Chap 1. Electrostatics 1

Laws of Electrostatics:

① There are 2 kinds electric charges: "positive "+" and negative "−".
② Like charges repel each other, opposite charges attract.
③ Charged objects attract neutral objects.

Electrostatics:

- Matter is made up of 2 charges, + and − by electrons and protons.
- Neutral objects have equivalent "+" and "−";
- Electrons can be transferred.
- Excess electrons yield negatively charged object.
- Deficit electrons yield positively charged object.

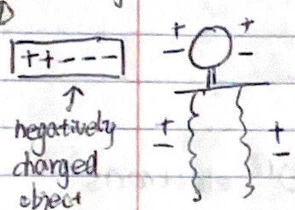
Neutral Objects. − + + − + − + −

Positive ~ + + + + − − −

Negative ~ − + + + + − − − −

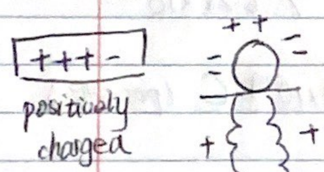
一. Leaf Electroscope Principal

①



The ball on top experience repulsion from negatively charged object, the electrons in the ball tend to escape and therefore transferred to the leafs in the bottom. after all, the leaves become negatively charged since electrons arrived, like charges repel, two leaves separate.

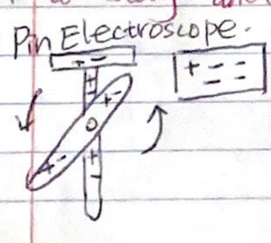
②



The electrons transferred to ball, leaving the two leaves positively charged, like charges repel, two leaves separate.

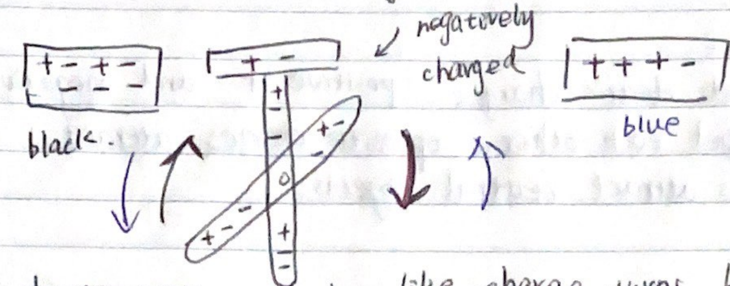
As we can see, electrons have tendencies to move around, positive particles tend to stay and attract

二. Pin Electroscope.



Electrons spread to the bottom. electrons on the swing repels with the electrons on the pole, therefore the swing moves.

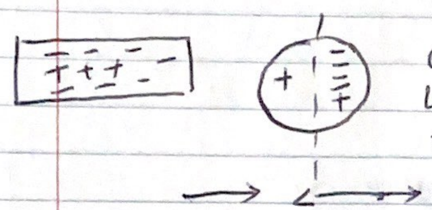
Charged Detector can determine charged objects



- Opposite charge turns vertical, like charge turns horizontal

三. Pith Electroscope only detects presence of charges.

①



electrons got repelled to the other side, leaving protons on the original position, therefore, attract the negative object.

$F \propto \frac{Q_s \text{ (charges)}}{r^2 \text{ (square of distance)}}$

Quantifying Electric Charge:

- Symbol for electric charge : Q or q.
- SI Unit for electric charge: Coulomb, C, which is 6.25×10^{18} electrons.
- the charge on one electron would be 1.60×10^{-19} C or $1/6.25 \times 10^{18}$.
- Elementary charge is $e = 1.60 \times 10^{-19}$ C.
- Electrons have charge $-e$ or -1.6×10^{-19} C, protons have 1.6×10^{-19} C (positive)

$Q = n \cdot e$ (n is # of electrons, e is elementary charge)

An object has a charge of +2.5C, If you remove 3.5×10^{18} electrons, find charge.

$2.5 - (-1.6 \times 10^{-19} \times 3.5 \times 10^{18}) = 3.06$ C

Coulomb's Law

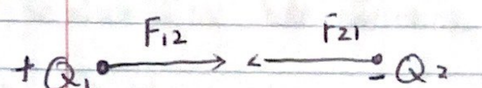
- The coulomb force is the force of repulsion attraction between charges. It is also called the Electric Force or Electrostatic Force.

K is the coulomb's Law Constant. $K = 9.00 \times 10^{9}\ N \cdot m^2/C^2$

$$\boxed{F = \frac{KQ_1Q_2}{r^2}}$$ $Q_1 Q_2$ in Coulomb's. (r in m)

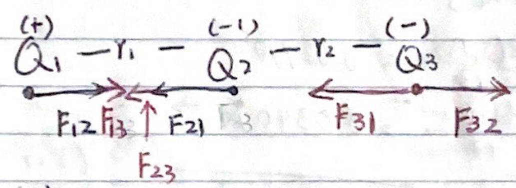
※ Using Coulomb's Law, a negative result means "attractive", positive means "repulsive".

- F_{12} means the force on 1 by 2.

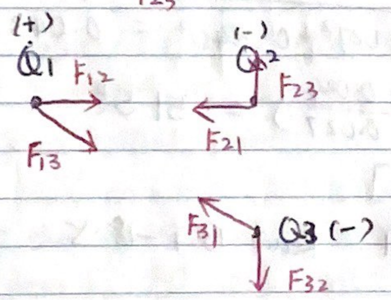


first subscript refers to the charge on which force acts.
Second subsript refers to the charge respoaible for the force.

ex1.



ex2.



Sample Questions in Cuolomb's Law.

1. Find Force of repulsion between two static charges that are 10cm apart if each has magnitude of 3.0 μC.

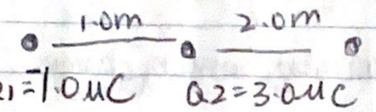
$F = \frac{KQ_1Q_2}{r^2}$

mass of each: $F = \frac{GM_1M_2}{r^2}$

$F = \frac{9.0 \times 10^9 \times [(3.0) \times 10^{-6}]^2}{(0.1)^2}$

$F =$

2. Given three charges on line below, find net force on charge 2.



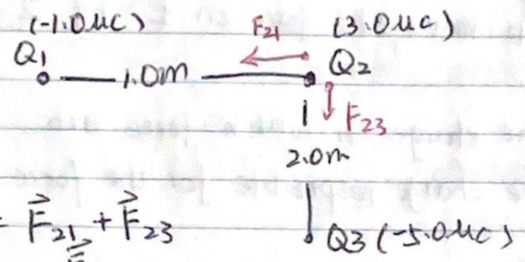
$F_{21} = \frac{KQ_2Q_1}{r^2} = \frac{9.00\times10^{9} \times 3.0\times10^{-6} \times (-1.0)\times10^{-6}}{1.0^2} = (-)\ 0.027\,N$

$F_{23} = \frac{KQ_2Q_3}{r_2} = \frac{9.00\times10^{9} \times 3.0\times10^{-6} \times (-5.0)\times10^{-6}}{(2.0)^2} = (-)\ 0.0340\,N$

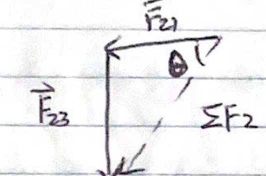
$F_{net} = F_{21} + F_{23} = 0.0270N$ [left] $+ 0.0340N$ [right] $= 0.0070N$ [right]

Note: (+), (-) don't mean directions.

3.



$\Sigma\vec{F}_2 = \vec{F}_{21} + \vec{F}_{23}$



$|F_{21}| = \frac{KQ_1Q_2}{r^2} = 0.027N$

$|F_{23}| = \frac{KQ_2Q_3}{r^2} = 0.0340\,N$

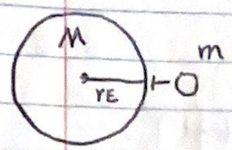
(2 or 3 sig fig)

$|\Sigma\vec{F}_2| = \sqrt{\vec{F}_{21}^{\,2} + \vec{F}_{23}} = \sqrt{0.027^2 + 0.0340^2} = 0.043\,N$

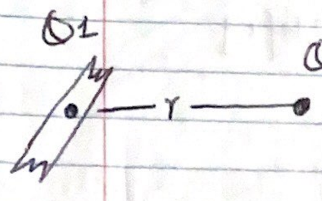
$\theta = \tan^{-1}\left(\frac{\vec{F}_{23}}{\vec{F}_{21}}\right) = \tan^{-1}\left(\frac{0.034}{0.027}\right) = 51.5°$

- $\Sigma\vec{F} = 0.043\,N$ [51.5° S of E]

problems # 1, 6, 17, 21, 31, 38, 51. Read 18.1 - 18.5



$F_g = \left[\frac{GM}{r_E^2}\right]m \Rightarrow g$ $\quad \vec{F}_g = m\vec{g}$, $\vec{g}$ N/kg

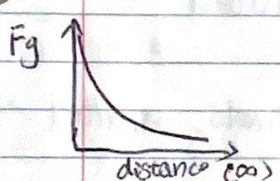


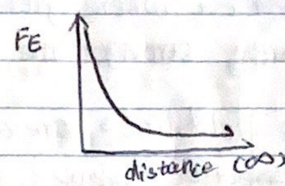
$F_E = \left[\frac{kQ_1}{r^2}\right]Q_2 \rightarrow \boxed{\vec{E}\ N/C}$ $\quad F_E = Q\vec{E}$

Electric Field.

Two charges approach, they exert forces on each other, the space surrounding will be altered by their presence, the altered space is called Electric Field.

A Force Field is any region in space that provides a force another object that enters that space.

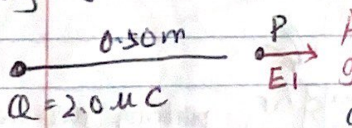




$\vec{F}_E = Q \cdot \vec{E}$

Direction of Electric Field, the direction of electric field at a given point in the field is defined as the direction of the force experienced by a "Positive" test charge at that point.

e.g.1. Calculate the electric field strength and direction at a point, P, 50 cm away from a 2.0 μC static charge.



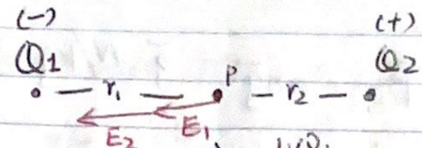
Assume a positive charge at P, the direction the + charge goes, is the direction of the electric Field, in this case it's to the right

$E = \frac{kQ}{r^2} = \frac{9.00\times10^9 \times 2.0\times10^{-6}}{(0.50)^2} = 7.2\times10^4$ N/C [right]

2) Calculate force on a $-3.0\,\mu C$ to its right.

$\vec{F} = Q\cdot\vec{E} = 7.2\times10^4 \times -3.0\times10^{-6} =$ [right]

ex2.

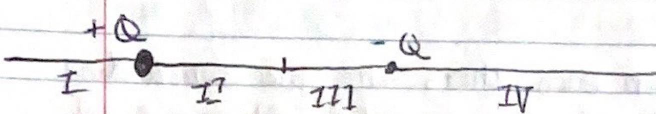


① We calculate $\vec{E_1} = \frac{kQ_1}{r_1}$ [left] ② We calculate $\vec{E_2} = \frac{kQ_2}{r_2}$ [left]

$\vec{E}_{net} = \vec{E_1} + \vec{E_2} = \vec{E_1}$ [left] $+ \vec{E_2}$ [left] $= \vec{E}_{net}$ [left]

Questions: #9, 10, 13, 16, 18, 22, 26, 27

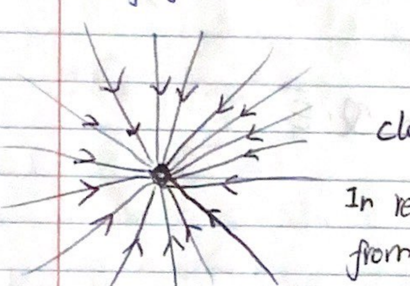
APQ:



Which one has a mgnitude of "0"?

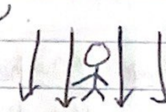
Earth:

Lines of force field lines: – never cross
– Have Direction
– Densest where field is greatest

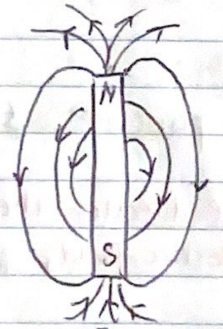


closer to earth, stronger the force

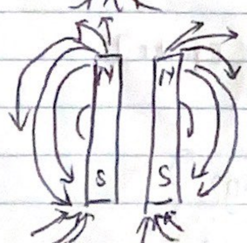
In reality, the field lines are approximately parallel from our ~~perspective~~ view



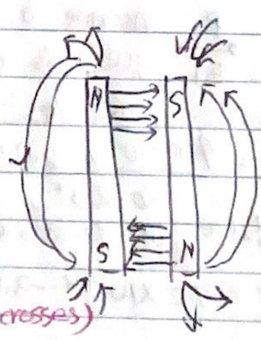
Magnets:



By convention, fields come out from north pole, and into the south pole.



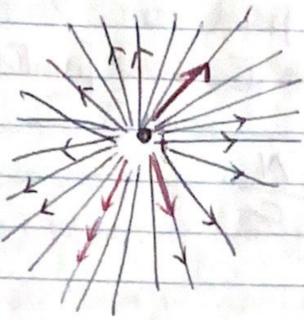
putting 2 magnets with like charges together, notice no electric field in between. (possible crosses)



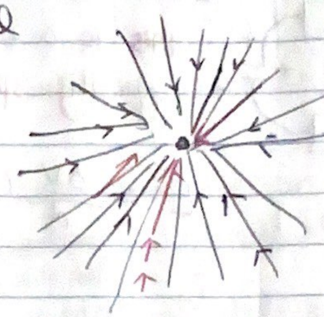
putting two magnets, opposite charges near each other

Mapping Electric Field

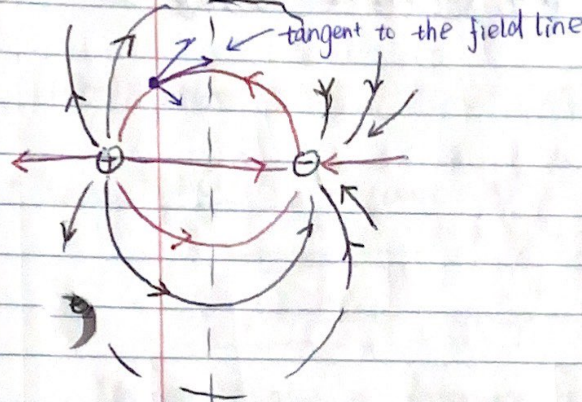
I. +Q.



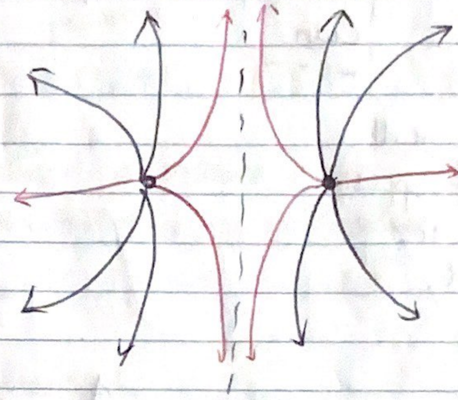
II −Q



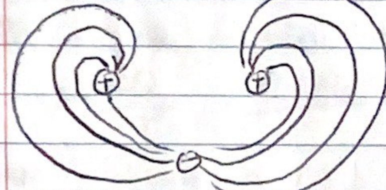
III. |+Q| = |−Q|



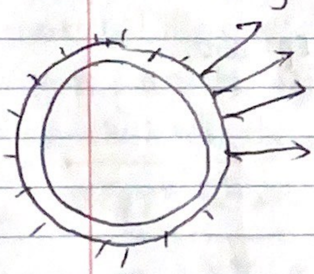
IV +Q = +Q



ex.

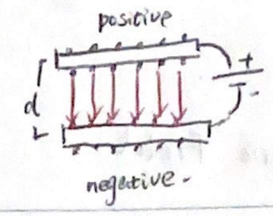


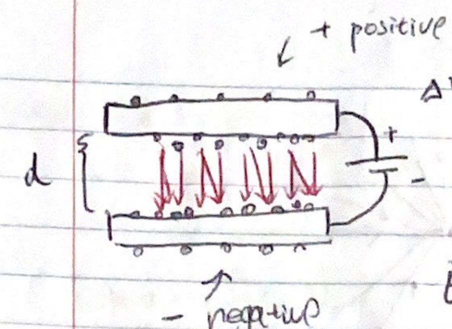
Hollow conducting sphere



only prependiculaw field lines exist, since other lines will cross the ~~ther~~ other lines eventually.

Inside the hollow sphere, no possible field lines exist, since field lines all cross each other, thus no charges exist.

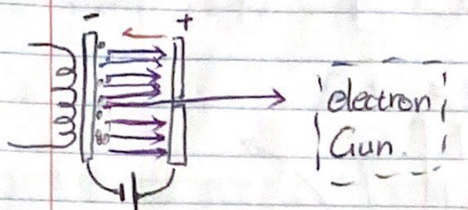




ΔV (voltage)

this is a uniform electric field,
equally spaced, uniform $\vec{E}$ betwee parallel plates

$$\vec{E} = \frac{\Delta V \text{ (volts)}}{d \text{ (meters)}} = \frac{N}{C}$$



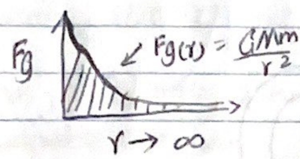
electron Gun

Problems # 4, 5, 11, 32, 45, 48

the electrons will travel to the opposite direction of the electric field.

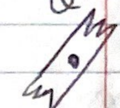
Review:

$$F_G = \frac{GMm}{r^2} \qquad E_p = -\frac{GMm}{r}$$



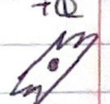
Force // Distance ⇒ + Work.
Force anti // Distance ⇒ - Work.

Electric Potential Energy



Q+ Q⁻

$\longrightarrow F$
$\longrightarrow d$ (try to separate) $+W$ ∞ E_p = zero



+Q +Q

$\longleftarrow F$
$\longrightarrow d$ $-W$ ∞

$W = \Delta E_p$, Energy is a Scalar. $W = \Delta E_p \ (E_{pf} - E_{pi})$

Zero at ∞ Electric Potential Energy

$\boxed{E_p = \frac{KQ_1Q_2}{r}}$ Where +, - must be used for Qs

① If the charges are opposite, it entails an attraction, thus the positive work / potential energy must be ~~positive~~ negative to separate them to ∞.

② If the charges are the same, it entails a repulsion, thus the negative work / potential Energy must be ~~negative~~ positive to separate to ∞

Work Problem : #7, 19, 24, 25, 33, 37, 41, 47, 53.

- $E_p = \left[\frac{KQ_1}{r}\right] Q_2$ = (unit : V) (Voltage is a measure of Electric Potential / Potential) (J/C) [amount of # energy per coulomb]

$\therefore \boxed{V = \frac{KQ}{r}}$ $\therefore E_p = Q_2 \cdot V$ [potential is a scalar]

Voltage is also a difference in potential

example ① Find the potential at a point, P, 2.0 m away from 2.0 μC charge.

Solution $V = \frac{KQ}{r} = \frac{9.0 \times 10^9 \times 2.0 \times 10^{-6}}{2.0}$ = 9000 Volts or 9000 J/C

② How much Ep would a 1.0 μC charge have at point P ?

Solution : $E_p = V \cdot Q = 1.0 \times 10^{-6} \times 9000$ J/C = 0.0090 J

- Potential Difference :

We define potential difference from point A to B to be $\Delta V_{A \to B} = V_B - V_A$ or ΔV, and we thus call the potential difference Voltage.

$\boxed{W = \Delta E_p = Q \cdot \Delta V}$

problems : #3, 8, 14, 28, 29, 33, 35, 39, 43, 44.

15,000V 9,000V

S ———→ T

<- - - - -o-

+o- - - - ->

Negative charges fall up.

Positive charges fall down

Falling means moving in a way such decreases the potential Energy.

Law of Conservation of Energy.

$\Delta E_{total} = 0$

$\boxed{\Delta E_K + \Delta E_P = 0}$

$E_i = E_f$

Speed of a Q accelerating through a potential difference

$\Delta E_K + \Delta E_P = 0$

$\Delta E_K = -\Delta E_P$

$E_{Kf} - E_{Ki} = -\Delta E_P$

$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = -Q\Delta V \rightarrow \frac{1}{2}m(v_f^2 - v_i^2) = -Q\Delta V$

$v_f^2 - v_i^2 = \frac{-2Q\Delta V}{m}$

$$\boxed{v_f = \sqrt{\frac{-2Q\Delta V}{m} + v_i^2}}$$

General Expression.

The final speed of the particles can't exceed 3.0×10^8 m/s (c speed of light)

Physics of Parallel Plates.

$\boxed{\vec{E} = \frac{V}{d}}$ [d is the distance of separation in meters]

When charges are placed between parallel plates:

They experience a force: $\vec{F} = Q \cdot \vec{E}$ / $\vec{F} = Q \cdot \frac{V}{d}$

problems # 2, 20, 23, 30, 34, 36, 40, 45, 52.

Electric Field Line Questions :

ex. Draw the field lines that at least one line crosses "P".

^ isoline ⊥ $\vec{E}$ at P.

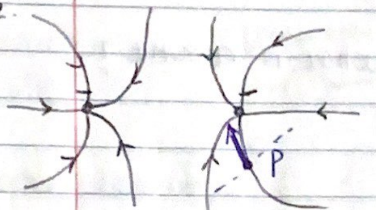
① shape

① Direction

① $\vec{E}$ tangent at P

① Isoline ⊥ to $\vec{E}$ at P.

ex2.

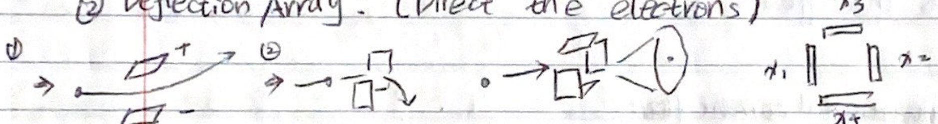


2 negative charges with equal magniude

Voltages :

① Accelerating voltage (Va or V_A), electron gun is supplied a potential difference by this voltage.

② Deflection Array : (Direct the electrons)



※ The faster the electron shot from the electron gun, the brighter the image created. electrons are, however, it would be less affected/ directed by the parallel plates, which means the ultimage image will be smaller.

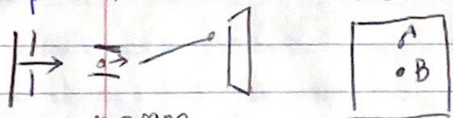


diagram.

To make A to B, we can

① Reduce the potential Difference between the plates,

② Increase the velocity

Protons never move,