Unit 20 · Electrons

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 32

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

The V in the formula is the **accelerating** p.d., 1500 V, not the 400 V across the plates (which gives only E). $\frac{e}{m} = \frac{(5.0 \times 10^4)^2}{2 \times 1500 \times (2.2 \times 10^{-3})^2} = \mathbf{1.7 \times 10^{11}\ C/kg}$, close to the accepted 1.76×10^{11} C/kg.

MARKING SCHEME

- ✓ The error: V must be the accelerating p.d., V_a.
- ✓ Correct substitution with 1500 V.
- ✓ e/m = 1.7×10^{11} C/kg.

2 Read the data

ANSWER HA · 4

(The readings are made up.)

i. About $\mathbf{1.6 \times 10^{-19}\ C}$: each charge divided by it is close to a whole number.

ii. 2, 3, 5, 4 and 7.

iii. Total charge ÷ total electrons = 33.61 ÷ 21 = $\mathbf{1.60 \times 10^{-19}\ C}$.

iv. Every multiple of 1.6 is also a multiple of 0.8, so these readings fit 0.8 too. Only when many drops are measured and none ever carries an odd multiple of 0.8×10^{-19} C (as Millikan found) is the smallest step shown to be 1.6×10^{-19} C.

MARKING SCHEME

- ✓ The common step 1.6×10^{-19} C.
- ✓ 2, 3, 5, 4, 7 electrons.
- ✓ e = 1.60×10^{-19} C.
- ✓ Multiples of 1.6 are multiples of 0.8 too: many drops are needed.

3 Predict, then explain

MARKING SCHEME U · 3

- ✓ Doubling V doubles y (4 mm).
- ✓ Doubling v quarters y (0.5 mm).
- ✓ Explained: y ∝ V; half the time, and y ∝ t^2.

4 Show that

MARKING SCHEME A · 3

- ✓ evB = eE gives v = E/B.
- ✓ $\frac{1}{2}mv^2 = eV_a$ gives $e/m = v^2/(2V_a)$.
- ✓ Combined: $e/m = E^2/(2V_aB^2)$.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

5 Estimate it

ANSWER A · 3

$m = \frac{4}{3}\pi(10^{-6})^3 \times 900 = 3.8 \times 10^{-15}$ kg, weight $\approx$ **3.7×10^{-14} N**. V = mgd/q = $3.7 \times 10^{-14} \times 0.005 \div 3.2 \times 10^{-19} \approx$ **580 V**.

A 1 mm drop has a thousand times the radius, 10^9 times the weight, so it would need about **6×10^{11} V**: impossible. Only tiny drops let a few electrons' charge balance the weight.

MARKING SCHEME

- ✓ Weight about 3.7×10^{-14} N.
- ✓ About 580 V.
- ✓ About 10^9 times as much for a 1 mm drop: only tiny drops work.

6 Which explanation fits?

MARKING SCHEME U · 2

- ✓ Charged particles.
- ✓ Fields bend moving charges, not light; bending towards + shows negative charge.

7 Correct the misconceptions

ANSWER U · 3

1. Millikan measured the electron's **charge**; its mass followed from Thomson's e/m.
2. Entering at right angles to an **electric** field, the beam moves along a **parabola**; a circle is its path in a magnetic field.
3. A velocity selector lets through particles of one **speed**, v = E/B, whatever their charge or mass.

MARKING SCHEME

- ✓ Millikan measured the charge.
- ✓ A parabola in an electric field (a circle in a magnetic one).
- ✓ It selects speed E/B, for any charge or mass.

8 Work backwards

ANSWER A · 3

$v = \sqrt{2(e/m)V} = \sqrt{2 \times 1.76 \times 10^{11} \times 500} = 1.33 \times 10^7$ m/s. From $r = \frac{mv}{Be}$:

$B = \frac{v}{(e/m)r} = \frac{1.33 \times 10^7}{1.76 \times 10^{11} \times 0.050} =$ **1.5×10^{-3} T**.

MARKING SCHEME

- ✓ v = 1.33×10^7 m/s.
- ✓ B = v/((e/m)r).
- ✓ B = 1.5 mT.

9 Design it

ANSWER A · 4

i. E = vB = $4.0 \times 10^6 \times 0.050 =$ **2.0×10^5 V/m**; V = Ed = $2.0 \times 10^5 \times 0.010 =$ **2000 V**.

ii. **Yes**: qE = qvB, so the charge cancels and the mass never enters; any ion at that speed goes straight.

iii. For them the magnetic force qvB is larger than the electric force qE, so they are bent **the way the magnetic force pushes**.

MARKING SCHEME

- ✓ E = 2.0×10^5 V/m.
- ✓ V = 2000 V.
- ✓ Works for any charge or mass (q cancels).
- ✓ Faster ions bend the way the magnetic force pushes.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

10 What if?

ANSWER HA · 2

i. They gain the same energy eV but are about 1840 times heavier, so their speed is about $\sqrt{1840} \approx 43$ times **smaller**.

ii. Their charge is positive, so each field bends them the **opposite way** to the electrons (towards the negative plate).

MARKING SCHEME

✓ Much slower (same energy, far larger mass).

✓ Bent the opposite way by each field.

11 Make your own

ANSWER HA · 2

For example: "A drop of weight 4.0×10^{-14} N is held still between plates 10 mm apart by a p.d. of 500 V. How many extra electrons does it carry?" $q = mgd/V = 4.0 \times 10^{-14} \times 0.010 \div 500 = 8.0 \times 10^{-19}$ C = 5e. Any numbers giving $q = 8.0 \times 10^{-19}$ C are right.

MARKING SCHEME

✓ A sensible problem.

✓ Solved correctly to 5 electrons with $qV/d = mg$.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	11	13	8	**32**

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking