

Exercise walk-through

9.3

Conservation of Electric Energy

AP Physics C: Electricity and Magnetism

Conservation of electric energy

Moving a charge through a **potential difference** does work:

Work and kinetic energy

$$W = q \Delta V, \quad \Delta K = q \Delta V$$

- a + charge speeds up moving to **lower** V
- 1 **eV** = 1.6×10^{-19} J (an energy)

Worked example

An electron through 200 V:

$$\Delta K = 200 \text{ eV} = 3.2 \times 10^{-17} \text{ J}$$

$$v = \sqrt{\frac{2 \Delta K}{m}} \approx 8.4 \times 10^6 \text{ m/s}$$

Which sign speeds up which charge

positive charge

speeds up moving to **lower** potential – it falls down the potential hill

negative charge

speeds up moving to **higher** potential – it falls *up* the hill

why

$\Delta U_E = q \Delta V$: flip the sign of q and you flip which direction loses energy

the check

if only the electric force acts, $\Delta K = -\Delta U_E$ – kinetic energy rises exactly as potential energy falls

Watch **both** signs together, the charge's and the potential change's. Getting one right and the other wrong gives a plausible number pointing the wrong way.

Worked example – a proton accelerated through a potential drop

A proton ($q = 1.6 \times 10^{-19} \text{ C}$, $m = 1.67 \times 10^{-27} \text{ kg}$) starts at rest and falls through 500 V. Find its final speed.

- $\Delta K = q \Delta V = (1.6 \times 10^{-19})(500) = 8.0 \times 10^{-17} \text{ J}$
- $\frac{1}{2}mv^2 = 8.0 \times 10^{-17}$
- $v = \sqrt{\frac{2(8.0 \times 10^{-17})}{1.67 \times 10^{-27}}} = 3.1 \times 10^5 \text{ m/s}$

Only the **end-point potentials** enter. Choose energy over kinematics whenever the field is non-uniform or the path curves – there is no constant a to put in a SUVAT equation.

Exam tips

- Relate field and potential by $V = - \int \vec{E} \cdot d\vec{l}$ and $\vec{E} = -\nabla V$ (in 1-D, $E_x = -\frac{dV}{dx}$).
- Potential is a **scalar** – add contributions with signs, no vector components needed.
- Potential energy of a pair is $U = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$; use energy conservation for a charge's speed.
- Know that no work is done moving along an **equipotential**, which is perpendicular to $\vec{E}$.
- Choose the zero of potential (usually infinity) and state it.

Exercises 2.1-2.3

2.1 An electron moves through a potential difference of 50 V. State the energy it gains, in eV. [1]

2.2 Convert 3.0 eV to joules ($e = 1.6 \times 10^{-19}$ C). [2]

2.3 A $+2.0 \mu\text{C}$ charge moves through 300 V. Find the energy it gains, in joules. [2]

Exercises 2.1-2.3

2.1 An electron moves through a potential difference of 50 V. State the energy it gains, in eV. [1]

2.1

- 50 eV

2.2 Convert 3.0 eV to joules ($e = 1.6 \times 10^{-19}$ C). [2]

2.2

- $3.0 \times 1.6 \times 10^{-19} = 4.8 \times 10^{-19}$ J

2.3 A $+2.0 \mu\text{C}$ charge moves through 300 V. Find the energy it gains, in joules. [2]

2.3

- $\Delta KE = q \Delta V = (2.0 \times 10^{-6})(300) = 6.0 \times 10^{-4}$ J

Exercises 3.1-3.2

3.1 One electron volt equals

[1]

☐

A 1 J

B 1.6×10^{-19} J

C 1 V

D 1 C

☐

A $q/\Delta V$

B $q \Delta V$

C $\Delta V/q$

D $\frac{1}{2}q \Delta V^2$

Exercises 3.1-3.2

3.1 One electron volt equals

[1]

☐

A 1 J

B 1.6×10^{-19} J

C 1 V

D 1 C

3.1 B

- 1.6×10^{-19} J.

3.2 A charge accelerated through a potential difference ΔV gains kinetic energy

[1]

☐

A $q/\Delta V$

B $q \Delta V$

C $\Delta V/q$

D $\frac{1}{2}q \Delta V^2$

3.2 B

- $q \Delta V$.

Exercise 3.3 (a)

3.3 A proton ($m = 1.67 \times 10^{-27}$ kg, $q = 1.6 \times 10^{-19}$ C) accelerates from rest through 500 V.

(a) Find its kinetic energy in joules.

[2]

Exercise 3.3 (a)

3.3 A proton ($m = 1.67 \times 10^{-27}$ kg, $q = 1.6 \times 10^{-19}$ C) accelerates from rest through 500 V.

(a) Find its kinetic energy in joules.

[2]

(a)

- $\Delta KE = q \Delta V = (1.6 \times 10^{-19})(500) = 8.0 \times 10^{-17} \text{ J}$

Exercise 3.3 (b)

3.3 A proton ($m = 1.67 \times 10^{-27}$ kg, $q = 1.6 \times 10^{-19}$ C) accelerates from rest through 500 V.

(b) Find its final speed.

[2]

Exercise 3.3 (b)

3.3 A proton ($m = 1.67 \times 10^{-27}$ kg, $q = 1.6 \times 10^{-19}$ C) accelerates from rest through 500 V.

(b) Find its final speed.

[2]

(b)

- $\frac{1}{2}mv^2 = 8.0 \times 10^{-17} \Rightarrow v = \sqrt{\frac{2(8.0 \times 10^{-17})}{1.67 \times 10^{-27}}} = 3.1 \times 10^5 \text{ m s}^{-1}$