$.

MARKING SCHEME

- ✓ $\tan\theta = 2\pi r/p$.
- ✓ $\theta = 51^\circ$.
- ✓ $v = qBr/(m \sin\theta) = 2.4 \times 10^5$ m/s.

8 Correct the misconceptions

ANSWER U · 3

1. A magnetic field does no work on a moving charge, so it **cannot** change its speed, only its direction.
2. The field inside a long solenoid is uniform over most of its length and falls to **half** at the ends.
3. Lines of force are **closed loops**: outside the magnet they go from N to S, and inside it from S back to N.

MARKING SCHEME

- ✓ No change of speed: the force is at right angles to the motion.
- ✓ The field is weakest (half) at the ends.
- ✓ The lines are closed loops (S to N inside the magnet).

9 Design it

MARKING SCHEME A · 3

- ✓ $n = B/(\mu_0 I) \approx 3980$ per meter.
- ✓ $N \approx 1590$ turns.
- ✓ Two sensible ways (larger current, an iron core, a shorter solenoid).

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10 Think

ANSWER HA · 2

Away. The electron's motion is a current in the **opposite** direction to the wire's current (it is negative), and unlike currents repel. (Equivalently: by Fleming's left-hand rule the force on a positive charge moving with the current would be towards the wire, and the electron's charge reverses it.)

MARKING SCHEME

- ✓ Away from the wire.
- ✓ The electron moving with the current is like a current in the opposite direction (unlike currents repel).

11 Make your own

ANSWER HA · 2

For example: "A flat coil of 40 turns and radius 5.0 cm carries a current. What current gives a field of 1.0 mT at its center?" $I = \frac{2rB}{\mu_0 N} = \frac{2 \times 0.05 \times 10^{-3}}{4\pi \times 10^{-7} \times 40} = 2.0$ A, and the field is then 1.0 mT. Any problem whose numbers give μ_0NI/2r = 1.0 mT is right.

MARKING SCHEME

- ✓ A sensible coil problem.
- ✓ Solved correctly with B = μ_0NI/2r.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Magnetic Lines of Force** (exhibit): The hanging screws point along the magnet's lines of force, showing its field's direction, each screw becoming a small magnet while it is near.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	9	18	7	**34**

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