Lab Work

Electromagnetism Preview:

If forces are aligned in a line (in dipole), then value is 1 and for random it is 0. But when current passes through dipole, random lines are also aligned.

Dipole.

Applications of electromagnetism are T.V remote etc

Glashow, Weinberg, Muhammad Abdus Salam got Nobel Prize for their Great Unification Theorey.

Basically, there were four basic forces:

1) Weak Nuclear force
2) Strong Nuclear force
3) Gravitational force
4) Electro-magnetic force

(1) & (3) are same according to G.W.S.

So, he made 3 basic forces instead of 4.

Electric Charge (Acc to Ancient Greeks).

Whenever you comb your hair, you feel an interaction (attraction & repulsion) b/w comb & your hair, that interaction is a result of some physical entity being transferred from one to the other when they are rubbed together. That physical entity is called Electric Charge.

Experiment:

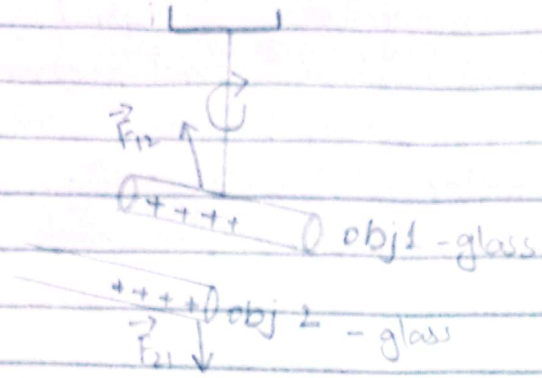
- A plastic rod (-ve) charge, as plastic gains electron
- A glass rod (+ve) charge, as glass losses electron
- Piece of fur

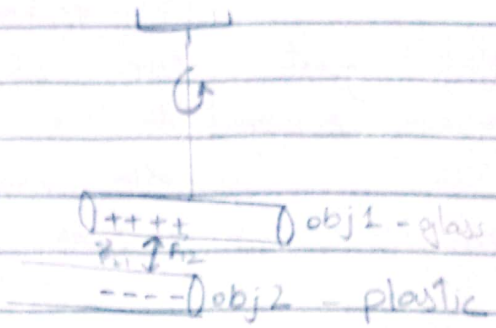
(insulators)

$\vec{F}_{12}$ = force on obj1 due to obj2

$\vec{F}_{21}$ = force on obj2 due to obj 1

$\because 1C = 6 \times 10^{18}\ e^-s$





Conclusions from fig (1) & fig(2):

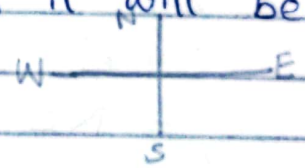
1) Like charges repel and unlike charges attract eachother.
2) Electrostatic force obeys Newton 3rd law of motion.

Symmetric:

If we rotate a thing, i.e transform its position and it remains same, the thing is called Symmetric i.e. if we rotate a ball, it will be same.

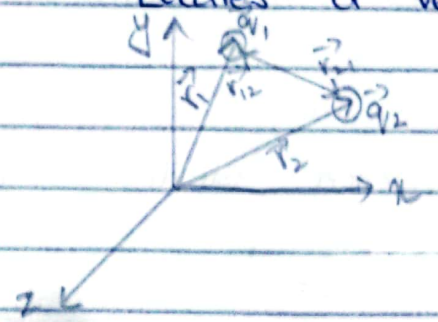
(•) dot : z : outward : upward

(x) cross : -z : inward : downward



Position Vector: ($\vec{r}$)

Locates a vector w.r.t origin.

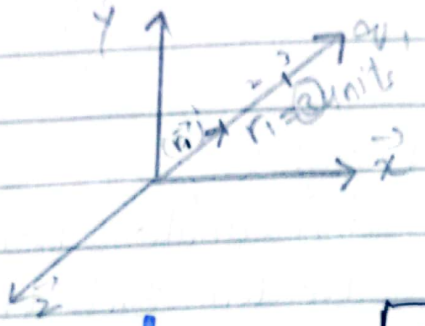


$\vec{r}_{12}$ & $\vec{r}_{21}$ are equal in magnitude but opposite in direction.

Unit Vector:

A vector whose magnitude is one, it's just for direction, but should not change the magnitude.

To make unit vector of a quantity, divide it in total no. of units of its magnitude.



Quantization of charge: $\boxed{e^- = 1.6 \times 10^{-19} C}$

Net charge is always an integral integer multiple of elementary charge, it can't be a float number.

i.e. charge can't be 1.25 electrons.

$q = Ne$ where $N = 0, \pm 1, \pm 2, \pm 3, ----$

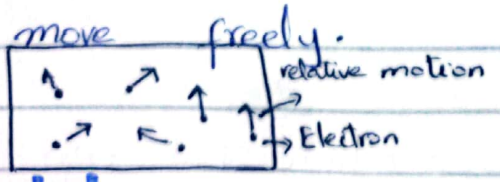
(0 means no charge)

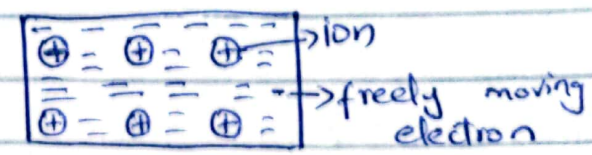
In short, charge is number of electrons.

Conductors:

A material in which electrons can move freely.

Generally, drawn as:





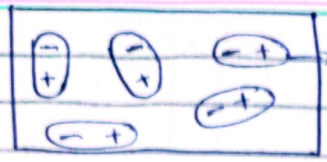
Insulators:

A material in which electrons cannot move freely.

$\because c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$

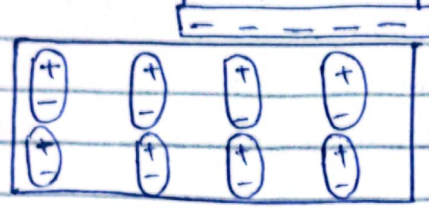
$\varepsilon_0 \rightarrow$ Electric behaviour

$\mu_0 \rightarrow$ magnetic behaviour.



Randomly ordered dipole

* If we brought a (-)vely charged rod near to an insulator, dipoles align themselves in a such a way that electrons of both i.e. (rod & dipole) repel each other.



--- (A)

Charging by Contact:

If we have two spheres one is positively charged & 2nd is ~~(negatively charged)~~ neutral, charge will be shifted. And $q/2$ will be the charge on both of the spheres.

Charges by induction:

Charging a surface by bringing a charged rod near it. as in fig(A).

Examples: (MCQ type):

(+ve) A $\xleftrightarrow{\text{attract}}$ B (-)

(-) B $\xleftrightarrow{\text{attract}}$ C (+)

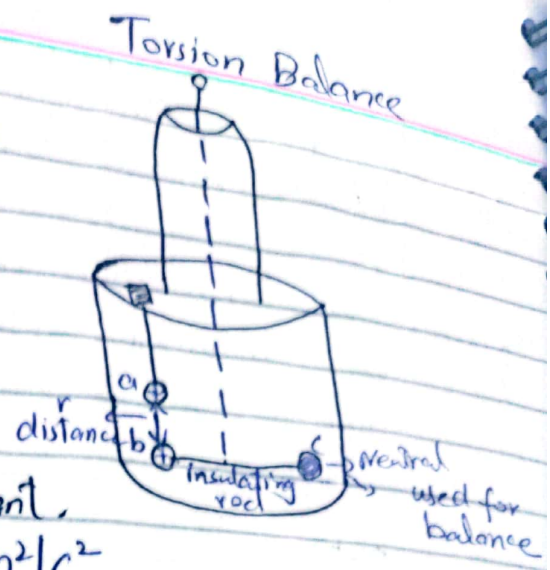
(+) A $\xleftrightarrow{\text{repel}}$ C (+)

- A $\xleftrightarrow{\text{repel}}$ B -

- B $\xleftrightarrow{\text{repel}}$ C -

- C $\xleftrightarrow{\text{repel}}$ A -

Coulomb's law:



$F \propto q_1 q_2$ (magnitude of charges)

$F \propto 1/r^2$

$F \propto \frac{q_1 q_2}{r^2}$

$F = k\frac{q_1 q_2}{r^2}$

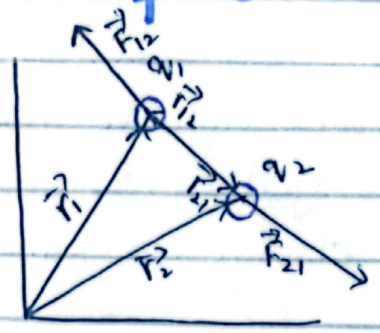
Where k is called Electric Constant.

$k = 8.99 \times 10^9 \Rightarrow 9 \times 10^9 \ Nm^2/C^2$

$k = \frac{1}{4\pi\varepsilon_0}$, ε_0 is permittivity of free space.

$\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$

Vector form of Coulomb's law:



For Like charges:

$$\vec{F}_{12} = k\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}, \quad \vec{F}_{21} = k\frac{q_1 q_2}{r_{21}^2}\hat{r}_{21}$$

For Unlike charges:

$$\vec{F}_{12} = k\frac{q_1 q_2}{r_{12}^2}\hat{r}_{21} \qquad \vec{F}_{21} = k\frac{q_1 q_2}{r_{21}^2}\hat{r}_{12}$$

$\because \hat{r} = \frac{\vec{r}}{r}$, $\vec{r} = r\hat{r}$

So, it can be written as,

$$\vec{F}_{12} = k\frac{q_1 q_2}{r_{12}^3}\vec{r}_{12}$$

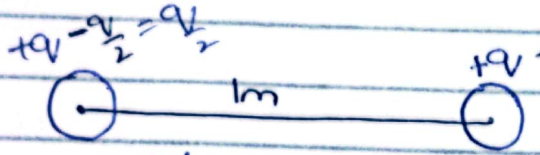
Q

If $\vec{F}_{12} = k\frac{q_1 q_2}{r_{12}^3}\vec{r}_{12}$, can we conclude that $F_{12} \propto \frac{1}{r_{12}^3}$?

No, it is not true. Because $\hat{r}_{12}$ is unit vector which is equal to $\frac{\vec{r}_{12}}{r_{12}}$, due to which it has become $\frac{1}{r_{12}^3}$. But when $\vec{r}_{12}$ will be ignored during taking proportionality, $\frac{\vec{r}_{12}}{r_{12}}$ will be ignored completely and it will be $\frac{kq_1q_2}{r_{12}^2}$.
And $F_{12} \propto \frac{1}{r_{12}^3}$ is against our main observation that $F_{12} \propto \frac{1}{r_{12}^2}$.

Q If $q_1 = 3\mu C$, $q_2 = -6\mu C$. $|\vec{F}_{12}| = ?$
As $\vec{F}_{12}$ & $\vec{F}_{21}$ are opposite & equal forces $|\vec{F}_{21}|$ it will be 1.

Force for like charges.

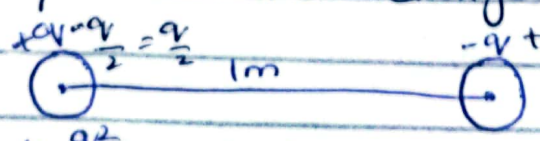


$F_0 = kq^2/r^2 \Rightarrow kq^2/1^2 \Rightarrow kq^2$

$F' = \frac{k(\frac{q}{2})(\frac{3q}{2})}{1} \Rightarrow \frac{3}{4}kq^2$

$$\boxed{F' = \frac{3}{4}F_0}$$

Force for unlike charges.



$\rightarrow$ - sign taken at charge but not in magnitude.

$F_0 = k\frac{q^2}{r^2} \Rightarrow kq^2$

$F' = k(\frac{q}{2})(\frac{q}{2}) \Rightarrow \frac{1}{4}kq^2$

$$\boxed{F' = \frac{1}{4}F_0}$$

Conservation of charge:

Net charge before a process is always equal to net charge after the process.

$\Sigma q = \text{constant} \Rightarrow q_i = q_f$

before process = After process.

Example: electron positron 2 γ-rays

$e^- + e^+ \longrightarrow \gamma + \gamma$ (Electron Positron pair)

$-1.6\times10^{-19} + 1.6\times10^{-19}$ $0 + 0$

$0 = 0$

(Neutron Decay):

$n \longrightarrow e^+ p + e^- + \nu$ (Neutrino-Neutral)

$0 = 1.6\times10^{-19} - 1.6\times10^{-19} + 0$

$0 = 0$

Superposition of forces:

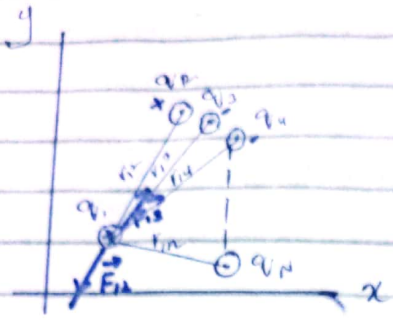
Electric force	Gravitational force
$F_e = k\frac{q_1 q_2}{r^2}$	$F_g = G\frac{m_1 m_2}{r^2}$
strong	$\sim 10^{39}$ times weaker than E
Both attractive & repulsive	Attractive force
Short range force	Long range force

Both forces are conservative

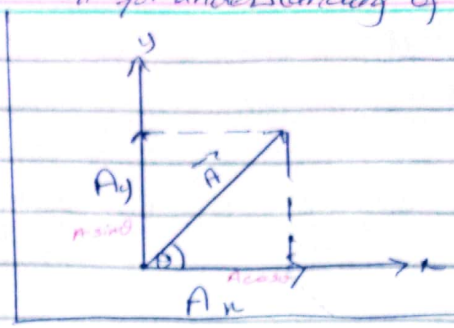
Superposition of forces:

- Adjacent with θ is cos & other is s

Consider N number of charge as shown in figure.



for understanding of cosθ & sinθ



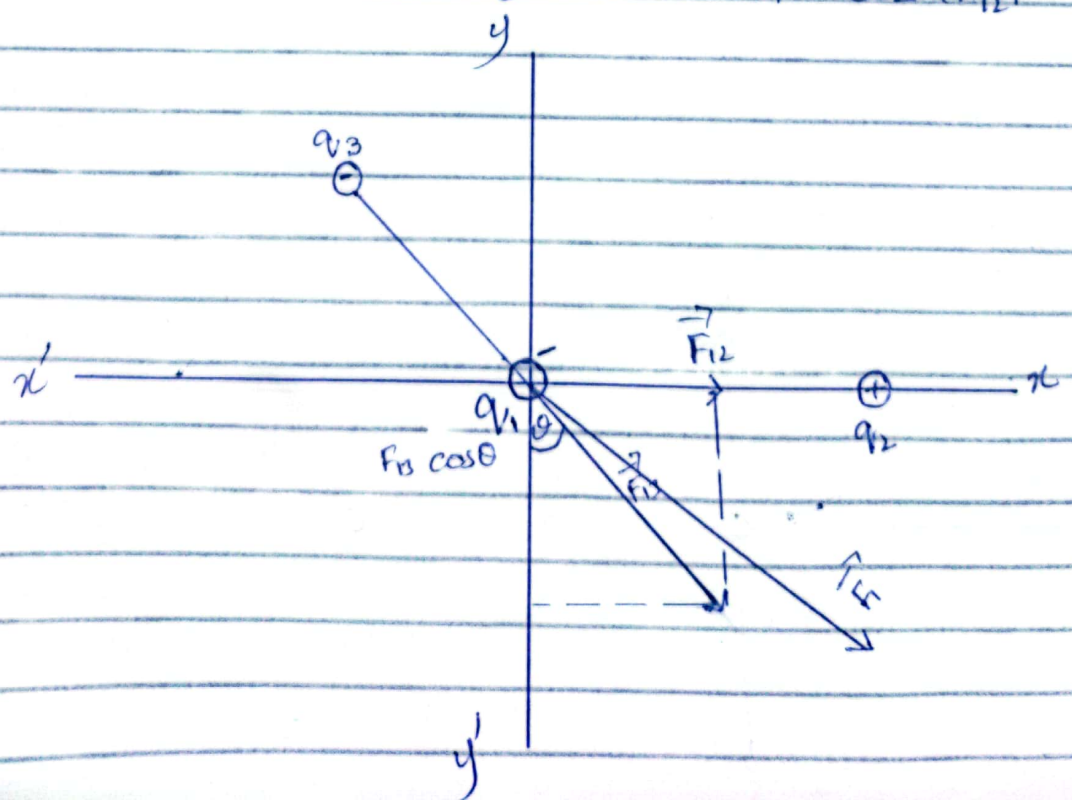
Superposition principle:

Force acting on one charge due to another charge is independent of whether or not other charges are present. So, we calculate the forces seperately. And then take their **vector sum** to find the resultant.

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \dots + \vec{F}_{1N}$$

Sample problem 25.5:

$\vec{F}_{12}$ is smaller than $\vec{F}_{21}$ bcz $|\vec{F}_{12}|$ is less than



$F_{13}\sin\theta$?

Just for direction, not used in calculation

$q_1 = -1.2\mu C$, $q_2 = 3.7\mu C$, $q_3 = -2.3\mu C$, $r_{12} = 15cm$

$r_{13} = 10cm$, $\theta = 32°$, $\vec{F_1} = ?$

$$\vec{F_1} = k\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12} + k\frac{q_1 q_3}{r_{13}^2}\hat{r}_{13} + \cdots + k\frac{q_1 q_n}{r_{1n}^2}\hat{r}_{1n}$$

$$= k q_1 \sum_{i=2}^{n} \frac{q_i}{r_{1i}^2}\hat{r}_{1i} \quad \text{or} \quad k\sum_{i=2}^{n} q_1 \frac{q_1}{r_{1i}^2}\hat{r}_{1i}$$

$$\vec{F_{12}} = k\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12} \Rightarrow \frac{9\times10^9 \times (1.2\times10^{-6}) \times (3.7\times10^{-6})}{(0.15)^2} \Rightarrow 1.77N$$

$$\vec{F_{13}} = k\frac{q_1 q_3}{r_{13}^2}\hat{r}_{13} \Rightarrow \frac{9\times10^9 \times (1.2\times10^{-6}) \times (2.3\times10^{-6})}{(0.10)^2} \Rightarrow 2.48N$$

$F_{1x} = F_{12x} + F_{13x}$

$F_{1x} = F_{12} + F_{13}\sin\theta = 1.77 + 2.48\sin 32° \Rightarrow 3.08N$

$F_{1y} = F_{12y} + F_{13y}$

$= 0 - F_{13}\cos\theta$ (-ve sign bcz of direction of -y).

$= 0 - 2.48\cos 32°$

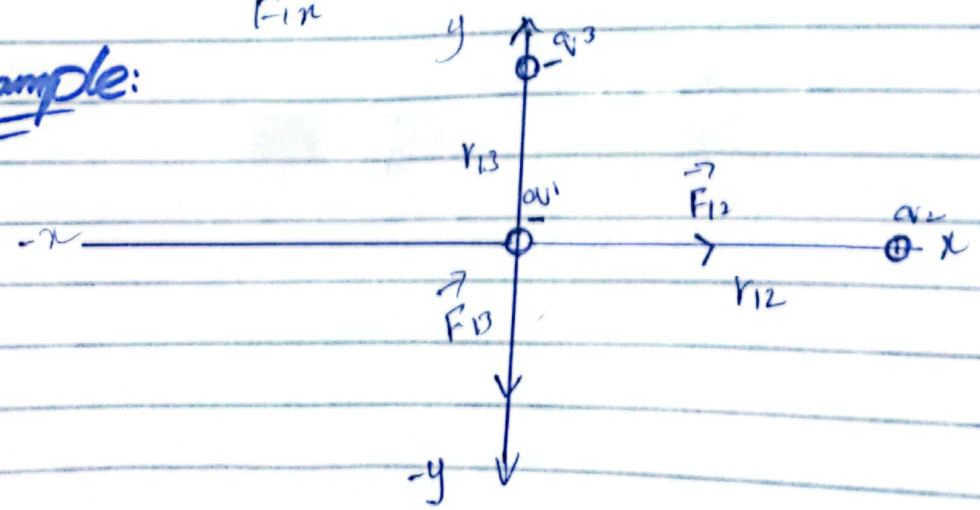
$= -2.1N$

$F_1 = \sqrt{F_{1x}^2 + F_{1y}^2}$

$F_1 = 3.73N$

$\phi = \tan^{-1}\frac{F_{1y}}{F_{1x}} \Rightarrow -34°$

Example:



Electric field:

$\because E = \frac{F}{q_0}$

$F = \frac{k q q_0}{r^2}$

$\frac{F}{q_0} = \frac{k q}{r^2}$

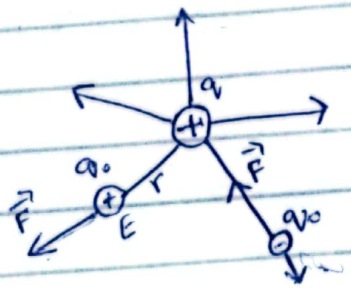
$E = \frac{k q}{r^2}$ $\because$ Electric field lines are due to one charge but force is on one charge due to second charge.

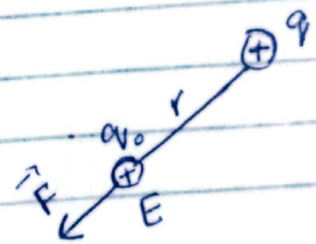
Fields:

- Scalar
- Vector

Scalar
- static: $T(x,y,z)$
- time-varying: $T(x,y,z,t)$

Vector
- static: $\vec{V}(x,y,z)$
- time-varying: $\vec{V}(x,y,z,t)$





Action at a distance:

charge $\rightleftarrows$ charge

Charge interacts with another charge nothing at between them is called action at a distance.

charge $\rightleftarrows$ field $\rightleftarrows$ charge

$\vec{E}$ does not depend upon F & q_0. Like: $\vec{E} = \vec{F}/q_0$.

whereas: $F \propto q q_0$. if $q_0 = 2q_0 \Rightarrow F = 2F$.

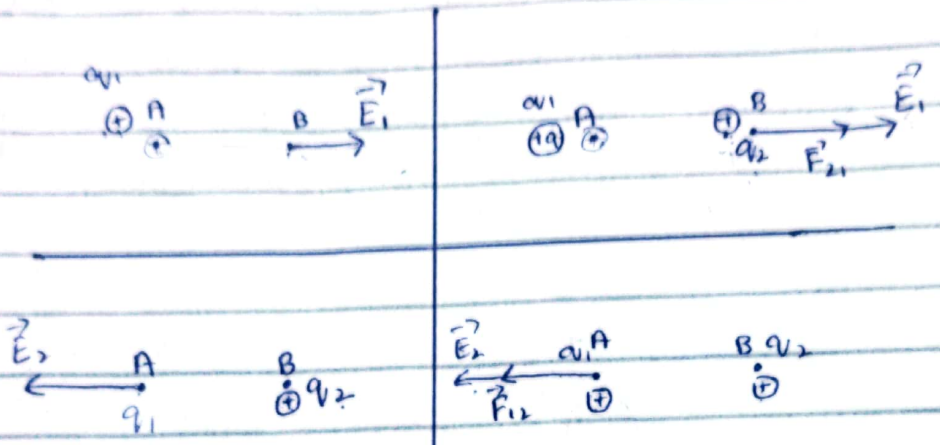
So: if: $\vec{E} = \frac{2\vec{F}}{2q_0} \Rightarrow \frac{\vec{F}}{q_0}$

F/q_0

• Force depends upon field but field does not depend upon force.

The charge **on** which force acts is q_0.

i.e. is always from +Q.



$F = q_0 E$ $\quad$ $F \propto E$

$F = \lim_{q_0 \to 0} q_0 E$

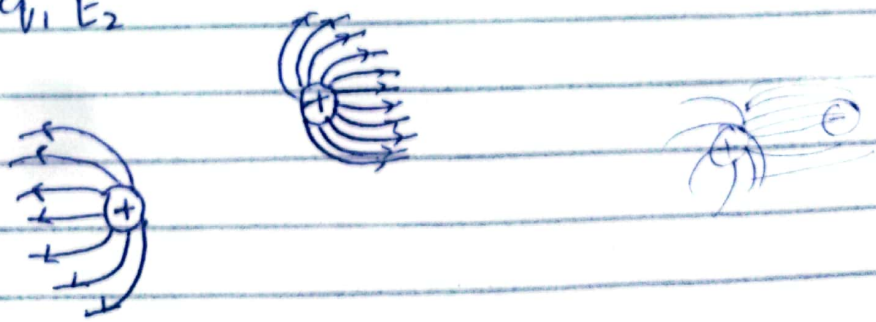
q_0 should be smallest (smallest value can be of electron, n its not zero because in that case, there will be no charge) so to test Not to disturb. As larger charge can disturb force & $\vec{E}$.

$F = q_0 E$

$\vec{F}_{21} = q_2 \vec{E}_1$

$\vec{F}_{12} = q_1 \vec{E}_2$

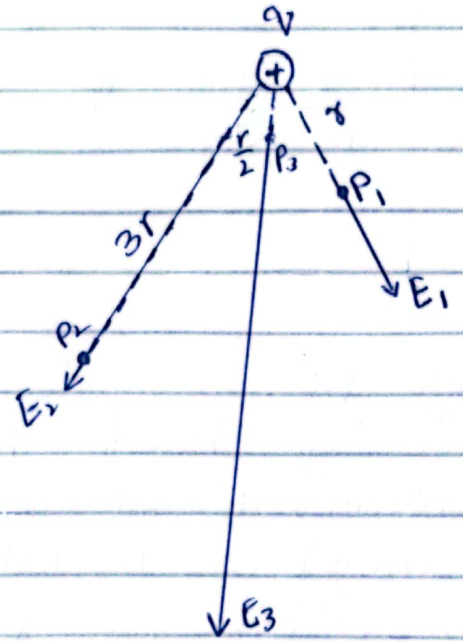
• Test charge can affect force, Not $\vec{E}$.



Electrostatic force obeys Newton's 3rd law of motion.

Superposition principle: (Same as for force).

Fields on a charge at a point is independent of whether or not other charges are present. We took fields individually & then take their vector sum.



if $r = r/2$:

$E_3 = \frac{kq}{(r/2)^2}$

$E_3 = \frac{kq}{r^2/4}$

$E_3 = 4\,kq/r^2$

$\boxed{E_3 = 4E_1}$

$E_1 = \frac{kq}{r^2}$

if $r = 3r$

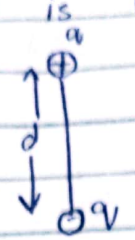
$E_2 = \frac{kq}{(3r)^2}$

$E_2 = \frac{1}{9}\frac{kq}{r^2}$

$\boxed{E_2 = 1/9\, E_1}$

An electronelectric dipole:

Two equal & opposite charges seperated by a distance d where d is very small is called Electric dipole.



(Direction from negative to positive).

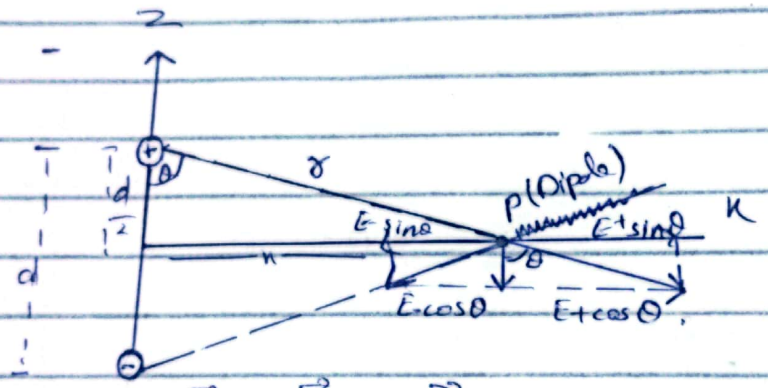
$$p = qd$$

Electric field of an Electric charge:

$$\vec{E}_p = \vec{E}_+ + \vec{E}_-$$

$$\boxed{\theta + \phi = 90^\circ}$$

Along perpendicular bisector:



$$\vec{E}_p = \vec{E}_+ + \vec{E}_-$$

$$E_+ = \frac{kq}{r^2}, \quad E_- = \frac{kq}{r^2}$$

According to fig & pythagoras theorem.

$$r^2 = x^2 + \left(\frac{d}{2}\right)^2 \longrightarrow (1A)$$

Along x-axis: opposite direction.

$$E_+ \sin\theta - E_- \sin\theta = 0$$

Along z-axis:

$$E_p = E_+ \cos\theta + E_- \cos\theta \Rightarrow 2E_+ \cos\theta \longrightarrow (2)$$

$$\boxed{E_p = E_{pz}}$$

Bcz x → zero.

From fig:

$$\cos\theta = \frac{(d/2)}{r} \rightarrow 1(B)$$

Base/Hyp

Substituting 1(A) & 1(B) in eq(2):

$$E_P = \frac{2Kq(d/2)/r}{r^2}$$

$$E_P = \frac{2Kq(d/2)}{r^3} \rightarrow (3)$$

From (1A):

$$r = \left(x^2 + \left(\frac{d}{2}\right)^2\right)^{1/2}$$

$$r^3 = \left(x^2 + \left(\frac{d}{2}\right)^2\right)^{3/2}$$

So eq(3):

$$E_P = \frac{2Kq(d/2)}{\left(x^2+\left(\frac{d}{2}\right)^2\right)^{3/2}} \quad \therefore p = qd$$

Vector form:

$$E_P = \frac{p}{\left(x^2+(d/2)^2\right)^{3/2}}(-\hat{k})$$

This shows That: $\boxed{E \propto \frac{1}{[r^3]}}$ r is distance of one charge but x is distance from dipole.

* Binomial Theorem:

$$(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \cdots$$

used when power is in fraction or negative.

$\because$ d is so small and when its square is taken, it becomes more small, so its higher power are negligible.

$$E = kp\left[x^2 + (d/2)^2\right]^{-3/2}$$

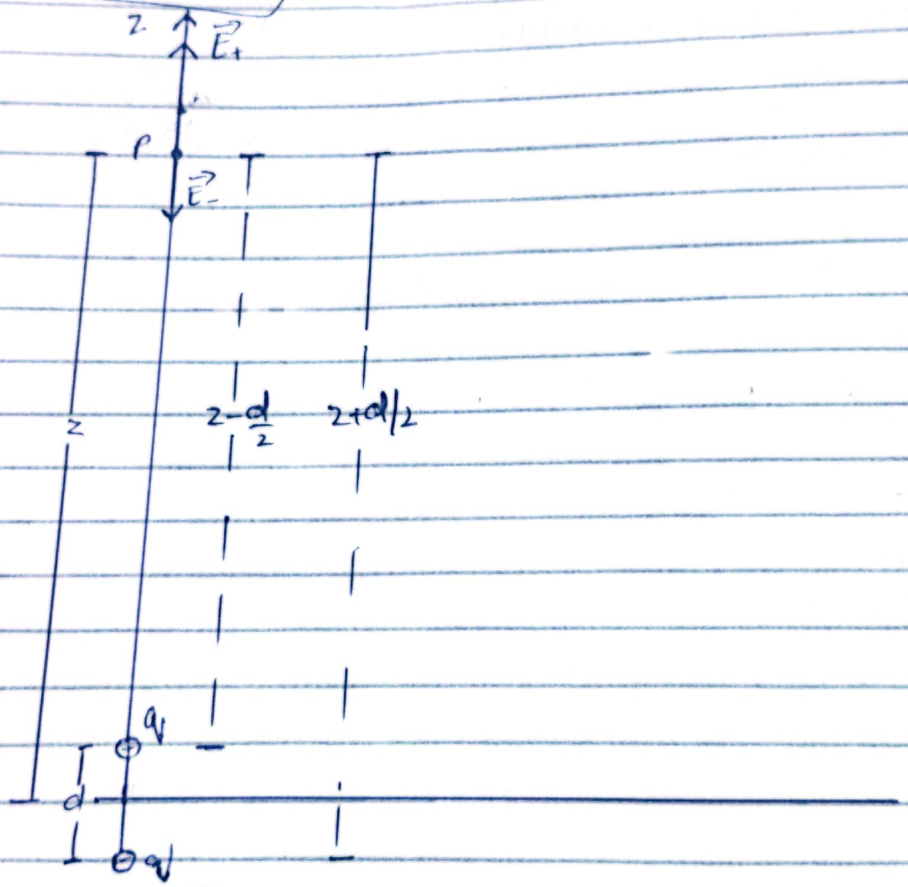
$$E = kp(x^2)^{-3/2}\left[1 + (d/2x)^2\right]^{-3/2}$$

approaches to 0.

Binomial theorem.

$$E = \frac{kp}{x^3}\left[1 + \left(\frac{-3}{2}\right)\left(\frac{d}{2x}\right)^2\right]$$

$$\boxed{E = \frac{kp}{x^3}}$$



$$E = E_+ - E_-$$

$$E = \frac{Eq}{r^2} - \frac{Eq}{r^2}$$

$$E = \frac{kq}{(z-\frac{d}{2})^2} - \frac{kq}{(z+d/2)^2}$$

$$E = kq\left(\frac{1}{(z-d/2)^2} - \frac{1}{(z+d/2)^2}\right)$$

$$E = kq\left(\frac{1}{z^2+\frac{d^2}{4}-zd} - \frac{1}{z^2+d^2/4+zd}\right)$$

$$E = kq\left(\frac{\cancel{z^2}+\cancel{d^2/4}+zd-\cancel{z^2}-\cancel{d^2/4}+zd}{(z^2+d^2/4-zd)(z^2+d^2/4+zd)}\right)$$

$$E = \frac{kq\ 2dz}{(z^2+\frac{d^2}{4})^2-(zd)^2}$$

As d^2 will be appr to zero, so ignore it.

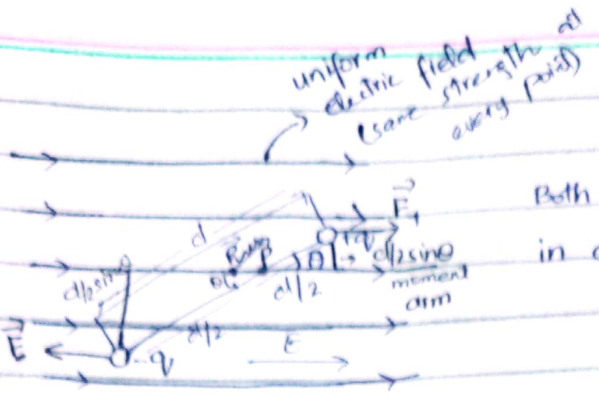
$$E = \frac{2kqd\cancel{z}}{z^{4}}$$

$\because$ $p = qd$

$$\boxed{E = \frac{2k\ p}{z^3}\ \hat{k}}$$

- Electric dipole
  Electric field of dipole
  Dipole in an Electric field.

Lecture # 7



Both forces are same & opposite in direction.

If forces are different, translatory motion in direction of more force.

$F_+ = qE$

$F_- = qE$

$\vec{F}_{net} = \vec{F}_+ + \vec{F}_-$

$F_{net} = qE - qE$, opposite direction.

$\boxed{F_{net} = 0}$

$\tau_+ = F_+(d/2)\sin\theta$

$\tau_- = F_-(d/2)\sin\theta$ $\quad \because F = qE$

$\tau_{net} = \tau_+ + \tau_-$

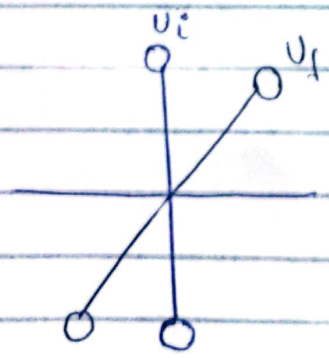
$= qE(d/2)\sin\theta + qE(d/2)\sin\theta$

$= \cancel{2}q\frac{d}{\cancel{2}}E\sin\theta$

$\tau_{net} = qdE\sin\theta$ $\quad \because p = qd$

$\tau_{net} = pE\sin\theta$.

$\boxed{\tau_{net} = \vec{p} \times \vec{E}}$ P aligns itself in $\vec{E}$ direction, Torque end



$\Delta U = U_f - U_i$

$\boxed{U = -W} \Rightarrow \int_{90}^{\theta} \tau\, d\theta$

$W = \vec{F}\cdot\vec{d}$ or $\vec{F}\cdot\vec{S}$

$\boxed{W = \vec{\tau}\cdot\vec{\theta}}$

$\because$ Rotatory effect of force is torque & of d is Angular distance.

$$W = PE\int_{90^\circ}^{\theta} \sin\theta \, d\theta$$

$$= PE(-\cos\theta)\Big|_{90^\circ}^{\theta}$$

$$= -PE(\cos\theta - \cos 90^\circ) \quad \because \cos 90^\circ = 0$$

$$\boxed{W = -PE\cos\theta}$$

$$\boxed{U = -\vec{P}\cdot\vec{E}}$$

$\int dl = l$

$\int dm = m$

Continuous Charge Distribution

- Coloumb's law is valid only for point charges.
- It is valid only for insulators.

* Continuous distribution of charge is defined by its charge density.

$\boxed{\lambda = \frac{q}{L}} \Rightarrow \frac{C}{m}$ → Linear charge distribution

surface CD

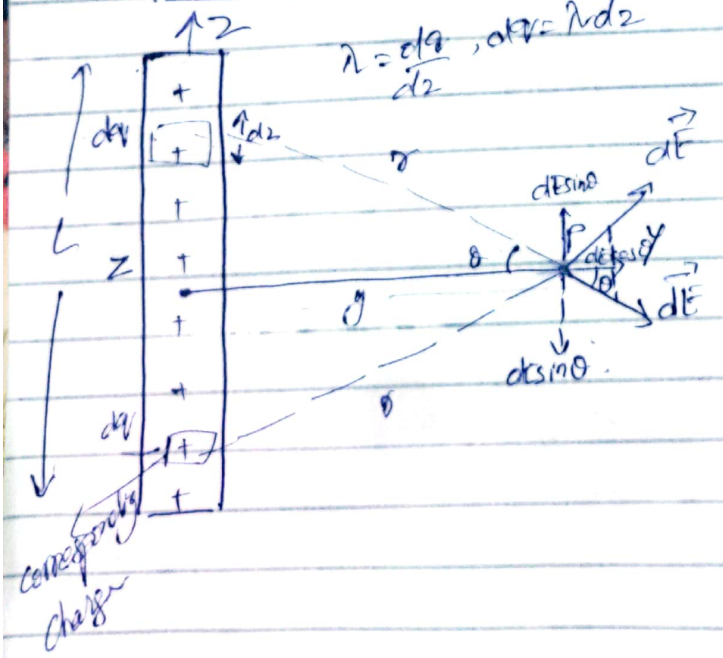
volume CD

$\boxed{\sigma = q/A}$ $\boxed{\rho = q/V}$

$E = \frac{kq}{r^2}$ (point charge)

$\lambda = \frac{dq}{dz}$, $dq = \lambda dz$

$dE = k\frac{dq}{r^2}$



$$dE = \frac{k\,dq}{r^2}$$

$$dE = k\frac{\lambda\,dz}{r^2}$$

For each charge element on one side, there is a corresponding charge element on other side. They establish their electric fields in such a way that

Along z axis:

$$dE_z = dE\sin\theta$$

$$\int dE_z = 0.$$

Along y-axis:

$$dE_y = dE\cos\theta$$

$$k\,dE_y = \frac{k\lambda\,dz}{r^2}\cos\theta.$$

$$= \frac{k\lambda\,dz}{r^2}\frac{y}{r_{l/2}} \Rightarrow \frac{k\lambda y\,dz}{r^3}$$

$$\int dE_y = k\lambda y\int_{-\frac{l}{2}}^{\frac{l}{2}}\frac{dz}{(y^2+z^2)^{3/2}} \rightarrow \text{Direct Integration}$$

$z = y\tan\theta$

$$E_y = k\lambda y\left(\frac{z}{y^2\sqrt{y^2+z^2}}\right)\Bigg|_{-l/2}^{l/2}$$

We know that.

$$E_y = \frac{k\lambda}{y}\left(\frac{l/2}{\sqrt{y^2+(l/2)^2}} - \frac{(-l/2)}{\sqrt{y^2+(-l/2)^2}}\right)$$

as square is positive $(-l/2)^2 = l^2/4$

$$E_y = \frac{k\lambda}{y}\left(\frac{l/2 + l/2}{\sqrt{y^2+(l/2)^2}}\right)$$

$$E = \frac{k\lambda l}{y\sqrt{y^2+(l/2)^2}}$$

Gauss' Law:

- It is more fundamental, basic and applicable as compare to Coulomb's law due to its high symmetry.
- It is also valid on ~~insulate~~ conductors.
- It is valid on point charge as well as objects.

$\phi_E = \vec{E}\cdot\vec{A}$ ∴ Here Area is a vector quantity

$\phi_E = EA\cos\theta$ whose magnitude is equal to magnitude of area and direction is outward normal to plane of surface.

$\vec{A} = \hat{n}A$

For small patch.

$\phi_E = \int \vec{E}\cdot d\vec{A}$

$\phi_E = \oint_S E\,dA\cos\theta$ closed surface

closed surface.

ϕ depends upon:

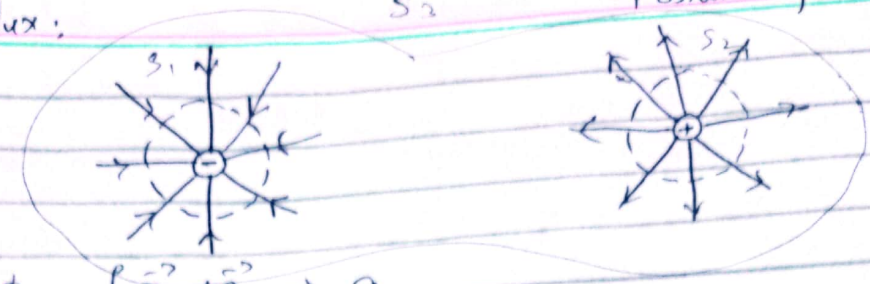
1) Angle
2) Magnitude of Area
3) Strength of field

Flux through a closed Surface:

Flux through a system is positive if field lines are outward.

+flux

Negative flux:



Positive flux:

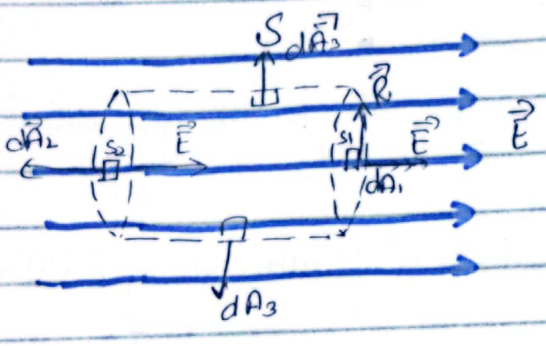
$$\phi_E = \oint \vec{E}\cdot d\vec{A} \Rightarrow \frac{q}{\varepsilon_0}$$

Note: whenever we have to deal with a scalar quantity we have to consider the sign of the charge.

$\phi_{S_1} = +q/\varepsilon_0$

$\phi_{S_2} = -q/\varepsilon_0$

$\phi_{S_3} = q-q/\varepsilon_0 \Rightarrow 0.$



$$\oint_S \vec{E}\cdot d\vec{A} = \int_{S_1} \vec{E}\cdot d\vec{A}_1 + \int_{S_2} \vec{E}\cdot d\vec{A}_2 + \int_{S_3} \vec{E}\cdot d\vec{A}_3$$

$$= \int_{S_1} E\,dA_1 \cos 0^\circ + \int_{S_2} E\,dA_2 \cos 180^\circ + \cancel{\int_{S_3} E\,dA_3 \cos 90^\circ}$$

$$= E\int_{S_1} dA_1 - E\int_{S_2} dA_2$$

$$= EA - EA$$

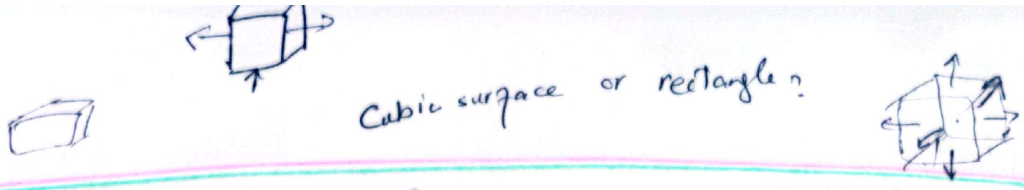
$$= 0$$

$$\Rightarrow \int_{S_1} dA_1 = \int_{S_2} dA_2$$

$= A$ (area of cap)

$= \pi R^2$

Area of circle.

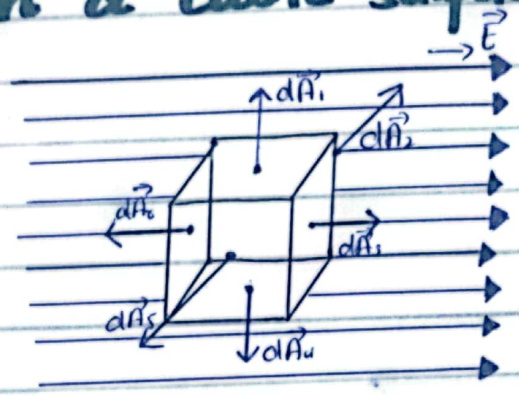


* flux through a closed surface placed within a uniform electric field is always equal to zero.

If a closed surface has no charge, ϕ will be zero

as: $q = q/\varepsilon_0 \Rightarrow q = 0$

Flux through a cubic surface:



$$\oint_S \vec{E}\cdot d\vec{A} = \int \vec{E}_1\cdot d\vec{A}_1 + \int \vec{E}_2\cdot d\vec{A}_2 + \int \vec{E}_3\cdot d\vec{A}_3 + \int \vec{E}_4\cdot d\vec{A}_4 + \int \vec{E}_5\cdot d\vec{A}_5 + \int \vec{E}_6\cdot d\vec{A}_6$$

$$= \int E_1 dA_1 \cos 90^\circ + \int E_2 dA_2 \cos 90^\circ + \int E_3 dA_3 \cos 0^\circ + \int E_4 dA_4 \cos 90^\circ$$

$$+ \int E_5 dA_5 \cos 90^\circ + \int E_6 dA_6 \cos 180^\circ$$

$$= \int E_1 dA_1 (0) + \int E_2 dA_2 (0) + \int E_3 dA_3 (1) + \int E_4 dA_4 (0) + \int E_5 dA_5 (0) + \int E_6 dA_6 (-1)$$

$$= \int E_3 dA_3 - \int E_6 dA_6$$

$\because$ E is same

$\because \int dA_3 = \int dA_6$

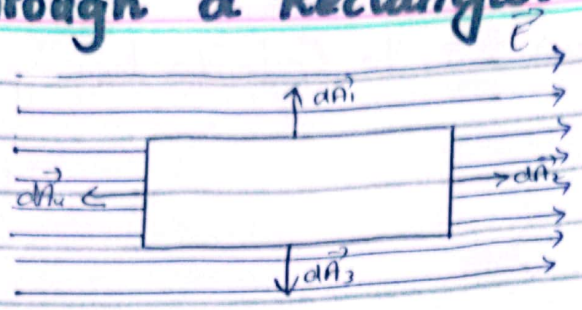
$= A$ (Area)

$$= E\int dA - E\int dA$$

$$= EA - EA$$

$$= 0.$$

Flux through a Rectangle:



$$\oint_S \vec{E}\cdot d\vec{A} = \int \vec{E}_1\cdot d\vec{A}_1 + \int \vec{E}_2\cdot d\vec{A}_2 + \int \vec{E}_3\cdot d\vec{A}_3 + \int \vec{E}_4\cdot d\vec{A}_4$$

$$= \int E_1 dA_1 \cos 90^\circ + \int E_2 dA_2 \cos 0^\circ + \int E_3 dA_3 \cos 90^\circ + \int E_4 dA_4 \cos 180^\circ$$

$$= \int E_2 dA_2 - \int E_4 dA_4 \qquad \because E \text{ is same.}$$

$$\therefore \int dA_2 = \int dA_4$$

$$= \int EA - \int EA \qquad = A$$

$$= 0$$

Gauss' Law:

→ It deals the flux. It is always for closed surface.

The closed surface integral of dot product of electric field & area vector is equal to $1/\varepsilon_0$ times the net charge enclosed by the (closed) Gaussian surface.

$$\varepsilon_0 \phi = q_{enc} \qquad \because \phi = \int \vec{E}\cdot d\vec{A}$$

$$\varepsilon_0 \oint \vec{E}\cdot d\vec{A} = q_{enc}$$

$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0} \longrightarrow (1)$$

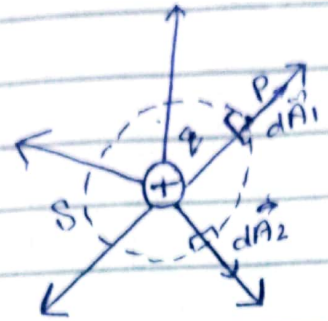
q_{enc} → Inside the Gaussian surface

$\vec{E}$ → on the Gaussian surface

$d\vec{A}$ → Area of Gaussian

Prove that:

Gauss's Law is Equivalent to Coulomb's law.



$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{ed}}{\varepsilon_0}$$

$$\oint E\,dA\cos 0^\circ = \frac{q}{\varepsilon_0}$$

$$E\int dA = q/\varepsilon_0$$

$\because$ Area of ~~surf~~ sphere $= 4\pi r^2$

" " circle $= \pi r^2$

" " ~~circumference~~ cylinder $= 2\pi r \times$ height $= 2\pi r \times l$

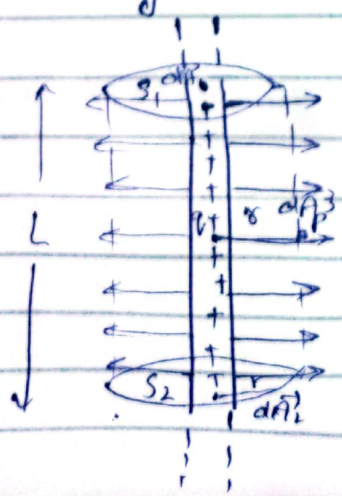
circumference length

$$E(4\pi r^2) = q/\varepsilon_0$$

$$\boxed{E = \frac{q}{4\pi\varepsilon_0 r^2}}$$

Infinite Line of Charge: (Application of Gauss' Law)

$$\oint \vec{E}\cdot d\vec{A} = q_{ed}/\varepsilon_0$$



$\rightarrow$ of line

$$\lambda = q/L$$

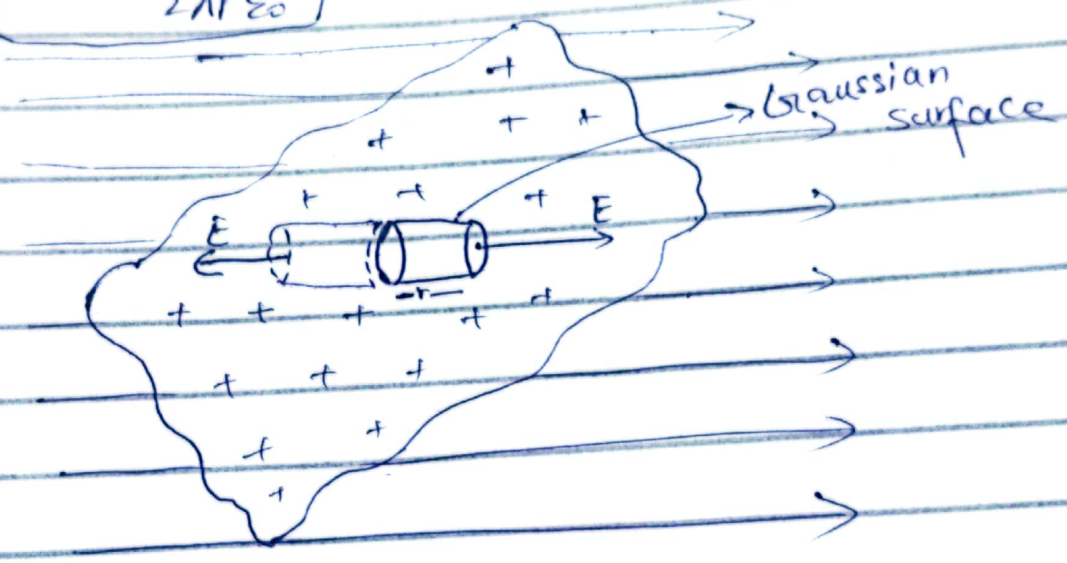
$$\oint \vec{E}\cdot d\vec{A} = \int E_1\cdot dA_1 + \int E_2\cdot dA_2 + \int E_3\cdot dA_3$$

$$= E_1 dA_1\cos 90^\circ + E_2 dA_2\cos 90^\circ + E_3 dA_3\cos$$

$$= E_3 dA_3$$

$$= E\int dA_3 = q/\varepsilon_0$$

$$E\,2\pi r\cancel{L} = \frac{\lambda \cancel{L}}{\varepsilon_0}$$

$$E\,2\pi r = \frac{\lambda}{\varepsilon_0}$$

$$\boxed{E = \frac{\lambda}{2\pi r \varepsilon_0}}$$