Chapter 19 - part deux

- Can we "normalize" this energy to energy per unit charge like we did with Force and Electric Field?

$$PE_a$$ Electric Potential Energy (J)

$$V_a = \frac{PE_a}{q}$$ Electric Potential (J/C) or (V)

$$V_{ba} = V_b - V_a = \frac{PE_b - PE_a}{q}$$ Electric Potential Difference

$$\boxed{\Delta PE = qV_{ba}}$$

Example

- Suppose an electron is accelerated from rest through potential difference (V_b - V_a = V_{ba} = +5000V)
  - What is the change in the electrical potential energy of the electron?
  - What is the KE of the electron?
  - What is the speed of the electron ($m = 9.11 \times 10^{-31}$ kg) as a result of this acceleration?

Example

- Can we use the understanding of "potential difference" to learn how an electron moves between charged plates?

$$\Delta PE = qV_{ba}$$

$$\Delta PE = q\left(V_b - V_a\right)$$

$$\Delta PE = (-1.6\text{x}10^{-19})(5000\text{V- }0\text{V})$$

$$\Delta PE = (-8.0\text{x}10^{-16}\,\text{J})$$

- So, the electron loses potential energy in the process.

Example

- …but how does the electron move? Let's remember the Conservation of Energy.

$$\Delta KE + \Delta PE = 0$$

$$\Delta KE = -\Delta PE$$

$$KE_b - KE_a = -\Delta PE$$

$$\tfrac{1}{2}m(v_b)^2 - \tfrac{1}{2}m(v_a)^2 = -\Delta PE$$ assume $v_a = 0$

$$\tfrac{1}{2}m(v_b)^2 = -\Delta PE$$

Example

- …but how does the electron move? Let's remember the Conservation of Energy.

$$\tfrac{1}{2}m(v_b)^2 = -\Delta PE \qquad \text{but} \qquad \Delta PE = qV_{ba}$$

$$\tfrac{1}{2}m(v_b)^2 = -qV_{ba}$$

$$(v_b)^2 = \frac{-2qV_{ba}}{m} \qquad v_b = \sqrt{\frac{-2qV_{ba}}{m}}$$

Example

- …but how does the electron move?

$$v_b = \sqrt{\frac{-2qV_{ba}}{m}}$$

$$v_b = \sqrt{\frac{2\left(-(-1.6\text{x}10^{-19})(5000\text{V})\right)}{9.11\text{x}10^{-31}}}$$

$$\boxed{v_b = 4.2\text{x}10^{7}\ \text{m/s}}$$

Example

- How about a proton moving between plates with a potential (Difference) of -5000 V?

$$\Delta PE = qV_{ba}$$

$$\Delta PE = (+1.6\text{x}10^{-19})(-5000\text{V})$$

$$\Delta PE = (-8.0\text{x}10^{-16}\,\text{J})!$$

- The energy difference is the same. What about the velocity?

Example

- …but how does the proton move?

$$v_b = \sqrt{\frac{-2qV_{ba}}{m}}$$

$$v_b = \sqrt{\frac{2\left(-(+1.6\text{x}10^{-19})(-5000\text{V})\right)}{1.67\text{x}10^{-27}}}$$

$$\boxed{v_b = 9.8\text{x}10^{5}\ {}^{\text{m}}\!/_{\text{s}}}$$

Potential vs. E-Field

$$W = -qV_{ba}$$

$$W = qEd$$

$$qEd = -qV_{ba}$$

$$E = \frac{-V_{ba}}{d}$$

Note, charge drops out.
Why?

Do One

- Consider the previous Example again. If the plates are separated by 15.0 cm, what is the magnitude of the E-Field?

A. $+3.3\text{x}10^4$ V/m

B. $+3.3\text{x}10^2$ V/m

C. 0 V/m

D. $-3.3\text{x}10^2$ V/m

E. $-3.3\text{x}10^4$ V/m

Do One

- Consider the previous Example again. If the plates are separated by 15.0 cm, what is the magnitude of the E-Field?

  A. **+3.3x10^4 V/m**

  B. +3.3x10^2 V/m

  C. 0 V/m

  D. -3.3x10^2 V/m

  E. -3.3x10^4 V/m

$$E = \frac{-V_{ba}}{d}$$

$$E = \frac{-(-5000\ \text{V})}{0.15\ \text{m}}$$

$$\boxed{E = 3.3\text{x}10^4\ \text{V}/\text{m}}$$

Example

- The question asks for "magnitude" so even if the answer is negative we just ignore the sign and include the numerical answer only.

See One

- The strength of the electric field for a spark through air is a constant **3x10⁶ V/m**, what is the magnitude of the Voltage of a 1.5 mm static-electrical spark that jumps from you finger to your sibling's ear?

$$V_{ba} = Ed$$

$$V_{ba} = (3.0 \text{x} 10^{6}\ \text{V}/\text{m})(1.5 \text{x} 10^{-3}\ \text{m})$$

$$V_{ba} = 4500\ \text{V}$$

Do One

- An average lightning bolt has a potential difference of $5x10^8$ Volts, what is the length of the lightning?

$$V_{ba} = Ed$$

$$d = \frac{V_{ba}}{E}$$

$$d = \frac{(5.0x10^8 \ \text{V})}{(3.0x10^6 \ {}^{\text{V}}\!/_{\text{m}})} \simeq 166\text{m}!$$

electron-Volt = Energy

- Remember…

$$\Delta PE = qV_{ba}$$

- So, to move one electron through one volt of potential difference requires…

$$\Delta PE = (-1.6\text{x}10^{-19}\,\text{C})(1\text{V})$$

- …but

$$(\text{C})(\text{V}) = \text{J}$$

- …so,

$$\Delta PE = 1.6\text{x}10^{-19}\,\text{J} \equiv 1\ \text{eV}$$

Potential for a Point Charge

- Remember, …

$$E = \frac{V}{d}$$

- Note: we're only interested in the magnitude right now.
- Can you derive the potential formula for a point charge?

Potential for a Point Charge

- So...

$$E = \frac{V}{d}$$

$$V = dE$$

- but...

$$E = \frac{kq}{r^2}$$

- So...

$$V = \left(\frac{kq}{r^2}\right)r$$

Potential for a Point Charge

- So…

$$V = \left(\frac{kq}{r}\right)$$

- NOTE: this is a **<u>scaler</u>** not a vector (so, no TRIG!) Also, …

$$V_{total} = \sum V_i$$

$$V_{total} = V_1 + V_2 + \cdots + V_n$$

… Point Charges

- Determine the potential at a location 10.0 cm from q_1=10 μC which is also 32.5 cm from q_2=-5.0 μC.

$$V_{total} = \left(\frac{kq_1}{r_1}\right) + \left(\frac{kq_2}{r_2}\right)$$

$$V_{total} = \left(\frac{(9\text{x}10^9)(10\text{x}10^{-6})}{1\text{x}10^{-1}}\right) + \left(\frac{(9\text{x}10^9)(-5\text{x}10^{-6})}{3.25\text{x}10^{-1}}\right)$$

$$V_{total} = 900{,}000\text{ V} + \left(-138{,}461\text{ V}\right)$$

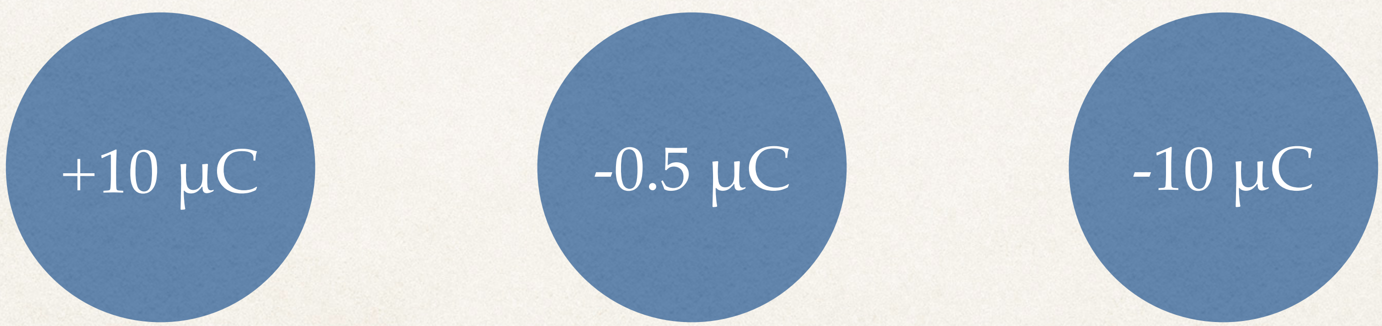
$$\boxed{V_{total} = 761{,}538\text{ V}}$$

Group Work

- Please post the solutions to the following three problems on PILOT in the drop box for today.

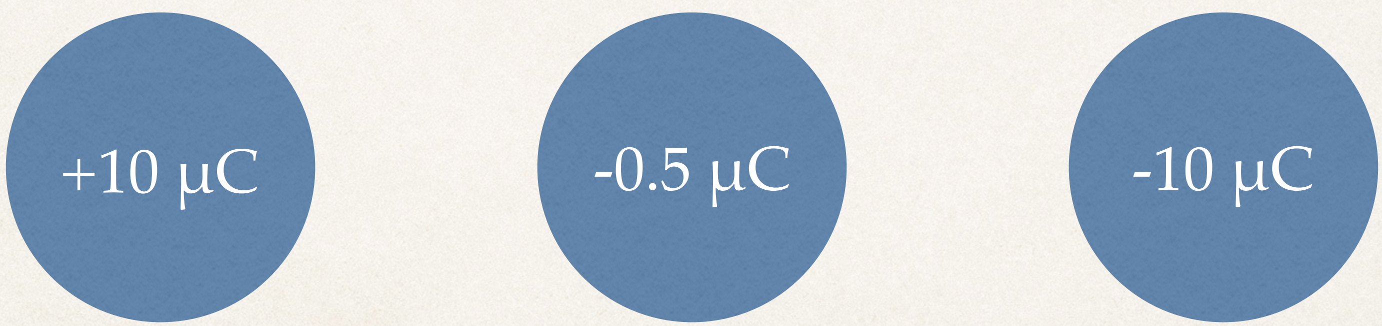
Forces, Fields, and Potentials

- A +10 μC and a -10 μC charge are spaced 20 cm apart. a -0.5 μC charged is placed exactly in the middle between the charges. Determine the Force on the -0.5 μC charge.



Forces, Fields, and Potentials

- A +10 μC and a -10 μC charge are spaced 20 cm apart. a -0.5 μC charged is placed exactly in the middle between the charges. Determine the E-Field at the -0.5 μC charge.



Forces, Fields, and Potentials

- A +10 μC and a -10 μC charge are spaced 20 cm apart. a -0.5 μC charged is placed exactly in the middle between the charges. Determine the Electrical Potential at the -0.5 μC charge.