B6 · Extra practice, worked solutions

Potential difference: energy per charge | Diploma-style set of 8

Easy · B6-X01. A charge of 2.50×10^{-18} C is moved through a potential difference of 12.0 V. Find the change in its electric potential energy in joules.

1. Givens: $q = 2.50 \times 10^{-18}$ C; $\Delta V = 12.0$ V. Question: ΔE.

2. $\Delta E = q\Delta V$.

3. $= (2.50 \times 10^{-18})(12.0) = 3.00 \times 10^{-17}$ J.

4. Answer: 3.00×10^{-17} J

Easy · B6-X02. An electron gains 4.80×10^{-18} J of kinetic energy. Express this energy in electron volts. Use $1\ \text{eV} = 1.60 \times 10^{-19}$ J.

1. Givens: energy $= 4.80 \times 10^{-18}$ J; $1\ \text{eV} = 1.60 \times 10^{-19}$ J. Question: the energy in eV.

2. Number of eV = energy in joules ÷ $(1.60 \times 10^{-19}$ J/eV).

3. $= 4.80 \times 10^{-18} \div (1.60 \times 10^{-19}) = 30.0$ eV.

4. Answer: 30.0 eV

Easy · B6-X03. Which pair shows the same unit?

A. 1 volt = 1 coulomb per joule
B. 1 volt = 1 joule × coulomb
C. 1 volt = 1 newton per coulomb
D. 1 volt = 1 joule per coulomb

1. Givens: the definition $\Delta V = \Delta E/q$. Question: which unit pair is right.

2. Energy in joules divided by charge in coulombs gives J/C, so 1 V = 1 J/C.

3. N/C is a unit for field strength, not for potential difference.

4. Answer: D. 1 volt = 1 joule per coulomb

Medium · B6-X04. A proton starts from rest and is accelerated through a potential difference of 2400 V. Use e = 1.60×10^{-19} C and proton mass mp = 1.67×10^{-27} kg. Find its final speed in m/s.

1. Givens: starts from rest (so $v_i = 0$ m/s); $\Delta V = 2400$ V; $q = 1.60 \times 10^{-19}$ C; $m = 1.67 \times 10^{-27}$ kg. Question: v.

2. The energy gained is kinetic: $q\Delta V = \frac{1}{2}mv^2$.

3. $q\Delta V = (1.60 \times 10^{-19})(2400) = 3.840 \times 10^{-16}$ J. Keep the full value on your calculator.

4. $v = \sqrt{(2q\Delta V \div m)} = \sqrt{(2 \times 3.840 \times 10^{-16} \div (1.67 \times 10^{-27}))} = 6.78 \times 10^5$ m/s.

5. Answer: 6.78×10^5 m/s

Medium · B6-X05. An electron and a proton are each released from rest and accelerated through the same 100 V. Which statement is correct?

A. The proton gains more kinetic energy, so it ends up faster.

B. They gain the same kinetic energy, and the electron ends up faster.

C. They gain the same kinetic energy and end up at the same speed.

D. The electron gains more kinetic energy because it is lighter.

1. Givens: same $\Delta V = 100$ V and the same size of charge, e. Question: compare the energy and the speed.

2. Energy gained = $q\Delta V$, the same for both.

3. With the same kinetic energy $\frac{1}{2}mv^2$, the lighter particle has the larger speed, so the electron is faster.

4. Answer: B. They gain the same kinetic energy, and the electron ends up faster.

Medium · B6-X06. An alpha particle ($q = 3.20 \times 10^{-19}$ C) starts from rest and gains 5.12×10^{-16} J of kinetic energy. Find the potential difference it crossed, in volts.

1. Givens: starts from rest; $q = 3.20 \times 10^{-19}$ C; gain = 5.12×10^{-16} J. Question: ΔV.

2. The kinetic energy gained equals $q\Delta V$.

3. $\Delta V = \Delta E \div q = 5.12 \times 10^{-16} \div (3.20 \times 10^{-19}) = 1600$ V.

4. Answer: 1600 V

Challenging · B6-X07. An electron moves at 3.00×10^{6} m/s into a region where it slows to rest. Use $e = 1.60 \times 10^{-19}$ C and electron mass $m_e = 9.11 \times 10^{-31}$ kg. Find the size of the potential difference that stops it, in volts.

1. Givens: $v_i = 3.00 \times 10^{6}$ m/s; vf = 0 m/s; $q = 1.60 \times 10^{-19}$ C; $m = 9.11 \times 10^{-31}$ kg. Question: $|\Delta V|$.

2. Initial kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}(9.11 \times 10^{-31})(3.00 \times 10^{6})^2 = 4.100 \times 10^{-18}$ J.

3. All of it becomes electric potential energy: $\Delta E = q\Delta V$.

4. $\Delta V = 4.100 \times 10^{-18} \div (1.60 \times 10^{-19}) = 25.6$ V.

5. Answer: 25.6 V

Challenging · B6-X08. A charge q is moved from point A to point B between charged plates and gains an amount of potential energy ΔE. A second charge, 2q, is moved between the same two points. Compare the energy change and the potential difference for the two charges, and explain.

1. Givens: charge q gains ΔE between A and B; a second charge 2q is moved between the same points. Question: compare ΔE and ΔV.

2. $\Delta E = q\Delta V$. The force on 2q is twice as large, so twice the work is done: the energy change is 2ΔE.

3. $\Delta V = \Delta E/q$. For the second charge, $2\Delta E \div 2q = \Delta E/q$, the same as before.

4. So the energy change doubles, but the potential difference stays the same. ΔV belongs to the two points, not to the charge.