08-10

Voltage/Potential

Electric Potential/Voltage

- Potential energy: Defined as stored energy
  - Examples
    - lift a heavy weight off the ground
    - Pull a rubber band back
    - Move an electron the opposite way an electric field want to push it (release it, and field will push it forward)
- Electric potential
  - Potential energy per charge, AKA: Volts (V)
  - Since energy is in Joules and charge in coulombs:
  - Most basic formula is V = J/C (Volts = Joules/Coulombs)
  - More directly: $\Delta V = kq/r$ (PE is Fd, PE = $F = kq_1q_2/r^2$)
    - r is the distance from charge (you find ΔV at a point in space)
    - q is the charge (can be + or -, so ΔV can be + or -)

Force - Coulomb's law (N) $F = k \dfrac{q_1 q_2}{r^2}$ • A single charge can't create a force (what would it push on...see Newton's 3 law!), so you have two q's for a force • Forces are vectors • r is the distance between charges • Negative values mean attraction and positive values mean repulsion	Electric Field Strength (Normalized Force, N/C, V/m) Force per charge $E = \dfrac{F}{q} = \dfrac{kq}{r^2}$ • r is the distance between charges • Electrics fields are vectors, there is a direction associated with electric fields • There is only q, because a single charge sets up an electric field, just like a single mass sets up a gravitation field (like earth has a gravitational field surrounding it) • See the charge, be the charge - just like you should have a <u>positive</u> attitude while studying this, you need to pretend you are a <u>positive</u> charge to figure the correct direction!
Work/Electrical Potential Energy (Force x Distance, J) Work = F x r, since r is the distance $W \text{ or } EPE = k \dfrac{q_1 q_2}{r}$ • This is the work done to bring a q_2 from ∞ to a distance r away from q1 • If q_2 and q_1 are like charges, they repel each other and <u>you do positive work</u> to bring them together (like pushing a spring inward, the force you have to apply means you are storing energy in the spring and doing work) • If q_2 and q_1 are opposite charges, they attract each other and <u>you do negative work</u> by allowing them together (like you released a previously compressed spring - you are getting rid of the energy stored in the spring) • You can do positive and negative work, but work and energy are scalars - positive and negative are useful for keeping track of conservation of energy • We say there is electrical potential energy associated with charges when they are close enough to interact	Voltage (Normalized Work/Energy, J/C ≡ Volts) Work per charge, known as "Electrical Potential" $\Delta V = \dfrac{W}{q} = \dfrac{kq}{r}$ • Since voltage is normalized, a single charge sets up a voltage (moving another charge into its "field" <u>would</u> require work per charge and change the energy per charge...see the connection with electric field strength?) • Voltage is a scalar, like work, there are positive and negative voltages, so be careful with you accounting for complex systems using multiple charges (keep + and - signs for charges!) • Voltage and electrical potential are synonyms; you often hear voltage called electrical potential, so: a) know the term b) distinguish it from electrical potential energy • You can think of something with high voltage as having a lot of energy or "push" for any charge residing in such a location

<u>NOT NOTES!</u>

My summary sheet..don't copy any of this, you get a summary page from me. This is just a reference (*120130StaticElectricityVoltageEtcWhyItsUsefulAndEquationSummaryJohnWilliams.docx*)

Static Electricity Equations

Equation	SI Units	Vector?	Comments
$F = kq_1q_2 /r^2$	N	Vector	Coulombs law; neg. value = attractive force
$E = F/q = kq/r^2$	N/C V/m	Vector	Electric Field Strength; direction? Pretend to be a positive test charge.
$\Delta PE = qEd$	J	Scalar	Only works if “uniform electric field”, like capacitors have
$\Delta V = kq/r = \Delta PE/q$	V J/C	Scalar	Voltage drop; what pushes circuit’s electrons; Voltage is the amount of energy per C of charge; Think about storing E in a spring (pushing two like charges stores energy); Just like you can do pos. or neg. work, you can have pos. or neg. voltage. Works for multiple charges.
$W = kq_1q_2 /r$	J	Scalar	W = Force x Distance; pushing charges together does positive work (stores energy just like compressing a spring); Negative work is done when PE is reduced (letting a pos. and neg. charge move together)
$\Delta V = Ed$	V	Scalar	Only works in “uniform electric field”, like capacitors have
$Q = ne$	C	Scalar	Charges are quantized (integer multiples of e, the fundamental charge)

Choosing the correct equation

Electrostatics - What equation should I use?

1. Someone whose name rhymes with "trivia" rubs 50,000 electrons from her hair onto a rubber balloon. If the balloon is held 25 mm from her hair, what is the electrostatic force between the balloon and her hair? (-9.22E-16 N)
2. What is the voltage at .30 µm from a +12 mC charge? (+3.60E+14 V)
3. From the previous problem, what would be the voltage in the same location if there were **also** a -24 µC charge 320 mm from the same location?

(-3.15E+14 V = (+3.60E+14) + (-6.75E+14 V)…voltage due to 2nd charge)

4. How much work is required to bring three charges together assuming they are separated by 74 µm? Space all the charges equally distant forming an equilateral triangle. The top-most charge is an alpha particle, the bottom two charges, each have 10 excess electrons.

(1.87E-22 J = (3.11E-22 J) + (-6.23E-23 J) + (-6.23E-23 J))

(Note: Negative work done for both neg-pos charge interactions, and positive work is done to bring two negative charges close together (compared to infinity))

(Think about it…you do positive work when you push things where they don't wanna go)

5. How much does the voltage change when a charge moves 25 µm in a uniform electric field whose strength is 300 N/C? (0.0075 V, to know whether this is pos. or neg. would need to know charge sign and direction charge moved relative to field)
6. What is the potential difference 0.15 mm from a +64 nC charge compared to very far from that charge? (+3,840,000 volts)

Need even more practice?

1. How much voltage would there be at 15 µm from a charge with 45 surplus electrons? (-0.00432 V)
2. What force exists between two charges 75 nm apart if one has a charge of +0.0050 nC and the other has 2.00 million surplus electrons? (-2.56 N)
3. How much work is needed to put 3 charges like below?

(W = 288 J: W_{68} = +1440 J, W_{84} = -720 J , W_{64} = -432 J)