Electric Fields

Net charge carried by a glass rod rubbed with silk is <u>positive</u>.
Net charge carried by a an amber rod rubbed with wool is <u>negative</u>.

Electrons carry negative charge and protons positive charge.

Which rod(s) will attract small pieces of paper? Why?

Which rod(s) will attract molecules of water? Why?

Which rods will attract small pieces of aluminum foil? Why?

What is 'grounding'?

Electroscopes can only indicate whether or not an object has a net charge. It cannot determine whether i's is positive or negative.

Charging by conduction refers to charging an uncharged object by placing it in contact with a charged body. Charging by induction refers to charging an uncharged object by bringing it close to a charged object, without allowing the two objects to come into contact.

Charge quantization:

$q = n \cdot e$

q (or Q) : charge (unit: C for coulomb)

n : whole number

e : elementary charge

$e = 1.6 \times 10^{-19} C$ $\quad e^- = -1e$ $\quad p^+ = +1e$

Coulomb's Law : $F_e = \frac{k q_1 q_2}{r^2}$ $\quad k = 9 \times 10^9 \frac{N \cdot m^2}{C^2}$

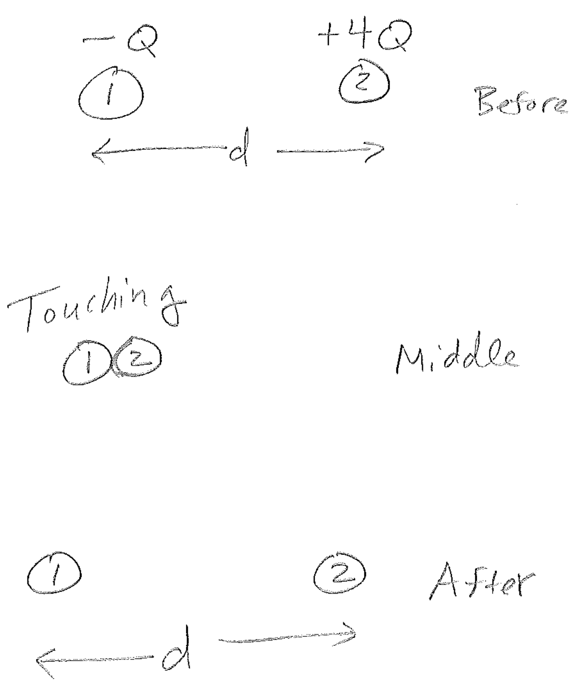
$K = \frac{1}{4\pi \epsilon_0}$ $\quad \epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N \cdot m^2}$

ϵ_0 is the permitivity of free space

For Coulomb's Law assume q_1 & q_2 are point charges.

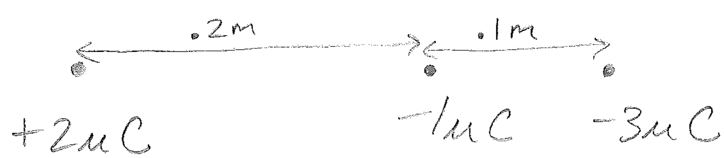
Charge Conservation

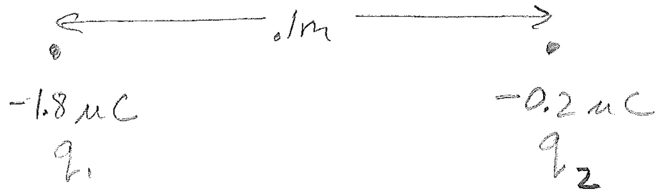
F_0



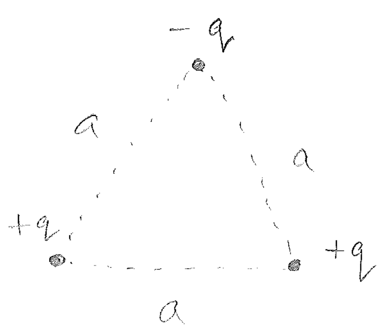
By what factor does F_0 change after the spheres touch and return to their original distance apart?

Find the net electric force on $-3\mu C$.





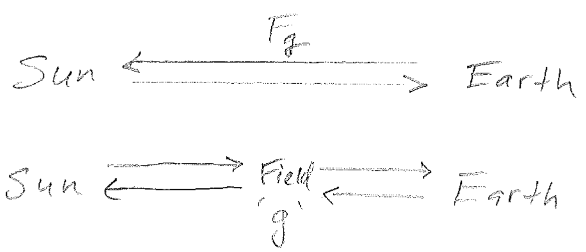
Where could a third charge (q_3) be placed so that the net electric force on q_3 would be zero?



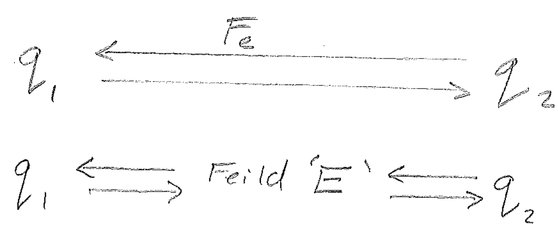
$q = .1 \mu C$, $a = .12\,m$. Find the net electric force on a.) the $-q$ and b.) the $+q$ in the lower right corner.

If you drop a vertically hanging slinky from the top, will the bottom of the slinky begin to fall immediately? Or will it delay?

If the sun all of a sudden disappears, what will happen to the earth?



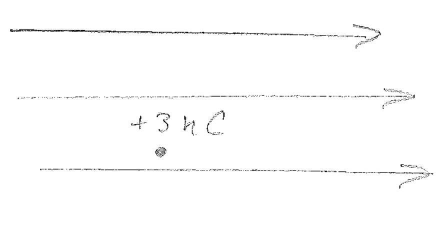
$F_g = m \cdot g$



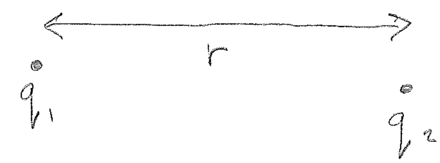
$F_e = q \cdot E$

$F_e = q\,E$ or $E = \frac{F_e}{q}$ The unit for E is N/C

Find the electric force acting on the +3nC charge in the 2000 N/C eastward electric field.



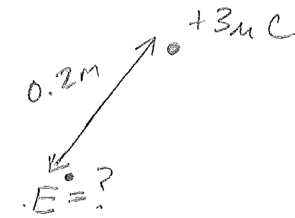
$$F_e = \frac{K q_1 q_2}{r^2}$$



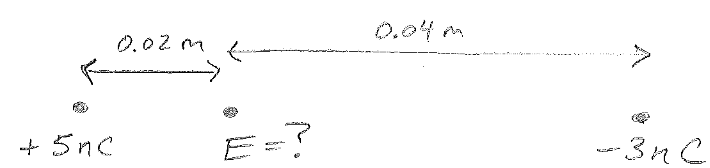
$$q_1 \rightarrow E_1 \rightarrow q_2$$

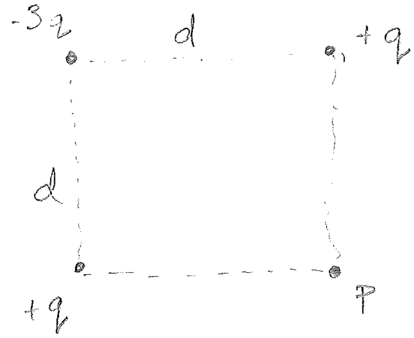
$$F = q_2 E_1$$

Find the the magnitude and direction of the electric field :

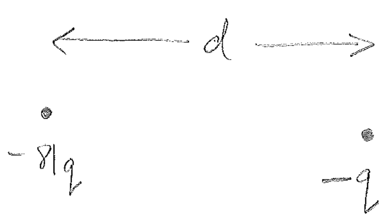


Find the magnitude and direction of the electric field:

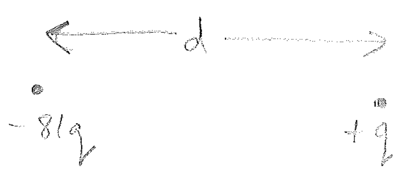




Find E at point P.



Where is the E=0?



Where is the E=0?

Electric Field Lines (or lines of force):

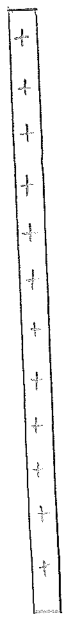
1. The direction of the lines is the direction of the field.
2. The density of lines is proportional to the strength of the field.
3. The lines originate from + charge or ∞ and end on − charge or ∞.
4. The # of lines out of or into a charge is proportional to the magnitude of the charge.

$\oplus q$ $\qquad\qquad$ $\oplus 2q$

$\ominus q$ $\qquad\qquad$ $\ominus 2q$

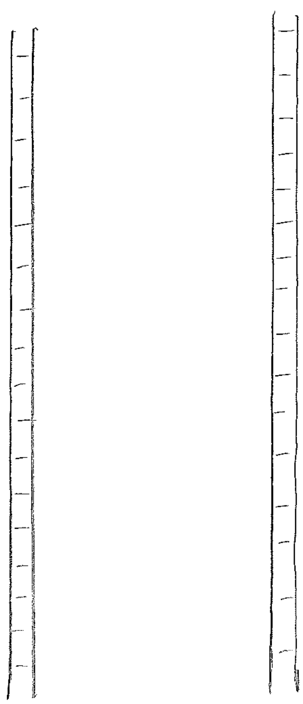
$\oplus q$ $\qquad$ $\ominus q$

Lines of Charges

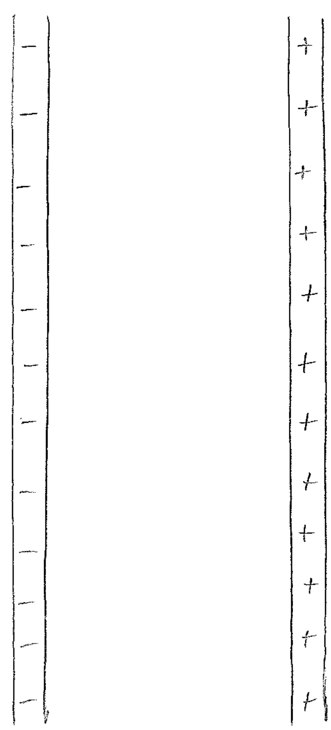


Large Sheet of Charges

Parallel Plates



Parallel Plates



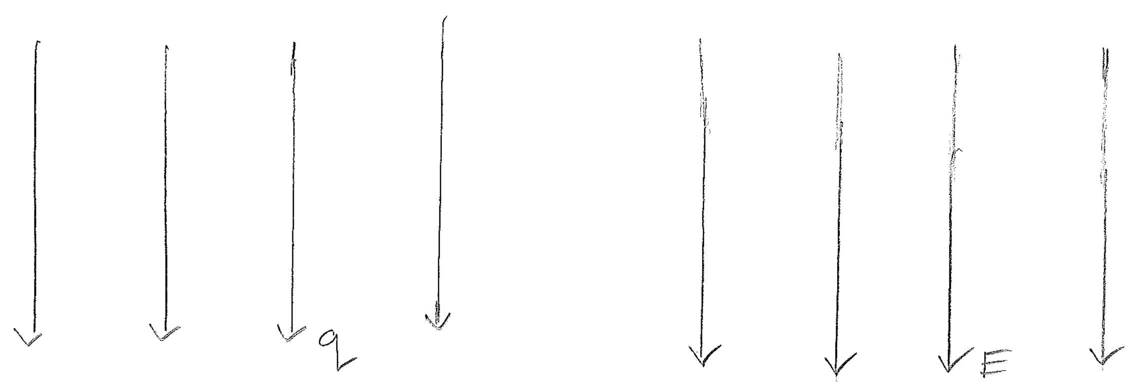
Electric Force is Conservative

Work done by a conservative force does not depend on the path taken. Work done only depends on the initial and final positions.

$\Delta U_{electric} = -Work$ 	U is electric potential energy

V is electric potential 	$V = U/q$

Are 'electric potential' and 'electric potential' energy vectors?



An Al^{+3} ion is released from rest at a point with 200 V and moves to a point with 50 V. Find:

a.) the final KE of the ion b.) $Work_{electric}$

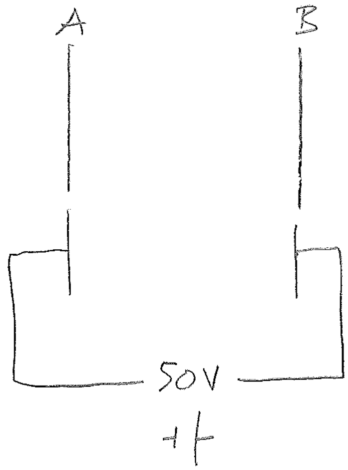
Answer in J and in eV.

What is the best way to create a uniform electric field?

If V = 300 V & d = .6 cm, what is E = ?

$q_{e^-} = 1.6 \times 10^{-19}$ C

What would be the acceleration of a proton in this E field? $M_{proton} = 1.67 \times 10^{-27}$ kg



Two parallel plates connected to a 50V battery are used to accelerate an e^- from rest.

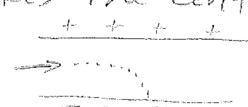
a.) If e^- accelerates from A to B, which plate has higher V?

b.) Find KE_{gain} in eV and J for an e^-

c.) Find the speed of e^- when it arrives at plate B ($M_{electron} = 9.11 \times 10^{-21}$ kg)

Parallel plates with .06 m width and .01 m plate separation provide uniform $E = 2000$ V/m. A beam of p^+ is sent into E midway between plates. The beam strikes the center of the lower plate.

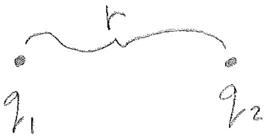
a.) Find the speed of p^+



b.) Find the V used to accelerate p^+. Ignore fringing & relativistic effects.

The potential energy of two charges is zero when they are infinitely far apart. $U_{r \to \infty} = 0$ $\Delta U = \text{work} = k\frac{q_1 q_2}{r}$ (Use signs!)

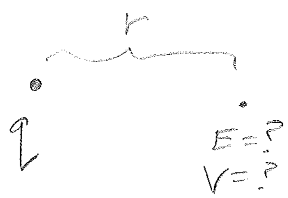
$F = k\frac{q_1 q_2}{r^2}$
(no signs)



$\text{Work} = F \cdot d = \left(\frac{k q_1 q_2}{r^2}\right)\left(\frac{r}{1}\right) = \frac{k q_1 q_2}{r}$

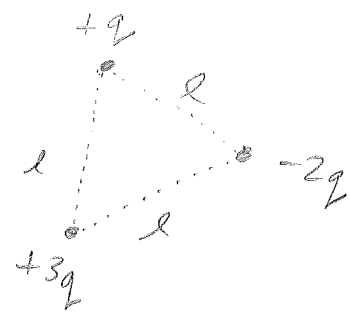
Point Charges

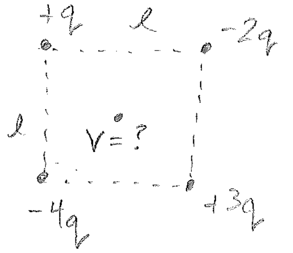
$E = \frac{kq}{r^2}$
(no signs)

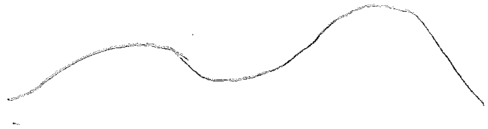


$U = qV$ $V = E \cdot d = \frac{kq}{r^2} \cdot r = k\,q/r$
(Use signs!)

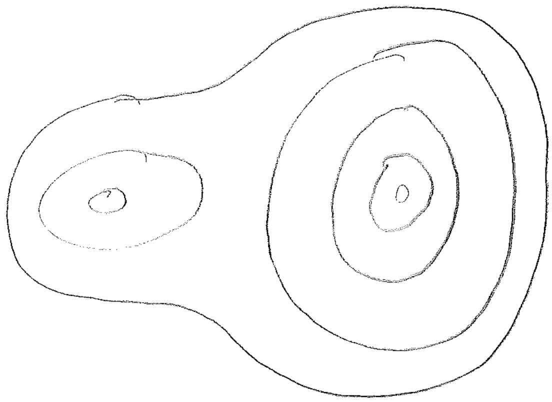
Find a) the total potential energy in the system
b.) the work required to assemble the system







SIDE VIEW



Top View

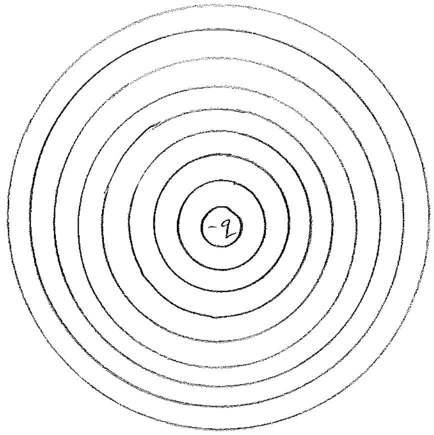
Contour Lines are similar to Equipotential Lines

$Work_{required} = \Delta U = q \cdot \Delta V^{\,0} = 0$

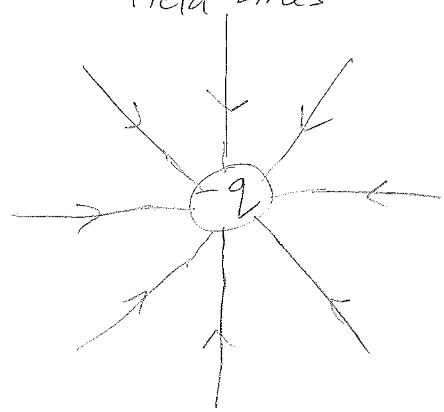
Water flows perpendicular to contour lines similar to the direction of the E field relative to equipotential lines.

$E \perp$ equipotential surfaces

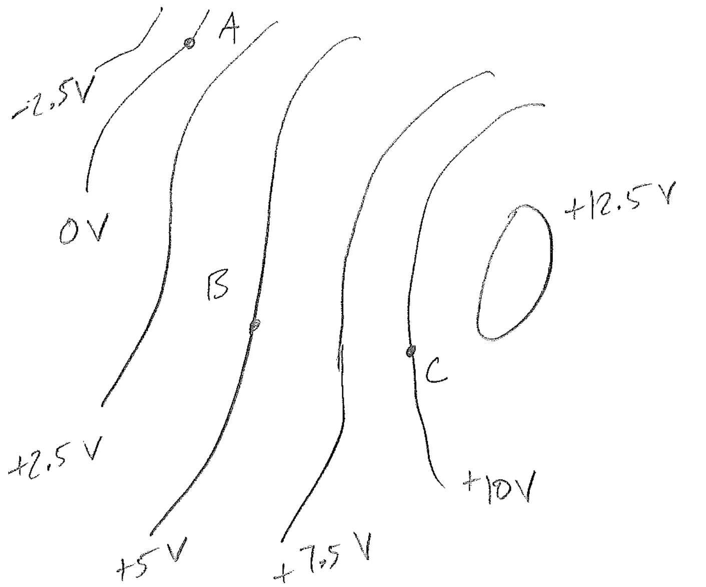
Equipotential Lines



Field Lines



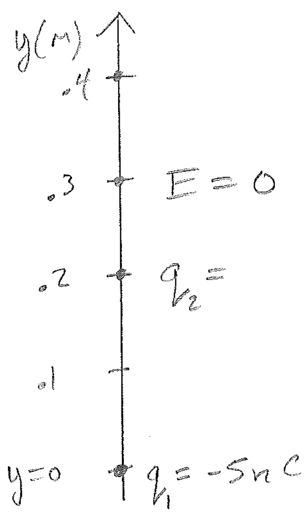
Draw field lines and equipotential lines for two charges near one another:



a.) Draw the direction of the E-field at points A, B or C.

b.) Rank E-field strength at A, B & C from high to low.

c.) Estimate magnitude of the E-field at point B.



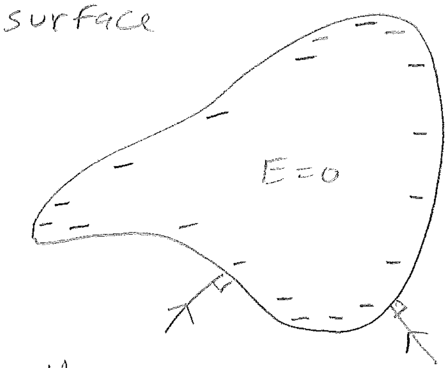
a. $q_2 = ?$

b. Where on the y-axis between q_1 & q_2 is the $V = 0$?

c. $Work_{required} = ?$ to bring $-2\,nC$ from $y \to \infty$ to the location location found in b.

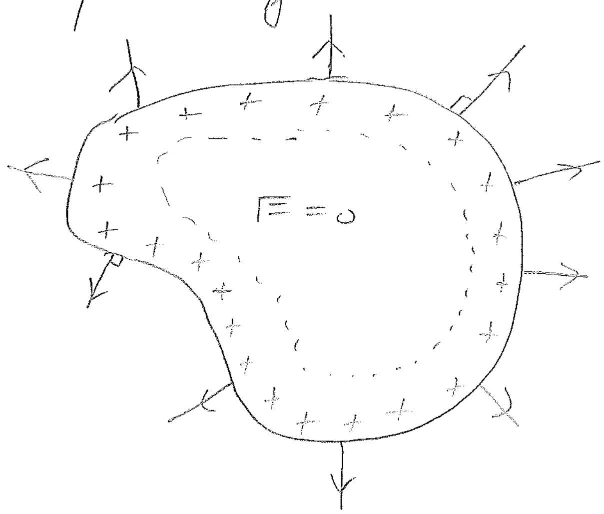
For a conductor in static situation

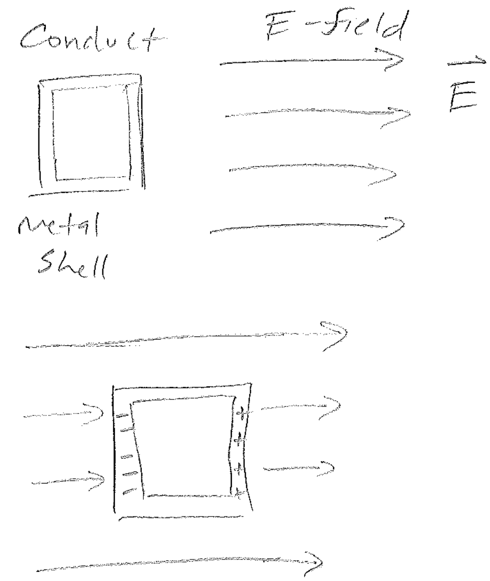
- Net charge can only be found on the surface
- $E = 0$ everywhere inside
- $E \perp$ surface immediately outside
- V is the same everywhere



Equipotential surface means voltage is the same everywhere on that surface.

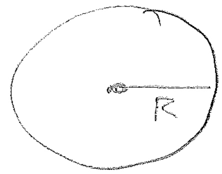
Faraday's Cage



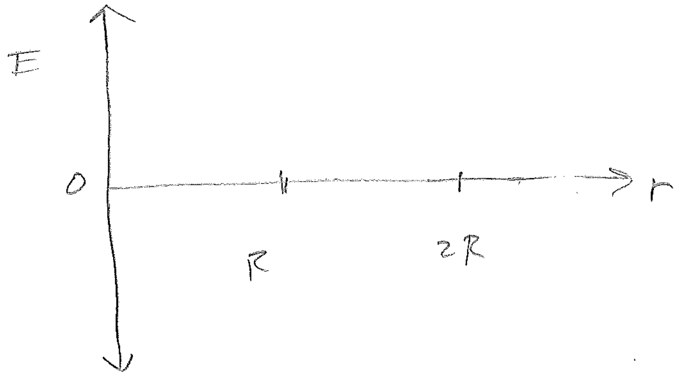


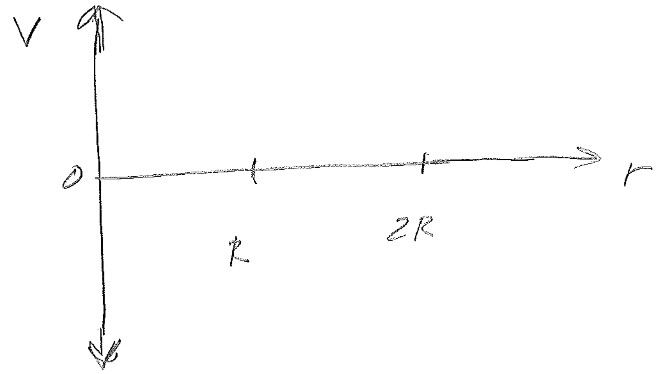
A microwave is an inside out faraday cage.

Conducting Sphere with R & +Q

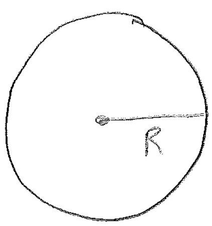


+Q

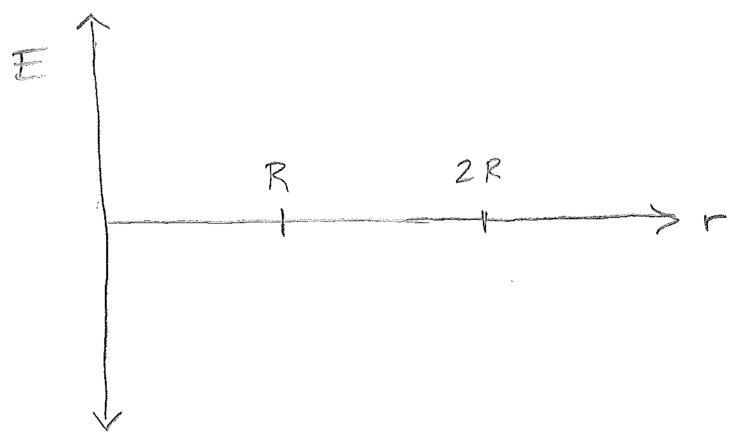


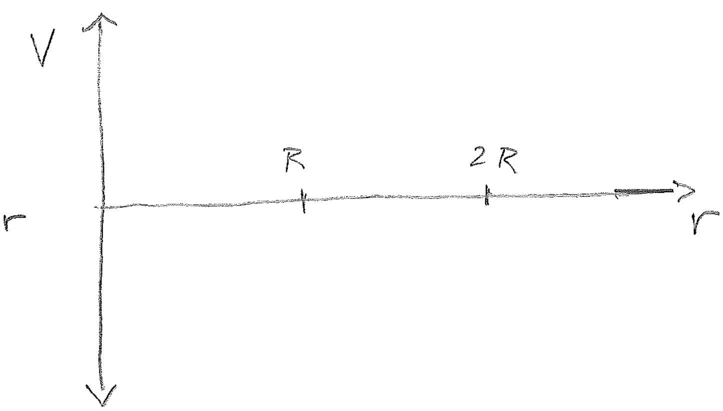


Conducting Sphere with R & -Q



-Q

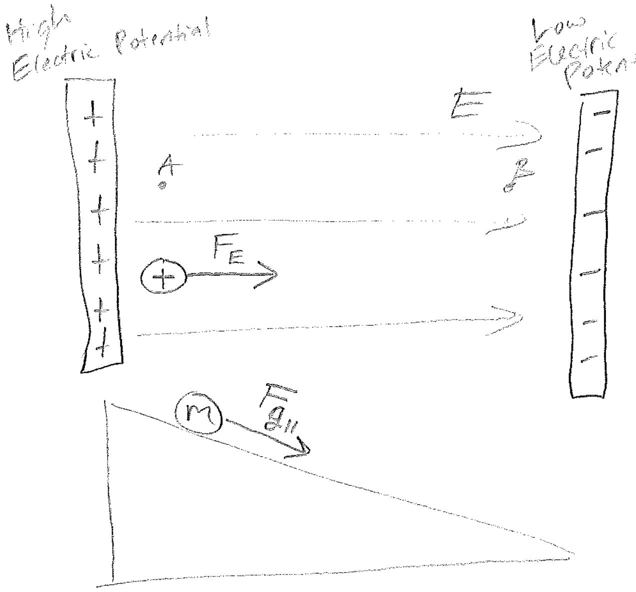




1 eV is the amount of energy associated with moving one electron through a potential difference of 1V.

$1\,eV = 1.6\times10^{-19}\,J$

$PE_A = 10\,eV \qquad PE_B = 2\,eV$



A positive change 'q' is accelerated by an electric field and is given kinetic energy. The process is analogous to an object being accelerated by a gravitational field. Both F_g & F_E are conservative. The path taken does not affect the total work done between two points for conservative forces.

Work done by a conservative force is the negative of the change in potential energy.

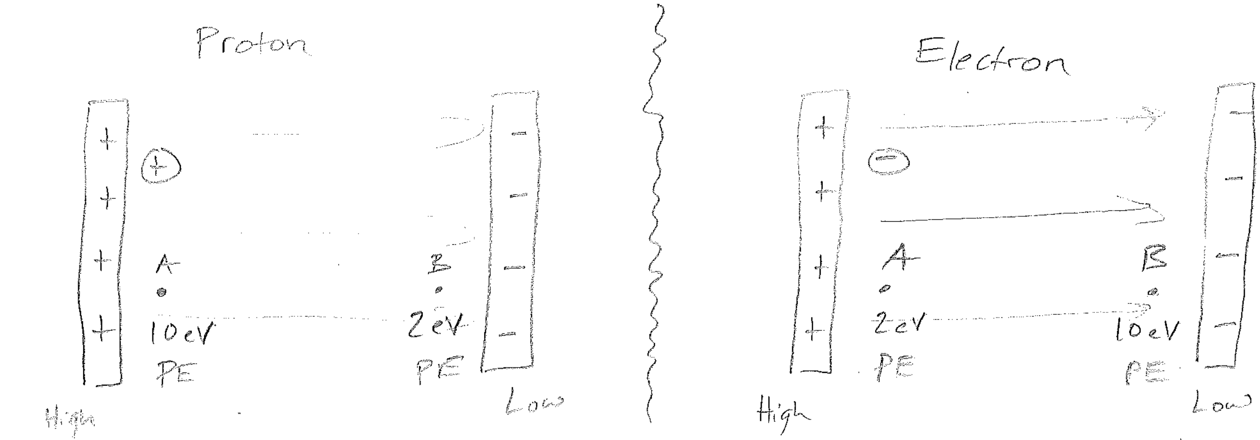
$$\text{Work} = -\Delta PE \qquad \Delta PE = PE_f - PE_i$$

For example, work done to accelerate a positive charge from rest is positive and results in a loss in PE, or negative PE. There must be a minus sign in front of ΔPE to make Work positive.

$+\Delta PE = PE_A - PE_B \qquad -\Delta P = PE_B - PE_A$

$10 - 2 \qquad\qquad 2 - 10$

$\text{Work} = -(+8) = -8\,eV \qquad \text{Work} = -(-8) = +8\,eV$



Electric Potential, Potential Energy & Work

B to A

$\Delta PE = PE_f - PE_i$

$\Delta PE = 10 - 2$

$\Delta PE = +8\ eV$

$Work = -\Delta PE = -8\ eV$

B to A

$\Delta PE = PE_f - PE_i$

$\Delta PE = 2 - 10$

$\Delta PE = -8\ eV$

$Work = -(-8) = +8\ eV$

Electric Potential v. Potential Energy

Higher electric potential by definition is nearer the positive plate while lower potential is nearer the negative plate. Therefore both the electron and the proton have higher electric potential when nearer the positive plate, but the electron would have lower potential energy compared to the proton located at the same position.

I recommend memorizing this convention.