B6 · Potential difference: energy per charge

Student notes - follow the slides, fill the blanks, work the questions

Explain potential difference as energy per charge, use $\Delta E = q\Delta V$, and use the electron volt.

Name: _____ Date: _____

Slide 1 of 7 · Work that stores energy between plates

A positive particle against the _____ plate is where it wants to be, so we call its electric potential energy (written Ep) _____ there, like a ball at the bottom of a hill.

To carry it toward the other plate something outside must push, because the plates pull and push it _____. Our push does _____.

The speed stays constant, so none of the work becomes _____. _____ the work is stored as electric potential energy: $\Delta Ep = 6.0 \times 10^{-16}$ J in the example, where Δ means _____. When released, Ep decreases and the same amount becomes kinetic energy, written Ek.

The positive plate _____ a positive charge away and the negative plate _____ it in.

Example. A positive particle with $q = 4.0 \times 10^{-17}$ C is carried at constant speed from the negative top plate (A) to B, gaining 6.0×10^{-16} J of electric potential energy. It is released from rest and gravity is too small to matter. Which way does it move, and how much kinetic energy does it have when it reaches the top plate?

Work:

Answer: _____

Try it. The same positive particle is held at B, with 6.0×10^{-16} J of electric potential energy, and is carried at constant speed back to the negative top plate at A. Does its electric potential energy increase or decrease, by how much, and what is its potential energy at A?

Work:

Answer: _____

Slide 2 of 7 · Potential difference: energy per charge

A bigger charge stores more energy, so divide out the charge. Electric potential difference is $\Delta V =$ _____: ΔE is the _____ (J) and q is the _____ (C).

Its unit is _____ (joules per coulomb). ΔV belongs to the _____, not the particle: a charge three times as big stores three times the energy, and $\Delta E \div q$ gives the _____ ΔV.

Rearrange for the unknown: $\Delta E =$ _____. Put in the size of the charge, then ask which way it moves: moving toward the plate that attracts it means it _____. If the plates do not change, ΔV stays the _____ for a new charge.

On a graph of ΔE against q, $\Delta E = q\Delta V$ matches $y = mx$, so the slope is _____. The line passes through the _____, because zero charge stores zero energy. Check powers of ten, since the charges are very small.

Example. On other plates, a charge $q = 6.0 \times 10^{-18}$ C stores 1.8×10^{-16} J when moved from A to B. Find the potential difference between A and B, then find the energy stored when a charge of 1.5×10^{-17} C is moved between the same two points.

Work:

Answer: _____

Try it. The same plates move several charges from A to B, and the energy stored is graphed against the charge. The line passes through C = (2.0×10^{-18} C, 0.60×10^{-16} J) and D = (8.0×10^{-18} C, 2.40×10^{-16} J). What does the slope represent, and what is its value?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 7 · Method: how to solve an energy-per-charge problem

Step 1: name the _____. Is it ΔE, q or ΔV? Write it before any number.

Step 2: write the equation with the unknown alone: ΔV = _____, ΔE = _____ or q = _____.

Step 3: put in the _____: the size of the charge in coulombs and the energy in joules. Then ask which way it moves: toward the plate that attracts it, it gains _____.

Step 4: calculate with units. Joules per coulomb is the _____. Check: a bigger charge stores _____ energy.

Example. A charge of 6.0×10^{-18} C stores 1.8×10^{-16} J when it is moved from A to B. A charge of 1.5×10^{-17} C is then moved between the same two points. Find the potential difference, then the energy stored for the new charge.

Work:

Answer: _____

Try it. A charge of 2.5×10^{-17} C stores 1.0×10^{-15} J when it is moved between two plates. Find the potential difference between the plates, then the energy stored when a charge of 8.0×10^{-18} C is moved between the same plates.

Work:

Answer: _____

Slide 4 of 7 · The volt: one joule per coulomb

One volt is one _____: 1 V = _____. “Voltage” is just _____. A battery label such as 9.0 V means ΔV = _____ in an equation. Unlike the field E, ΔV has _____.

A 9.0 V battery gives _____ to each coulomb that passes through it. A battery does not store charge to hand out; it supplies _____ for each coulomb already in the wires.

Pick the form that matches the unknown: energy from charge, ΔE = _____; charge from energy, q = _____. The unit V can always be swapped for _____.

Example. A battery is labelled 9.0 V and is connected to a heating coil. A charge of 4.0 C flows through the coil. Find the energy delivered.

Work:

Answer: _____

Try it. A 6.0 V battery is connected to a lamp. How much energy is delivered when 2.5 C of charge passes through the lamp, and how much charge must pass to deliver 90 J?

Work:

Answer: _____

Slide 5 of 7 · A charge accelerated through a voltage

Voltage supplies energy and the particle turns it into speed. Rearrange $\Delta V = \Delta E/q$ to $\Delta E = q\Delta V$. Kinetic energy is $E_k = \frac{1}{2}mv^2$; the small i means _____ and f means _____. Only the electric force changes the energy here, so all of $q\Delta V$ becomes kinetic energy: $q\Delta V$ = _____.

The initial term drops out only when the problem says _____ (v_i = _____). Do not drop it automatically.

From rest: v = _____, where $E_k = q\Delta V$. If it is already moving, find the _____ energy $\frac{1}{2}mv_i^2$ and the _____ $q\Delta V$. Final E_k = start + gain, then solve for v.

Use the particle's own q and m (electron, proton and alpha particle differ). Check: a particle sped up by the voltage must end _____ than it started.

Example. An electron starts from rest at the negative plate of an electron gun and is accelerated through $\Delta V = 1.80 \times 10^3$ V. With $q = 1.60 \times 10^{-19}$ C and $m = 9.11 \times 10^{-31}$ kg, find its speed at the positive plate.

Work:

Answer: _____

Try it. An electron enters the gap at $v_i = 1.50 \times 10^7$ m/s and is accelerated through $\Delta V = 6.00 \times 10^2$ V. Find its final speed. Use $q = 1.60 \times 10^{-19}$ C and $m = 9.11 \times 10^{-31}$ kg.

Work:

Answer: _____

Slide 6 of 7 · Method: how to find the speed of a charge accelerated through a voltage

Step 1: write the energy rule _____. The energy gained from the voltage becomes _____.

Step 2: find the energy _____: qΔV, with the size of the charge in coulombs and the voltage in volts. The answer is in _____.

Step 3: find the _____ energy. “From rest” means ½mv_i² = _____. If it is already moving, work out ½mv_i² with the particle’s own _____.

Step 4: final Ek = start + _____. Then v = _____. Check: the unit is _____, and a particle sped up by the voltage ends _____ than it began.

Example. An electron starts from rest and crosses a gap with a voltage of 1.80×10^{3} V. With $q = 1.60 \times 10^{-19}$ C and $m = 9.11 \times 10^{-31}$ kg, find its speed at the end.

Work:

Answer: _____

Try it. A proton starts from rest and is accelerated through 2.00×10^{3} V. With $q = 1.60 \times 10^{-19}$ C and $m = 1.67 \times 10^{-27}$ kg, find its final speed.

Work:

Answer: _____

Slide 7 of 7 · The electron volt

The electron volt (eV) is a unit of _____, not of voltage. One eV is the energy an electron gains when accelerated through _____.

1 eV = qΔV = $(1.60 \times 10^{-19}\ \text{C})(1\ \text{V})$ = _____ (data sheet).

A charge of n electrons gains _____ for each volt: an electron through 24.0 V gains _____ eV, an alpha particle (charge 2e) through 15.0 V gains _____ eV.

To switch units: eV × 1.60×10^{-19} = _____, and joules ÷ (1.60×10^{-19}) = _____. The equation ΔE = qΔV still needs joules, coulombs and volts. Read the unit in the question first and finish in it.

Example. An alpha particle (charge 3.20×10^{-19} C) is accelerated from rest through 45.0 V. Find the kinetic energy it gains, first in electron volts and then in joules.

Work:

Answer: _____

Try it. An electron enters the gap at 1.0×10^{6} m/s and is accelerated through 80.0 V. Find its final kinetic energy in electron volts. Record the answer as a.bc × 10^{n} eV. Use m = 9.11×10^{-31} kg.

Work:

Answer: _____

B6 · practice

Potential difference: energy per charge | Questions 1-2 of 7

Constants from the Alberta Physics 30 data sheets: $k = 8.99 \times 10^{9}$ N·m²/C², $e = 1.60 \times 10^{-19}$ C, electron mass $m_e = 9.11 \times 10^{-31}$ kg, proton mass $m_p = 1.67 \times 10^{-27}$ kg, $g = 9.81$ m/s².

Easy · B6-N01. A charge of 5.0×10^{-18} C is moved between two points, and 1.5×10^{-16} J of energy is stored. Find the potential difference.

Work:

Final answer (with unit and sign): _____

Easy · B6-N02. A 12 V battery drives 8.0 C of charge through a motor. How much energy does the battery deliver, in joules?

Work:

Final answer (with unit and sign): _____

B6 · practice

Potential difference: energy per charge | Questions 3-4 of 7

Easy · B6-N03. The potential difference between two points is 30 V. A second charge, twice as large, is moved between the same points. What is the new potential difference?

A. 60 V, because the charge doubled
B. 15 V, because q is in the denominator
C. Zero, because the energy cancels
D. 30 V, because ΔV belongs to the points and not to the charge

Work:

Final answer (with unit and sign): _____

Medium · B6-N04. An electron is accelerated from rest through 3500 V. Use $e = 1.60 \times 10^{-19}$ C and electron mass $m_e = 9.11 \times 10^{-31}$ kg. Find its final speed.

Work:

Final answer (with unit and sign): _____

B6 · practice

Potential difference: energy per charge | Questions 5-6 of 7

Medium · B6-N05. A particle with charge 4.80×10^{-19} C is accelerated from rest through 25.0 V. Find the kinetic energy it gains, in electron volts.

Work:

Final answer (with unit and sign): _____

Challenging · B6-N06. An electron enters a gap moving at 2.0×10^{7} m/s and is accelerated through 4.00×10^{2} V. Find its final speed.

Work:

Final answer (with unit and sign): _____

B6 · practice

Potential difference: energy per charge | Questions 7-7 of 7

Challenging · B6-N07. An electron and a proton are each accelerated from rest through the same 100 V. Which gains more kinetic energy, and which ends with the greater speed? Explain.

Work:

Final answer (with unit and sign): _____