Unit 14 · Electricity and Magnetism

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 56

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

She has left the distance in centimeters. r = 10 cm = 0.10 m, so $r^2 = 0.01\ m^2$.
$F = 9 \times 10^9 \times 6 \times 10^{-12} \div 0.01 = 0.054 \div 0.01 =$ **5.4 N**, ten thousand times her answer: a repulsion.

MARKING SCHEME

- ✓ The mistake: the distance must be in meters.
- ✓ $r^2 = 0.01\ m^2$.
- ✓ F = 5.4 N.

2 Three charges in a line

ANSWER HA · 5

i. From the +4 μC: $F = 9 \times 10^9 \times 4 \times 10^{-6} \times 10^{-6} \div (0.10)^2 =$ **3.6 N**, toward the +9 μC charge. From the +9 μC (0.20 m away): $F = 9 \times 10^9 \times 9 \times 10^{-6} \times 10^{-6} \div (0.20)^2 =$ **2.025 N**, toward the +4 μC charge. Resultant = 3.6 − 2.025 = **1.575 N, toward the +9 μC charge**.

ii. Between two like charges their fields point opposite ways. Near one, its field is the larger; near the other, the other's. So somewhere between they are equal and cancel: a neutral point.

iii. At x cm from the +4 μC: $4/x^2 = 9/(30 - x)^2$. Taking square roots, $2/x = 3/(30 - x)$, so $60 - 2x = 3x$ and x = **12 cm**. (Check: $4/0.12^2 = 9/0.18^2 = 278$.)

MARKING SCHEME

- ✓ The two forces, 3.6 N and 2.025 N, in opposite directions.
- ✓ Resultant 1.575 N toward the +9 μC charge.
- ✓ The fields are opposite between like charges, and each is larger near its own charge, so they cancel somewhere.
- ✓ $4/x^2 = 9/(30 - x)^2$.
- ✓ x = 12 cm.

3 Is the charge possible?

ANSWER A · 4

i. **Negative.** The force must be upward, to balance the weight, and it is opposite to the field, so the charge is negative.

ii. $qE = mg$, so $q = 9.6 \times 10^{-15} \times 10 \div (3 \times 10^5) =$ **3.2×10^{-19} C**.

iii. $3.2 \times 10^{-19} \div 1.6 \times 10^{-19} =$ **2 electrons**.

iv. $2.4 \times 10^{-19} \div 1.6 \times 10^{-19} = 1.5$: a drop can't carry half an electron. A charge must be a whole number of electrons' charges.

MARKING SCHEME

- ✓ Negative, since the force is upward, opposite to the field.
- ✓ $q = 3.2 \times 10^{-19}$ C.
- ✓ 2 electrons.
- ✓ 2.4×10^{-19} C would be 1.5 electrons, which is impossible.

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4 Estimate it

ANSWER A · 3

$F_e \div F_g = (ke^2/r^2) \div (Gm^2/r^2) = ke^2/Gm^2$: the r^2 cancels.

$= 9 \times 10^9 \times (1.6 \times 10^{-19})^2 \div (6.67 \times 10^{-11} \times (1.66 \times 10^{-27})^2) \approx \mathbf{1.3 \times 10^{36}}$.

Big bodies have almost exactly as much positive as negative charge, so their electric forces cancel, while their masses always add.

MARKING SCHEME

- ✓ The r^2 cancels in the ratio.
- ✓ The ratio is about 10^{36}.
- ✓ Charges cancel in big bodies, while masses add.

5 Check the readings

ANSWER HA · 4

i. 500, 500, 500, about 617 μF.

ii. The reading at **12 V**. At 500 μF: $Q = 500 \times 10^{-6} \times 12 = \mathbf{6.0\ mC}$.

iii. **No.** For any one capacitor the charge is directly proportional to the voltage, so $C = Q/V$ is fixed.

iv. 12 V is above the highest safe voltage printed on it, 10 V: the dielectric can break down and let charge spark across.

MARKING SCHEME

- ✓ The row 500, 500, 500 and about 617 μF.
- ✓ The 12 V reading; 6.0 mC expected.
- ✓ No: Q/V is fixed for a capacitor.
- ✓ 12 V is more than its 10 V limit, so the dielectric can break down.

6 A defibrillator

ANSWER A · 4

i. $Q = 32 \times 10^{-6} \times 2{,}000 = \mathbf{0.064\ C}$.

ii. $I = 0.064 \div (5 \times 10^{-3}) = \mathbf{12.8\ A}$.

iii. $t = Q/I = 0.064 \div (8 \times 10^{-3}) = \mathbf{8\ s}$.

iv. $V = Q/C = 0.064 \div (64 \times 10^{-6}) = \mathbf{1{,}000\ V}$.

MARKING SCHEME

- ✓ $Q = 0.064$ C.
- ✓ $I = 12.8$ A.
- ✓ $t = 8$ s.
- ✓ $V = 1{,}000$ V.

7 Closer plates

ANSWER HA · 4

Closer plates mean a larger capacitance, in both cases.

a. The battery holds V fixed. From $Q = CV$, the **charge rises**: more flows on from the battery.

b. With no path for charge, Q is fixed. From $V = Q/C$, the **voltage falls**.

MARKING SCHEME

- ✓ Closer plates give a larger capacitance.
- ✓ a. V fixed by the battery.
- ✓ a. So the charge rises.
- ✓ b. Q fixed, so the voltage falls.

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8 Where does the compass point?

ANSWER A · 3

a. **South.** To the side of its middle the magnet's field points south, and close up it is stronger than the Earth's.
b. **No particular direction.** The two fields are equal and opposite, so the resultant is zero.
c. **North.** Far from the magnet the Earth's field wins.

MARKING SCHEME

✓ 5 cm: south, as the magnet's southward field is stronger there.
✓ 12.5 cm: no particular direction (neutral point).
✓ 40 cm: north, as the Earth's field is stronger there.

9 How far off?

ANSWER A · 4

In the plane of the circle, $\tan \delta' = V/(H \cos \varphi)$, and $V/H = \tan 45^\circ = 1$.

i. $\tan \delta' = 1 \div \cos 60^\circ = 2$, so $\delta' =$ **63.4**°.
ii. $2.75 = 1 \div \cos \varphi$, so $\cos \varphi = 0.364$ and $\varphi =$ **68.7**°.
iii. **90**°: in a plane at right angles to the meridian the needle feels none of the horizontal part, only the vertical part, so it stands straight up and down.

MARKING SCHEME

✓ $\tan \delta' = V/(H \cos \varphi)$.
✓ 63.4°.
✓ 68.7°.
✓ 90° from the meridian, with no horizontal part felt.

10 Two parts of the field

ANSWER A · 3

$H = 49 \times 0.719 =$ **35.2 μT**. $V = 49 \times 0.695 =$ **34.1 μT**.
$\sqrt{(35.2^2 + 34.1^2)} = \sqrt{(1{,}239 + 1{,}163)} = \sqrt{2{,}402} = 49.0$ μT.
$V/H = 34.1 \div 35.2 = 0.97$, and $\tan 44^\circ = 0.966$.

MARKING SCHEME

✓ H = 35.2 μT and V = 34.1 μT.
✓ The resultant, by Pythagoras, is 49 μT.
✓ $V/H \approx 0.97 = \tan 44^\circ$.

11 Does it matter?

ANSWER A · 3

Sideways distance $\approx 10{,}000 \times 0.0070 =$ about **70 m**, small for a walk.
It would matter **much more** near the magnetic poles, where the declination can be tens of degrees, so a walker could end up kilometers off.

MARKING SCHEME

✓ About 70 m.
✓ It matters more near the magnetic poles.
✓ The declination there can be tens of degrees.

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12 Design a fair test

ANSWER A · 4

i. She changes the number of rubs (say 5, 10, 20), and measures how far the stream bends, against a ruler behind it.

ii. Any three: the same balloon; the same sweater; the same tap setting; the same distance from balloon to stream; the same spot on the stream.

iii. Repeat each number of rubs several times and average; let the balloon lose its charge between tries.

iv. A larger bend with more rubs. In wet monsoon air the charge leaks away quickly, so results would be weak and uneven.

MARKING SCHEME

✓ Changes the number of rubs; measures the bend.
✓ Any three things kept the same.
✓ Repeats and averages.
✓ A larger bend with more rubs; wet air lets the charge leak away.

13 Correct the misconceptions

ANSWER U · 3

1. It is magnetically a **south pole**: it attracts a compass's N pole.
2. The lines **don't stop**: inside the magnet they continue from S to N, so each is a closed loop.
3. The plates hold +Q and −Q, so the **total is zero**; "stores a charge Q" means the charge on either plate.

MARKING SCHEME

✓ The pole in the north is magnetically a south pole.
✓ The lines continue inside the magnet, as closed loops.
✓ The plates hold +Q and −Q; the total is zero.

14 Which explanation fits the evidence?

ANSWER HA · 3

Bhawana's. The needle's weight is the same everywhere, and it would pull the same end down in every country. But the needle changes which end dips, and doesn't dip at all at the magnetic equator: just what the lines of force do, going into the ground in the north, parallel to it at the magnetic equator, and coming out of it in the south.

MARKING SCHEME

✓ Bhawana's explanation.
✓ Weight would pull the same end down everywhere.
✓ The lines of force slope one way in the north, lie level at the magnetic equator, and slope the other way in the south, matching the needle.

15 Make your own

ANSWER HA · 2

For example, +1 μC and −1 μC, 10 cm apart: $F = 9 \times 10^{9} \times 10^{-6} \times 10^{-6} \div (0.10)^{2} =$ **0.9 N**, an attraction. (Another: +1 μC and −4 μC, 20 cm apart.)

MARKING SCHEME

✓ Unlike charges chosen.
✓ The calculation gives 0.9 N.

16 Think

ANSWER

i. $F = mg = 3 \times 10^{-3} \times 10 = 0.03$ N. $r^{2} = kq_{1}q_{2}/F = 9 \times 10^{9} \times 2 \times 10^{-12} \div 0.03 = 0.6$ m^{2}, so r = **0.77 m**.

ii. Closer, the force grows as $1/r^{2}$, and is then more than the weight, so the ball is **pushed back up**.

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iii. **No.** Unlike charges attract: the fixed charge below would pull it down, along with its weight, and nothing would hold it up. HA · 4

MARKING SCHEME

✓ $F = mg = 0.03$ N.
✓ $r = 0.77$ m.
✓ Closer, the force grows above the weight, pushing the ball back.
✓ A negative charge is pulled down, so it can't hang there.

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.

- **Static Electricity** (exhibit): Watch the light beads jump and cling: each charged bead feels a force in the electric field of the charges around it.
- **Magnetic Lines of Force** (exhibit): The hanging screws line up along the magnet's lines of force, each screw becoming a small magnet for a while: the field made visible.
- **Earth's Magnetic Field** (exhibit): Find Nepal, where the angle of declination is close to zero, then a place where a compass points far from true north.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	28	22	**56**

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