Unit 21 · Potential, Potential Difference and Potential Energy

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 29

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

Potential is a **scalar**: the potentials just add as numbers, with no angles or components. V = 60 + 60 = **120 V**. (Resolving with cos 30° is for the field, a vector.)

MARKING SCHEME

- ✓ The error: potentials were resolved like vectors.
- ✓ Potential is a scalar; potentials add algebraically.
- ✓ V = 120 V.

2 Two answers

ANSWER HA · 4

Let P be x cm from O.
Between O and A: $6/x = 2/(40 - x)$, so $240 - 6x = 2x$, **$x = 30$ cm**.
Beyond A: $6/x = 2/(x - 40)$, so $6x - 240 = 2x$, **$x = 60$ cm**.
On the far side of O, the larger positive charge is always nearer than the negative one, so its positive potential always wins: no zero there.

MARKING SCHEME

- ✓ Between O and A: $6/x = 2/(40 - x)$.
- ✓ x = 30 cm.
- ✓ Beyond A: x = 60 cm.
- ✓ On the far side of O the nearer, larger + charge always wins.

3 Work backwards

ANSWER A · 3

$V = kQ/r$ and $E = kQ/r^2$, so $r = V/E = 900 \div 4500 =$ **0.20 m**. $Q = Vr/k = 900 \times 0.20 \div 9.0 \times 10^9 =$ **$+2.0 \times 10^{-8}$ C** (positive, since V is positive).

MARKING SCHEME

- ✓ r = V/E.
- ✓ r = 0.20 m.
- ✓ $Q = +2.0 \times 10^{-8}$ C.

4 A real setting

ANSWER A · 3

i. At the closest point all its kinetic energy has become potential energy: $k(2e)(79e)/r = 5.0$ MeV $= 5.0 \times 10^6 \times 1.6 \times 10^{-19}$ J. So $r = k \times 2 \times 79 \times e \div (5.0 \times 10^6\ V) = 9.0 \times 10^9 \times 158 \times 1.6 \times 10^{-19} \div 5.0 \times 10^6 =$ **4.6×10^{-14} m**.

ii. The particle bounced back by repulsion alone, so the nucleus's charge is packed within about **10^{-14} m**, ten thousand times smaller than the atom (about 10^{-10} m).

MARKING SCHEME

- ✓ Kinetic energy = potential energy kQq/r at the closest point.
- ✓ $r = 4.6 \times 10^{-14}$ m.
- ✓ The nucleus is smaller than about 10^{-14} m, far smaller than the atom.

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

5 Reading a graph

ANSWER HA · 3

i. 0–3 cm: slope +60 V ÷ 0.030 m = 2000 V/m, so E = **2000 V/m towards −x** (towards lower V). 3–5 cm: flat, **E = 0**. 5–9 cm: slope −60 ÷ 0.040 = −1500 V/m, so E = **1500 V/m towards +x**.

ii. At 4.0 cm there is no field: it **stays put** (no force).

MARKING SCHEME

✓ 0–3 cm: 2000 V/m, towards −x.

✓ 3–5 cm: zero field.

✓ 5–9 cm: 1500 V/m towards +x; at 4.0 cm the electron feels no force and stays.

6 Estimate it

ANSWER A · 3

i. $V = kQ/r = 9.0 \times 10^9 \times 0.5 \times 10^{-6} \div 0.5 \approx$ **9,000 V**, about 10 kV.

ii. Energy $\approx \frac{1}{2}QV = 0.5 \times 0.5 \times 10^{-6} \times 9000 \approx$ **2×10^{-3} J**: a few thousand volts, but only about 2 mJ, which is why the spark stings but does no harm.

MARKING SCHEME

✓ V ≈ 9,000 V.

✓ Energy ≈ 2 mJ.

✓ High voltage but very little energy.

7 Predict, then explain

ANSWER HA · 3

The proton moves to the **negative** (0 V) plate, the electron to the **positive** (12 V) plate. Starting at a plate each, both gain the **same** kinetic energy, eV = 12 eV, since their charges are equal in size. The **electron** is far faster: with $\frac{1}{2}mv^2$ the same, $v \propto 1/\sqrt{m}$, and it is about 1,840 times lighter, so about 43 times faster.

MARKING SCHEME

✓ Proton to the lower potential, electron to the higher.

✓ Equal kinetic energy, 12 eV each (q of the same size).

✓ The electron is faster ($v \propto 1/\sqrt{m}$, about 43 times).

8 Correct the misconceptions

ANSWER U · 3

1. V = 0 doesn't mean E = 0: halfway between +Q and −Q the potential is zero but the field is not. The field depends on how V **changes**.
2. The electron volt is a unit of **energy** (1.6×10^{-19} J), not of potential.
3. A positive charge moves to **lower** potential, losing potential energy.

MARKING SCHEME

✓ V = 0 doesn't imply E = 0 (example: midpoint of ±Q).

✓ The eV is a unit of energy.

✓ A positive charge moves towards lower potential.

9 Think

ANSWER HA · 2

If V is the same everywhere, $\Delta V = 0$ between any two points, so the potential gradient is zero and $E = -\Delta V/\Delta x =$ **0** everywhere inside: the box shields what it holds from outside fields.

MARKING SCHEME

✓ Constant V means zero potential gradient.

✓ So E = 0 inside (shielding).

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

10 Make your own

HA · 2

ANSWER

For example 4.0 cm apart and 200 V: E = 200 ÷ 0.040 = 5,000 V/m. The electron gains eV = **200 eV**. Any pair with V/d = 5,000 V/m is right; the energy in eV equals the p.d. in volts.

MARKING SCHEME

- ✓ A gap and p.d. with V/d = 5,000 V/m.
- ✓ Kinetic energy in eV = the p.d. in volts.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	9	14	**29**

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