Unit 16 · Magnetic Fields

ANSWER KEY · FOR TEACHERS

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 Key words

1. webers
2. teslas
3. neutral point
4. Lorentz
5. helix
6. Hall voltage
7. toroid
8. permeability

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. pointer
2. coil, end on
3. soft iron core
4. hairspring

Each carries 0.5 mark. **K · 2**

3 Multiple choice

i. **b.** 0.17 Wb **A · 1**

The angle in $N\varphi = NBA\cos\theta$ is measured from the normal: the plane at 60° to the field puts the normal at 30°. $N\varphi = 200 \times 0.4 \times 25 \times 10^{-4} \times \cos 30° = 0.17$ Wb. (0.10 Wb comes from using the 60°.)

ii. **c.** zero **K · 1**

F = Bqv sin θ with $\theta = 0°$: no force, so the particle goes straight on at the same speed.

iii. **b.** four times the radius, in four times the time **U · 1**

$r = \frac{mv}{qB}$ and $T = \frac{2\pi m}{qB}$: both are in proportion to the mass.

iv. **b.** 30 μT **A · 1**

$B = \frac{\mu_0 I}{2\pi a} = \frac{2 \times 10^{-7} \times 6}{0.04} = 3 \times 10^{-5}\ \text{T} = 30\ \mu\text{T}.$

v. **a.** attract each other **K · 1**

Like currents attract; unlike currents repel (the opposite of the rule for charges).

4 Short answers

a. **MARKING SCHEME** **U · 2**

- ✓ The force is always at right angles to the velocity, so no work is done and the speed stays the same.
- ✓ It changes the direction of the motion (a circle or helix).

b. **MARKING SCHEME** **U · 2**

- ✓ Outside: each turn passes through twice in opposite directions, net current zero, so B = 0.
- ✓ In the hole: no current is enclosed, so B = 0.

c. **MARKING SCHEME** **U · 2**

- ✓ Current sensitivity NBA/k doubles with N.
- ✓ R doubles too, so NBA/(kR) is unchanged.

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5 Long answer

ANSWER U · 4

The drifting electrons (speed v_d) feel a Lorentz force Bev_d at right angles to the current and the field, and collect on one face, leaving the opposite face positive. The charges set up an electric field $E = V_H/d$ across the width d, which pushes each electron back with a force eV_H/d. Charge collects until the two balance: $eV_H/d = Bev_d$, so $V_H = Bdv_d$. The current is $I = nev_d\,dt$, so $v_d = \dfrac{I}{ne\,dt}$, and

$$V_H = Bd \cdot \frac{I}{ne\,dt} = \frac{BI}{net}.$$

MARKING SCHEME

- ✓ The Lorentz force pushes the electrons to one face, the other face is left positive.
- ✓ The electric field of the charges balances the magnetic force: $eV_H/d = Bev_d$.
- ✓ $I = nev_d\,dt$, so $v_d = I/(ne\,dt)$.
- ✓ $V_H = BI/(net)$.

6 Numerical problems

a. **ANSWER** A · 3

$$r = \frac{mv}{eB} = \frac{9.1 \times 10^{-31} \times 2.0 \times 10^{7}}{1.6 \times 10^{-19} \times 1.5 \times 10^{-3}} = 0.076 \text{ m} = \mathbf{7.6\ cm}.$$

$$T = \frac{2\pi m}{eB} = \frac{2\pi \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 1.5 \times 10^{-3}} = \mathbf{2.4 \times 10^{-8}\ s}.$$

MARKING SCHEME

- ✓ r = mv/(eB).
- ✓ r = 7.6 cm.
- ✓ T = 2πm/(eB) = 2.4×10^{-8} s.

b. **ANSWER** A · 4

i. M = NIA = $150 \times 0.5 \times (0.04 \times 0.05)$ = **0.15 A m²**.

ii. τ = NBIA cos α = $0.15 \times 0.25 \times \cos 30^\circ$ = **0.032 N m**.

iii. With the plane along the field: τ = MB = **0.0375 N m**.

iv. W = MB(cos 0° − cos 180°) = 2MB = **0.075 J**.

MARKING SCHEME

- ✓ M = 0.15 A m².
- ✓ τ = 0.032 N m at 30°.
- ✓ The largest torque 0.0375 N m.
- ✓ W = 2MB = 0.075 J.

c. **ANSWER** A · 3

n = 800 ÷ 0.50 = 1600 turns/m. Inside: B = μ_0nI = $4\pi \times 10^{-7} \times 1600 \times 2.5$ = **5.0×10^{-3} T** (5.0 mT). At an end it is half: **2.5 mT**.

MARKING SCHEME

- ✓ n = 1600 turns per meter.
- ✓ B = 5.0 mT inside.
- ✓ 2.5 mT at the end (half).

7 Think

ANSWER HA · 3

The electric force qE is the same at any speed, the magnetic force qvB grows with speed; the beam goes straight when v = E/B. i. Faster electrons feel a magnetic force larger than the electric force, so they are pushed to the magnetic force's side. ii. Protons at the same speed go straight through: both forces reverse with the sign of the charge and both are in proportion to q, so they still balance; the condition v = E/B depends on neither the charge nor the mass.

MARKING SCHEME

- ✓ Undeflected when qE = qvB, v = E/B.
- ✓ Faster electrons: the magnetic force wins, so they are deflected (towards its side).
- ✓ Protons at the same speed also pass undeflected: v = E/B doesn't depend on charge or mass.

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8 Activity: A swinging wire (Activity 16.4)

(not marked)

WHAT STUDENTS SHOULD FIND

The wire jumps sideways, at right angles to both itself and the field (into or out of the gap). Reversing the current reverses the swing; turning the magnet over as well brings it back to the first direction. The force depends on the directions of both the current and the field, as Fleming's left-hand rule gives: the motor effect.

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	8	11	12	3	**34**

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