Date: _____ Applied Physics

Physics by Halliday, Resnick and Krane
Vol II 5th Edition

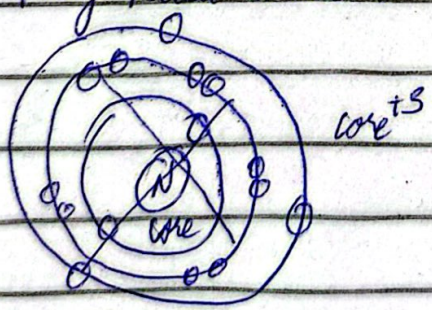
Section
1st Electrostatics
2nd Electrodynamics
3rd Magnetism — Earth magnetic field is highly protective for u

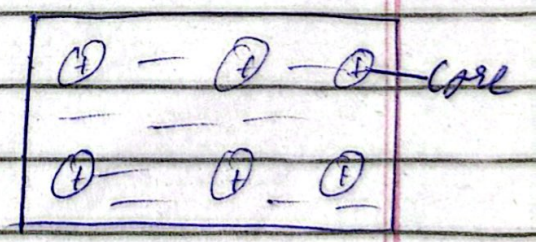
Earth's Magnetic Field is highly protective for our Earth

Auroras : Northern Lights

4th Electromagnetism
5th Optics

Fully Filled shell + nucleus → core, ion core





Metallic state

Date: AP

Ch # 25 : Electric Charge & Coulomb's law

The Electromagnetism : A preview.

• Electricity :

• Computer system : gets Dipoles

Fig 25.1 --> Book

Timeline

785 Charles Augustin Coulomb

4 Fundamental Forces Concept

Strong N.F — Weak Nuclear Force

Gravitational Force — Electromagnetic Force

Dr Abdusalam

Electra weak Force — Strong Nuclear Force

Gravitational Force

Higgs Boson

• Electric Charge :

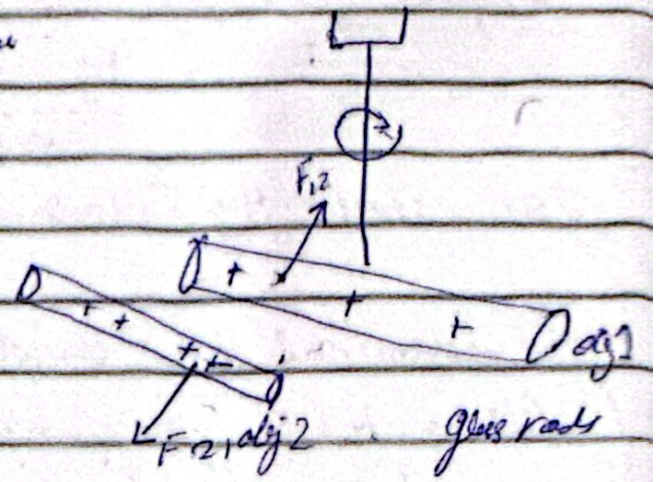
Wherever you comb your hair you feel an interaction between comb and hair that interaction is a result of some physical entity being shifted from one object to the other. That physical entity is called Electric Charge

Date: _____

Frictional energy is not enough to charge a conductor
Also can't charge every insulator with friction

Plastic -
Glass rod +
Piece of fur

not parallel
we want force



Fig(1)

on 1 from 2 $\vec{F}_{12}$

on 2 from 1 $\vec{F}_{21}$

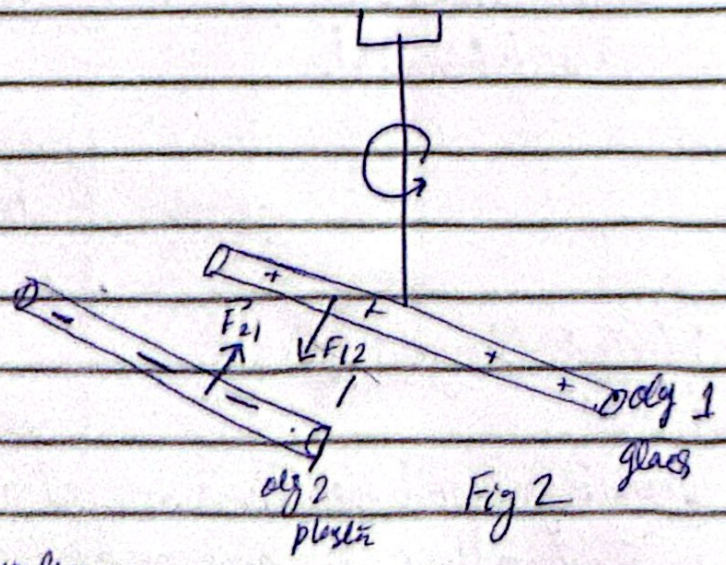


Fig 2

Observation
1. like charges repel each other opposite charge attract each other

Date: _____

2. Electrostatic force obeys Newton 3rd law of Motion

Charge q unit : C

$1C = 6 \times 10^{18}$ es

μC and nC

10^{-6} 10^{-9}

Quantization of Charge :

Net charge on an object is always an integer multiple of elementary charge

$$\underset{\text{net charge}}{q} = \underset{\text{number of e}}{N}e$$

$$N = (0, \pm 1, \pm 2, \pm 3 \ldots)$$

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

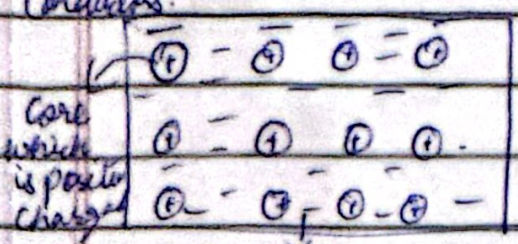
always integer not in fraction

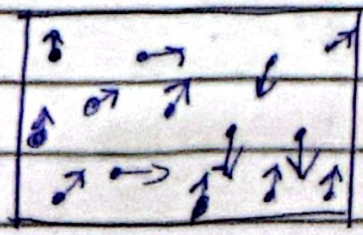
$$N = \frac{q}{e}$$

Date: _____

Conductors & Insulators

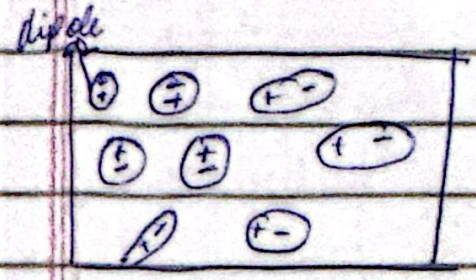
Conductors:





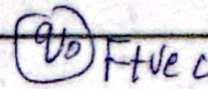
conductive slab
random motion of é:
(relative motion)
from one particle

Insulators:

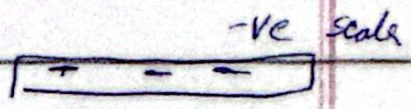


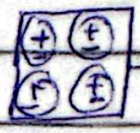
randomly oriented dipoles

charging by contact



Charging by induction





Charging by friction

Date:

If there is attraction b/w 2 objects

1 (one is -ve, one is +ve) 2. charges are induced

Coulomb's Law

empirical law = observation

$F \propto q_1 q_2$

$F \propto \frac{1}{r^2}$

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

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

electric const

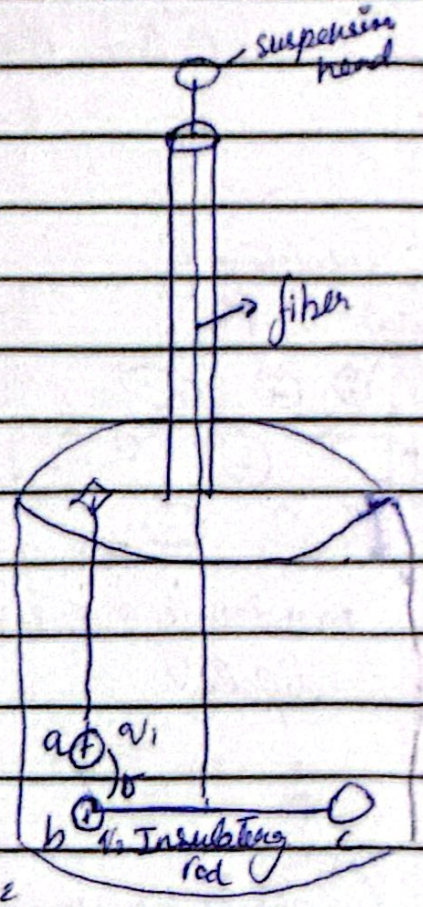


Fig Torsion Balance

$K = 8.99 \times 10^9 \, Nm^2C^{-2}$

K is electric constant

$K = \frac{1}{4\pi\varepsilon_0}$

$\varepsilon_0 = 8.85 \times 10^{-2} (N^{-1}m^{-2})$

permittivity of free space which shows electric

• outward/upward
X inward/

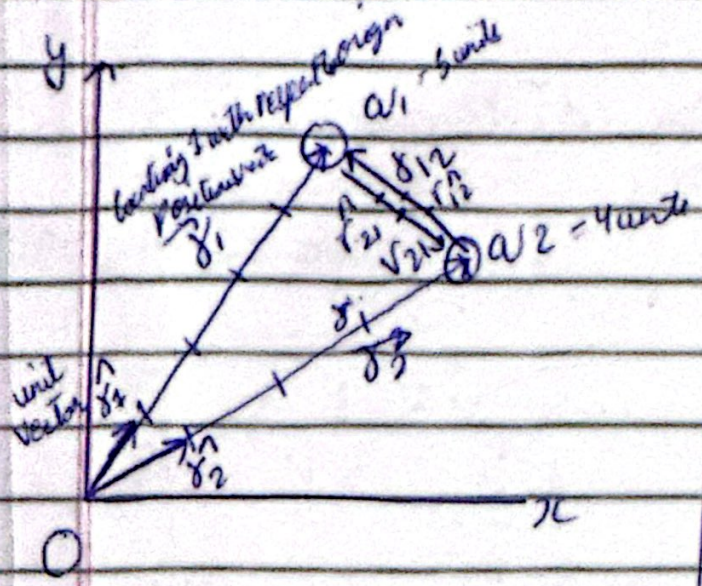
Date: _____

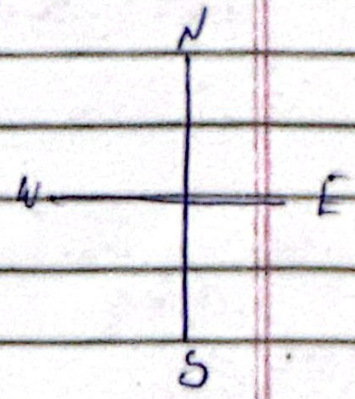
$E = mc$

$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ → permittivity electric

↳ permeability magnetic

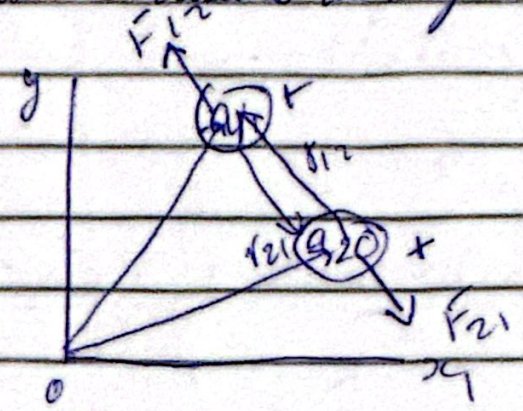
• Vector form of Coulomb's law





• upward/outward
X downward/inward

unit vector needed to tell direction and unit is for to not disturb the magnitude



This is just reversed step

$$\vec{F}_{12} = \frac{K q_1 q_2}{r_{12}^2} \hat{r}_{12} \rightarrow \vec{F}_{12} = \frac{K q_1 q_2 \vec{r}_{12}}{r_{12}^3}$$

$$F_{12} \propto \cancel{\frac{1}{r^3}}$$

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

$$\vec{F}_{21} = \frac{K q_1 q_2}{r_{12}^2} (-\hat{r}_{12})$$

$$\vec{F}_{21} = -\vec{F}_{12}$$

Scanned with CamScanner

Pg 581 Pg 574 3 sample Prob 25.2 3 4 exercises

Date: _____

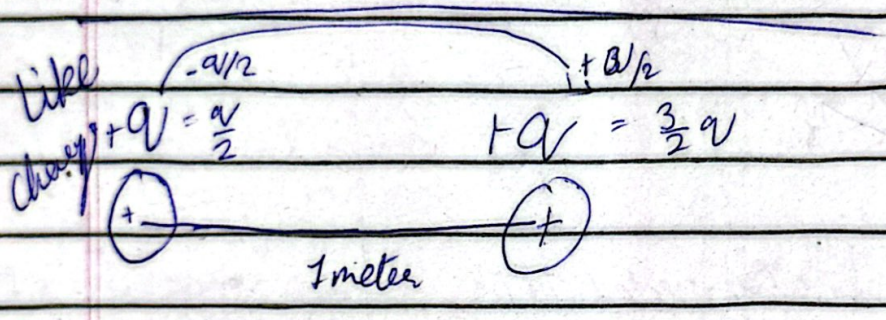
$\hat{r} = \frac{\vec{r}}{r}$ or $\vec{r} = r\hat{r}$

Gravitation 10^{-39} times weaker than electrostatic force

attractive

attractive / repulsive

Like charge



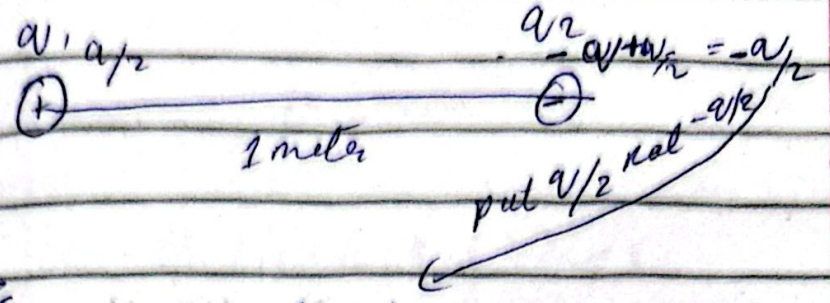
$F_0 = \frac{kq^2}{(1)^2}$

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

$F' = 3/4\, kq^2$

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

Date: _____ unlike



$$F = K \cdot q/2\,(q/2)$$

$$F' = \frac{1}{4} K q^2$$

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

Conservation of Charge:

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

$$\sum q = \text{constant}$$

$$q_i = q_f$$

e.g. annihilation of matter

$$\underset{\text{electron}}{e^-} + \underset{\text{positron}}{e^+} \longrightarrow \gamma + \gamma$$

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

$$0 \qquad 0$$

---

neutron decay

$$0 \longrightarrow 1.6\times10^{-19}C + (-1.6\times10^{-19}C) + 0 = 0$$

$$n^0 \longrightarrow p + e^- + \nu \text{ neutrino}$$

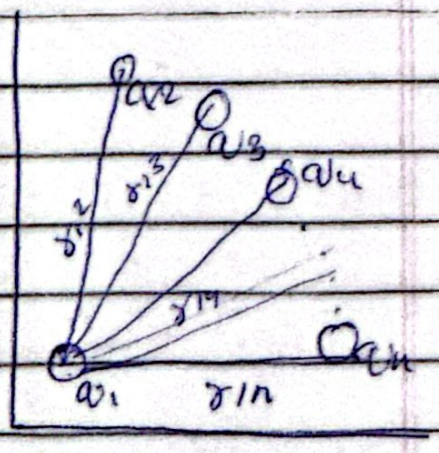
$$(+) \quad (-) \quad + \text{ neutral}$$

Date: Applied Physics

$F_e = \frac{k q_1 q_2}{r^2}$	$F_g = \frac{G m_1 m_2}{r^2}$
strong force	$\sim 10^{39}$ times weaker force
attractive as well as repulsive	only attractive
strong but short range	weak but long range

Superposition of forces

Force is a property of system (more than one charge)



Principal of Superposition:

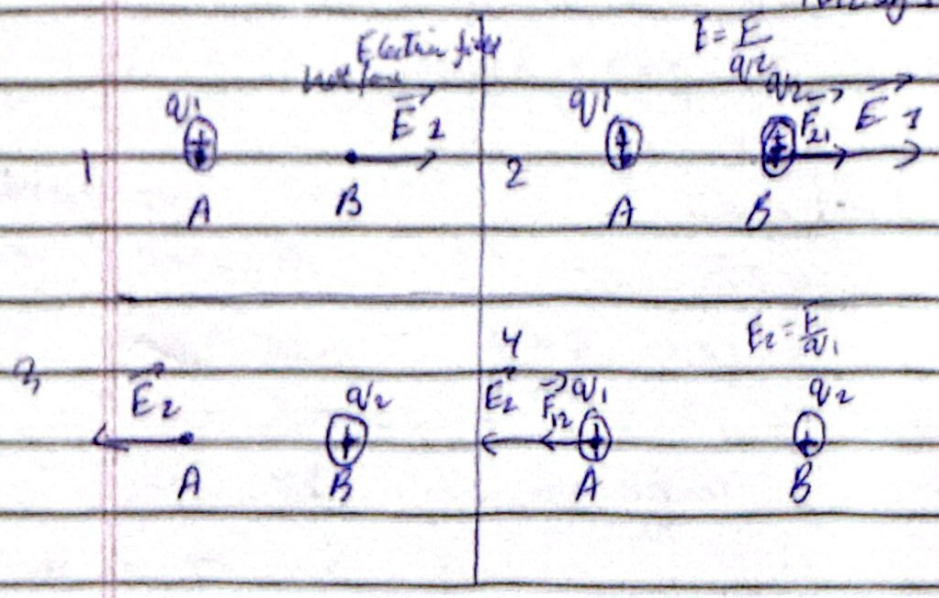
Force acting on one charge due to another charge is independent of whether or not other charges are present, so we calculate the

Date: _____ Force & Field Vector quantity

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

$$\vec{F} = \frac{kq}{r^2}\hat{r}$$

If unlike charge Force is reversed



$F = q_0 E$

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

Test charge should be small because we don't want to disturb field of q

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

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

Field of a charge is independent of whether or not other charges are present

Date:

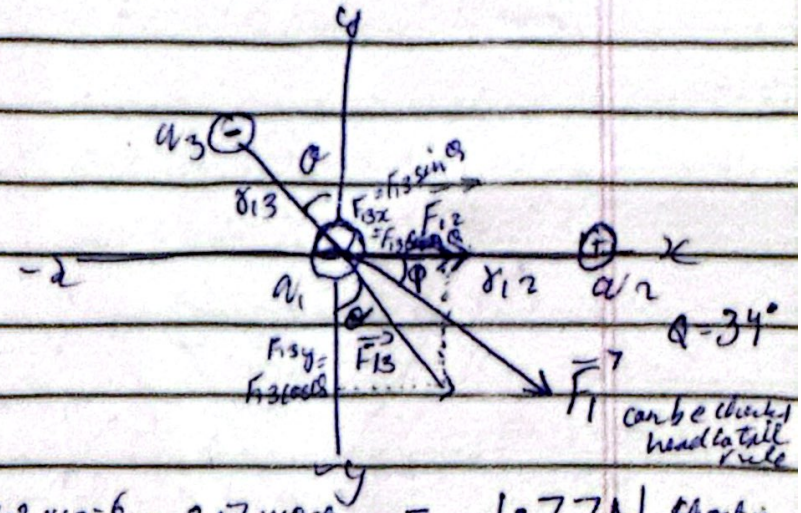
Sample problem 25.5

Fig shows 3 charged particles

$q_1 = -1.2\ \mu C$ 10^{-6} $\qquad r_{12} = 15cm$

$q_2 = +3.7\ \mu C$ $\qquad r_{13} = 10cm$

$q_3 = -2.3\ \mu C$ $\qquad \theta = 32°$



can be checked head to tail rule

F_1?

$$F_{12} = \frac{9\times10^9 \times 1.2\times10^{-6} \times 3.7\times10^{-6}}{(15\times10^{-2})^2} = 1.77N$$ short is. cept

$$F_{13} = \frac{9\times10^9 \times 1.2\times10^{-6} \times 2.3\times10^{-6}}{(10\times10^{-2})^2} = 2.48N$$

$F_{1x} = F_{12x} + F_{13x} = F_{12} + F_{13}\sin\theta$

$= 1.77 + 2.48\sin 32 = 3.08N$

$F_{1y} = F_{12y} + F_{13y} = 0 - F_{13}\cos\theta$

$= -2.48\cos 32 = -2.10N$

$F_1 = \sqrt{F_{1x}^2 + F_{1y}^2} = \sqrt{(3.08)^2 + (-2.1)^2} = 3.73N$

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

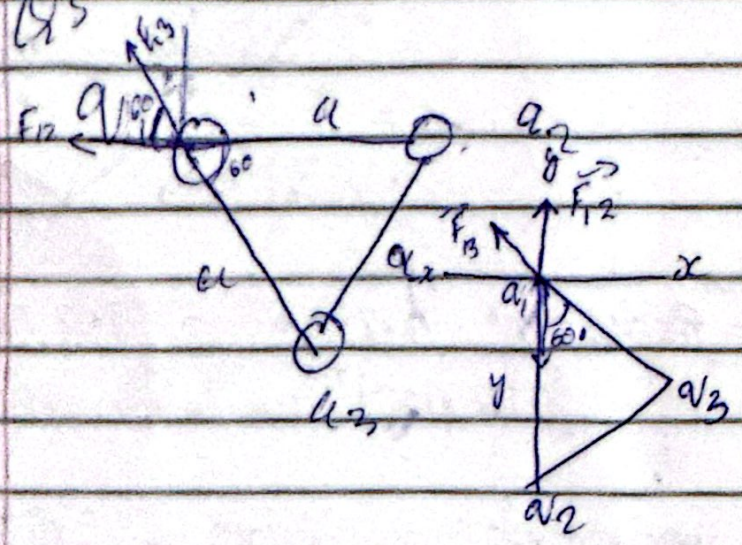
Date: _____

Assignment # 1

Page no. 683 Exercises no 1→8

Sand 8

Q5



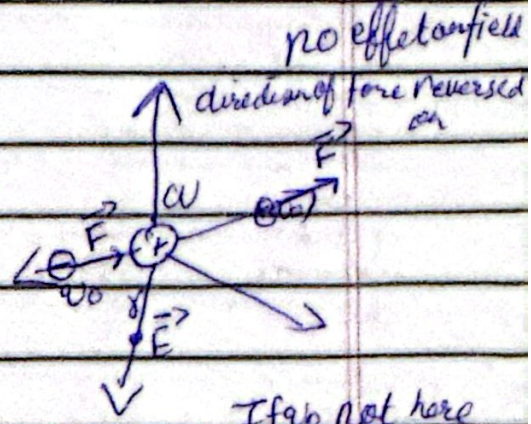
Date: _____

If we can associate a physical quantity at each point in a region of space S then we can say that a field exists in that region

- Field is a property of individual
- Force is a property of system

$F = \frac{K q_1 q_0}{r^2}$

$E = \frac{F}{q_0} = \frac{Kq}{r^2}$ $\quad E \propto q$, $E \propto \frac{1}{r^2}$



Electric Field $E = \frac{F}{q_0}$ Force exerted on q_0 due to $\vec{E}$

If q_0 not here field still exists

$E = \frac{Kq}{r^2}$ $\quad \vec{E}$ of q at r

charge q establish $\vec{E}$ at r distance

- Scalar Fields → static fields $T(x,y,z)$ (Temp)
  → Time varying $T(x,y,z,t)$ (time)
- Vector Fields → static fields $\vec{V}(x,y,z)$
  → Time Varying $\vec{V}(x,y,z,t)$

mass $\overset{\text{Interact}}{\rightleftharpoons}$ mass nothing happens

Charge $\rightleftharpoons$ charge and nothing happens is known as action at a distance

wrong

$2F \propto q_1 2q_2$

$E = \frac{2F}{2q_0}$

Force is dependant on E but E is not dependant on F

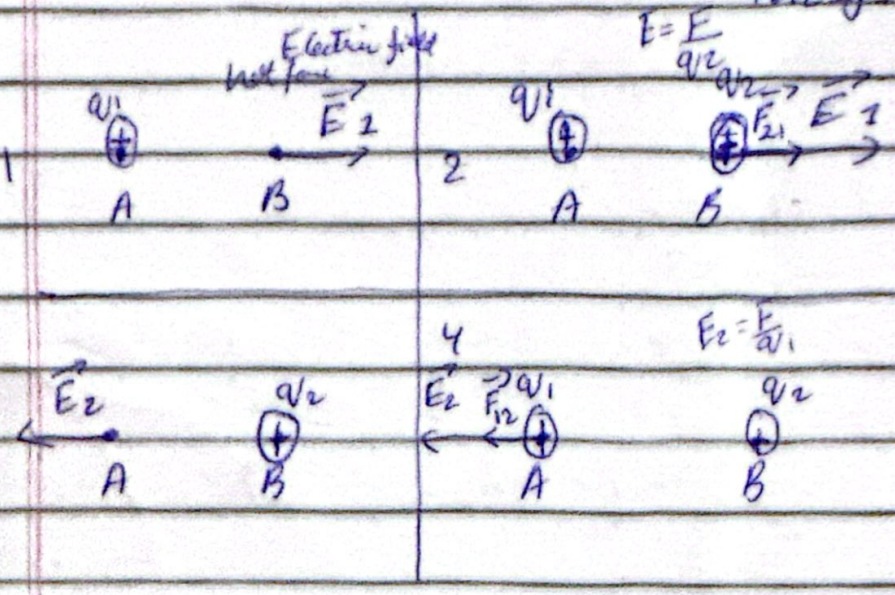
Date: ____ ____

Force & Field Vector quantity

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

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

If unlike charge Force is reversed



$F = q_0 E$

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

Test charge should be small because we don't want to disturb field of q

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

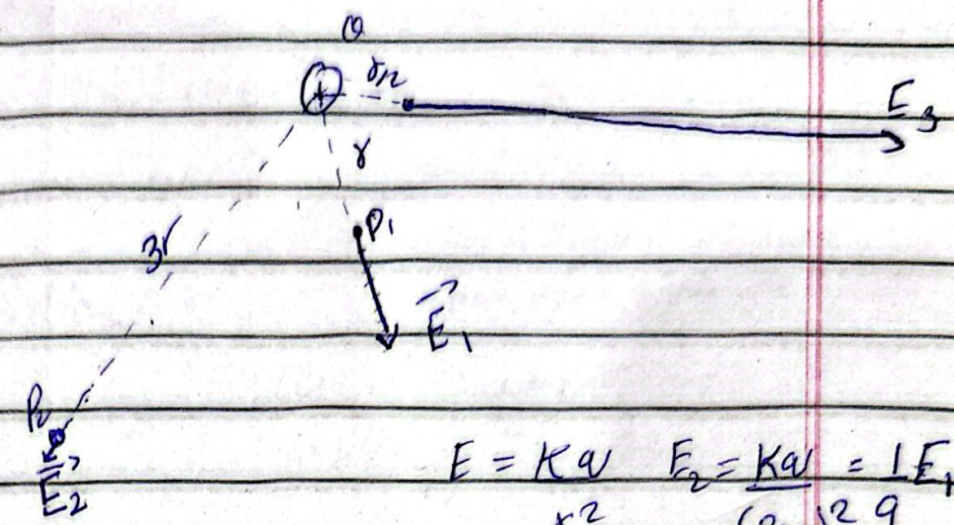
$\vec{F}_{12} = q_1 \vec{E}_2$

Field of a charge is independant of whether or not other charges are present

$F = \frac{Kq q_0}{r^2}$

Date: $\frac{F}{q_0} = \frac{F}{q_0} = q_0 E$

dependance upon distance



$E = \frac{Kq}{r^2}$ $E_2 = \frac{Kq}{(3r)^2} = \frac{1}{9}E_1$

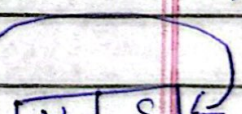
$E_3 = \frac{Kq}{(r/2)^2} = 4E_1$

Electric field line

Originate	+ve charge	Monopole exist in electrostatics
Terminate	-ve charge	

Monopole does not exist in magnetic because N and S can't exist independently

$\vec{E}$ is shown by tangent on any point



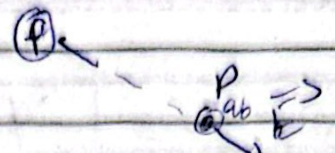
flux : no of field lines passing through a unit area held perpendicular to field lines

$\Rightarrow$ Force same at any point

uniform electric field magnitude same at any point

non uniform

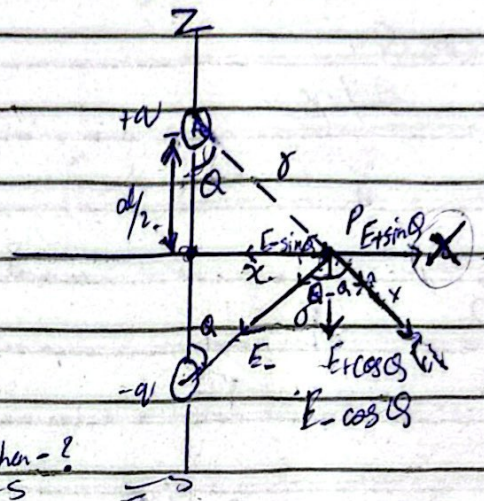
Date: $\frac{Q}{B}$ Applied Phy



$E_+ = \frac{Kq}{r^2}$

$F = q_0 E_+$ q_0 ccc so it doesn't distribute field

Electric field of a dipole



angle with Q is cos

when + when − ?

$\vec{E}_p = \vec{E}_+ + \vec{E}_-$ supperposition have to supermose both of ea

$E_+ = \frac{Kq}{r^2}$

$E_- = \frac{Kq}{r^2}$

a

2 vector opp in direction along x axis

$E_{px} = E_+ \sin\theta - E_- \sin\theta = 0$ −minus with component of −ve sial

E_{tp} at x axes

2 vectors in same direction along z-axis

$E = E_{pz} = E_+ \cos\theta + E_- \cos\theta = 2E_+ \cos\theta$ — (1)

dipole is superposition of 2 charges

Date:

From Fig

$r^2 = x^2 + (d/2)^2$ — 2(a)

$\cos\theta = \frac{d/2}{r}$ — 2(b)

From Fig

$r^2 = x^2 + (d/2)^2$

$\cos\theta = \frac{d/2}{r}$

from eq (1)

$E = 2E_+ \cos\theta$

$E = 2\frac{Kq}{r^2}\frac{d/2}{r}$

$qd = P$

$\because qd = P$

$E = \frac{KP}{r^3}$ $\quad E \propto \frac{1}{r^3}$

r shows I charge answer should be in term of x because x shows dipole

$\because r = [x^2 + (d/2)^2]^{1/2}$

$\because r^3 = [x^2 + (d/2)^2]^{3/2}$

$r^3 \simeq x^3$

$E = \frac{KP}{[x^2 + (d/2)^2]^{3/2}}$

Binomial Theorem :- when power is fractional or -ve

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

Date:

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

$$= KP\,(x^2)^{-3/2}\left[\overset{1}{1} + \overset{x}{\left(\frac{d}{2x}\right)^2}\right]^{\overset{n}{-3/2}}$$

$$\frac{KP}{x^3}\left[1 + \cancel{\left(\frac{-3}{2}\right)\left(\frac{d}{2x}\right)^2} + \dots\right]$$

d^2 is so small so it ≈ 0

$$\vec{E} = \frac{KP}{x^3}(-\hat{k}) \quad \text{from}$$

$d^2 \approx 0$

$$E \propto \frac{1}{x^3}$$

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

$$KP\,x^{2\times -\frac{3}{2}}\left(1 + (d/2x)^2\right)^{-3/2}$$

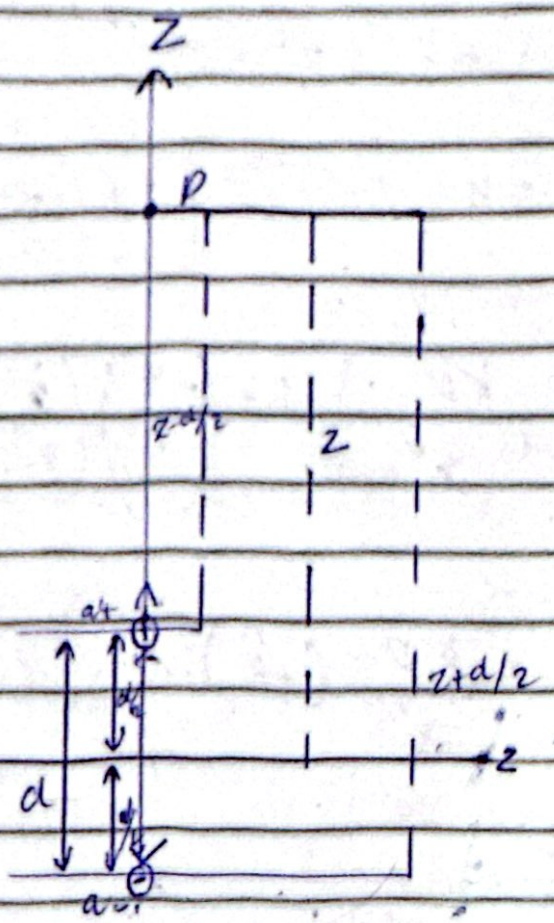
$$(1 + x)^n = 1 + nx$$

$$\frac{KP}{x^3}\left(1 + \frac{-3}{2}\left(\frac{d}{2x}\right)^2\right)$$

$$\frac{KP}{x^3}(\hat{k})$$

$$E \propto \frac{1}{x^3}$$

Date: _____



$$E_+ = \frac{Kq}{(z-d/2)^2} \qquad E_p = E_+ - E_-$$

$$E_- = \frac{Kq}{(z+d/2)^2}$$

$$E_p = Kq\left[\frac{1}{(z-d/2)^2} - \frac{1}{(z+d/2)^2}\right]$$

$$Kq\,\frac{(z+d/2)^2 - (z-d/2)^2}{z^4 - (d/2)^4}$$

$$Kq\left\{\frac{z^2 + \frac{d^2}{4} + 2z\frac{d}{2} - \left(z^2 + \frac{d^2}{4} - 2zd\right)}{z^4 - (d/2)^4}\right\}$$

Date: $a^2 - b^2$ do not ignore d but ignore powers

$$Kq\left[\frac{z^2 + \frac{d^2}{4} + zd - z^2 + \frac{d^2}{4} + zd}{z^4 - (d/2)^4}\right]$$

$a^2 - b^2$ $(z^2)^2 - \left(\frac{d^2}{4}\right)^2$

$\left(\frac{d}{2}\right)^4$ neglected

$$Kq\left[\frac{2\cancel{z}d}{z^{\cancel{4}3}}\right]$$

$$E_p = \frac{2Kqd}{z^3}$$

$$E_p = \frac{2KP}{z^3}$$

Scanned with CamScanner

Date: _____ Applied Phy

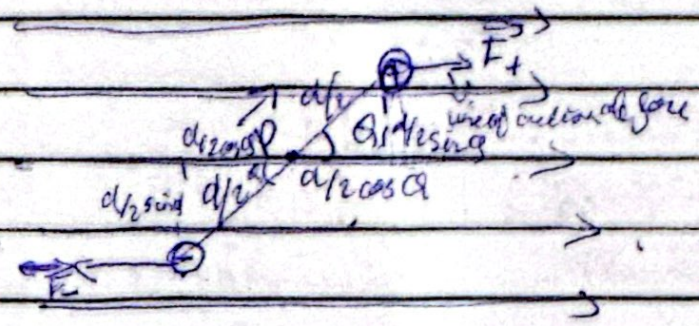
Dipole in electric Field

Force, Torque
P.E, Work

$P = qd$
direction from -ve to +ve
θ angle b/w $\vec{P}$ and $\vec{E}$

Torque will be produced until P align with direction of E

Torque = Force × moment arm



Perpendicular distance from line of action of force to axis of rotation Moment arm

$\tau_+ = F_+ (d/2) \sin\theta$
$\tau_- = F_- (d/2) \sin\theta$
$\tau_{net} = \tau_+ + \tau_-$
$\tau = qE(d/2)\sin\theta + qE(d/2)\sin\theta$
$\tau = qdE\sin\theta$
$\tau = \vec{P}E\sin\theta$
$\vec{\tau} = \vec{P} \times \vec{E}$ Cross product = vector

info of small differentiation

Date: _____ from small to big integration

Where x product right hand rule

Work done by Electric field

$\Delta U = U_f - U_i$

$U = -W$

$W = \vec{F} \cdot \vec{d}$ or $\vec{F} \cdot \vec{s}$ no translatory work because it rotates

Turning effect of work $\rightarrow$ $W = \vec{\tau} \cdot \vec{\theta}$

$U = -W = -\int_{90}^{0} \tau \, d\theta$ derivative of θ

Σ sum by +1	$\int dx = x$ $\int dL = L$
$\int$ sum of all parts points	$\int dy = y$ $\int dA = A$
$\int dA = A$	combining all y's will give y

$\int \sin\theta = -\cos\theta$

only integral

$U = -W = -\int_{90}^{0} \tau \, d\theta$ $\int \sin\theta = -\cos\theta$

$= -\left(\int_{90}^{0} PE \sin\theta \, d\theta\right)$ $\int d\theta = \theta$

$= -\left(PE \int_{90}^{0} \sin\theta \, d\theta\right)$ so whole $\int \sin\theta \, d\theta = \cos\theta$

$= -\left(PE(-\cos\theta)\right|_{90}^{0}$

$= +PE(\cos\theta)\Big|_{90}^{0}$

$= -PE(\cos\theta - \cos 90)$ The upper lim The lower lim

$= +PE\cos\theta$

Date:

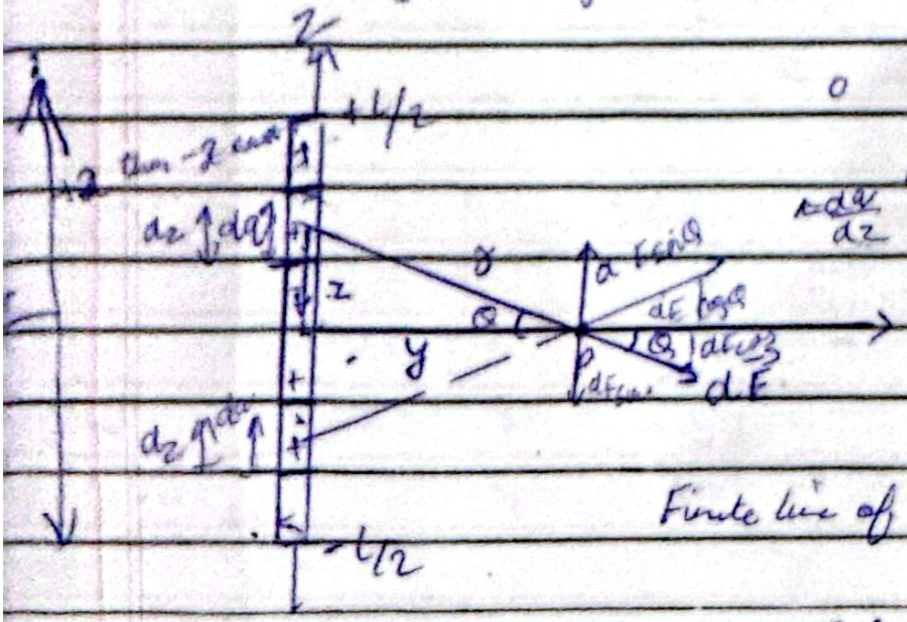
uniform density $\frac{q}{L} = \frac{dq}{dl}$ $\frac{dq}{dA} = \frac{q}{A}$ $\frac{dq}{dV} = \frac{q}{V}$

Continuous charge distribution (charge on obj)

Discrepancy of Coulomb's law :-

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

line of charge
ring
disk
sphere
shell



Linear charge density q

Linear: $\lambda = \frac{q}{L} = \frac{C}{m}$ $= \frac{dq}{dz}$

Surface $\sigma = \frac{q}{A}$ Cm^{-2}

Volume $\rho = \frac{q}{V} = Cm^{-3}$

Finite line of charge

Infinite charge line $\lim_{\infty} E = \frac{\lambda}{r}$

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

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

For each charge element on one side there is a corresponding charge element on another side, they establish their electric the field in such way

along z axis

$dE_z = dE \sin\theta$

$E_z = \int dE_z = 0$

Date:

along y-axis:

$$dE_y = dE\cos\theta \quad (2)$$

From fig

$$r^2 = y^2 + z^2$$
$$\cos\theta = y/r$$

∴ Variable are z and r but I consider

From eq (2)

$$dE_y = \frac{K\lambda dz}{r^2}\,\frac{y}{r} \qquad y^2\sqrt{y^2+z^2}$$

$$= K\lambda y\,\frac{dz}{r^3}$$

$$\int dE_y = \int K\lambda y\,\frac{dz}{(y^2+z^2)^{3/2}}$$

$$E_y = K\lambda y \int_{-L/2}^{L/2} \frac{dz}{(y^2+z^2)^{3/2}}\,dz$$

put limit of z

We know that

Date:

upper limit - lower limit dz

$$E_y = K\lambda y \frac{z}{y^2\sqrt{y^2+z^2}} \Bigg|_{-L/2}^{+L/2}$$

$$E_y = \frac{K\lambda}{y}\left[\frac{+L/2}{\sqrt{y^2+(L/2)^2}} - \frac{(-L/2)}{\sqrt{y^2+(\frac{L}{2})^2}}\right]$$

$$E_y = \frac{K\lambda}{y}\left[\frac{L}{\sqrt{y^2+(\frac{L}{2})^2}}\right]$$

$$E = \frac{\lambda}{2\pi\varepsilon_0 y} \qquad \frac{\sigma}{2\varepsilon_0}$$

Scanned with CamScanner

$\oint E\,dl = 0$

Date: _____ Applied Phy

d -> part of Total

2 component cancel

2 reinforce

CH 3

Gauss' law

Gauss law is more fundamental, basic and applicable as compared to coulombs law because :-

point charg insulator

- It is valid for point charges as well as continuous charge distribution
- It is also valid for conductors

It is Highly Symmetric

Under certain transformation it remains invariant

No. of field lines passing through unit Area is called Flux

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

$$\phi_E = \vec{E} \cdot \vec{A} = EA\cos\theta$$

$$\phi_E = \int \vec{E} \cdot d\vec{A} = \int E\,dA\cos\theta$$

perpendicular $\cos 0 = 1$

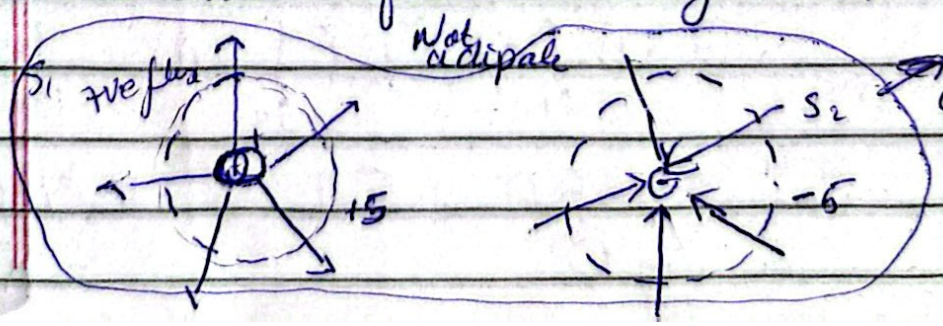
parallel $\cos 90 = 0$

For loop :-> passing

For closed surface -> entering and leaving

+ve flux

Not a dipole



charge inside the S

so flux 0

no of lines leaving and entering

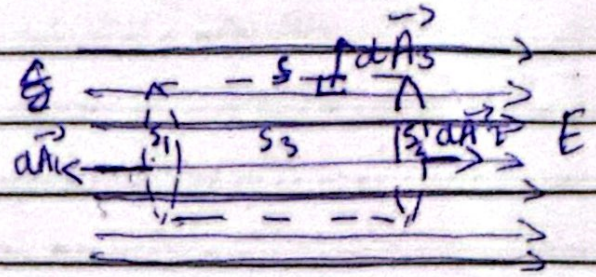
Date: ~~closed surface of back of pag~~ $\phi = E \cdot A = \frac{q}{\epsilon_0}$

closed $\oint_S \vec{E} \cdot d\vec{A} = \frac{+q}{\epsilon_0} - \frac{q}{\epsilon_0} = 0$

$\oint_{S_1} \vec{E} \cdot d\vec{A} = \frac{+q}{\epsilon_0}$ $\oint_{S_2} \vec{E} \cdot d\vec{A} = \frac{-q}{\epsilon_0}$

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

Sample problem



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

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

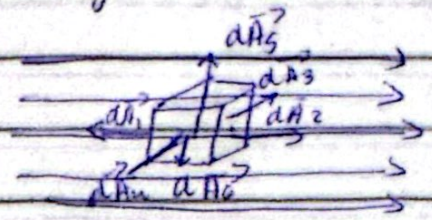
$= -E \int_{S_1} dA_1 + E \int_{S_2} dA_2$ $\int_{S_1} dA_1 = \int_{S_2} dA_2$

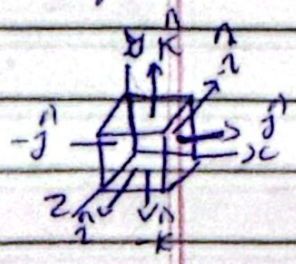
$= -EA + EA$ $= A$ (Area of cap)

$= 0$ $= \pi r^2$

Date: _____ $\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1$

Prove that the flux through a cubic closed surface placed in a uniform electric field is 0





$$\oint_C \vec{E}\cdot d\vec{A} = \int_{S_1} \vec{E}\cdot d\vec{A}_1 + \int_{S_2} \vec{E}\cdot d\vec{A}_2 + \int_{S_3} \vec{E}\cdot d\vec{A}_3 + \int_{S_4} E\cdot d\vec{A}_4 + \int_{S_5} E\cdot d\vec{A}_5 + \int_{S_6} E\cdot d\vec{A}_6$$

$$= \int_{S_1} E\,dA\cos 180^\circ + \int_{S_2} E\,dA\cos 0 + \int_{S_3} E\,dA\cos 90 + \int_{S_4} E\,dA\cos 90 + \int_{S_5} E\,dA\cos 90 + \int_{S_6} E\,dA\cos 90$$

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

$$= -EA + EA$$

$$= 0$$

Property: Flux through a closed surface placed in a uniform electric field is alway equal to zero

3/2/2

Date:

$\vec{E} = 4\hat{i} + 3\hat{j}$ $\qquad \hat{i}\cdot\hat{j}$ $\quad \hat{j}\cdot\hat{j}$

$\vec{A} = (2m)^2\hat{j} = 4\hat{j}$

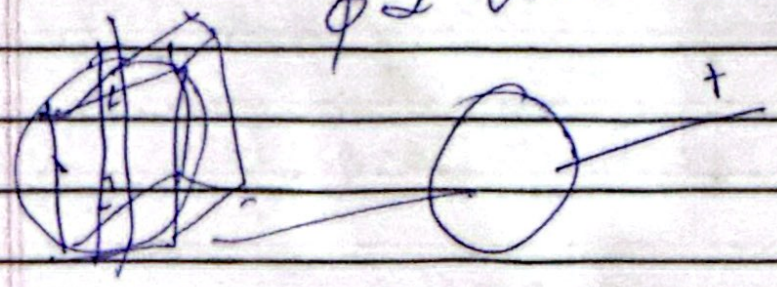
$\phi = \vec{E}\cdot\vec{A}$

$= (4\hat{i} + 3\hat{j})\cdot(4\hat{j})$

$= 16\,\hat{i}\cdot\hat{j} + 12\,\hat{j}\cdot\hat{j}$

$= 12\ NC^{-1}m^2$

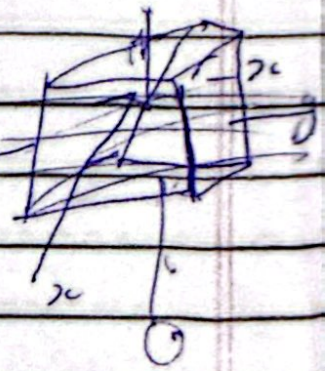
$\phi \propto$ area



$E = 4\cdot 0\,\hat{i} - 3(0^2 + 2\cdot 0)\hat{j}$ $\qquad 0$

$4\hat{i} - (3y^2 + 6)\hat{j}$ $\qquad z$

$(2)^2 - \hat{i}$ $\qquad -\hat{j}$



$E\cdot A$ $\quad 2\hat{i}\,(4\hat{i} + 3\hat{j}$

$-8\hat{i} + 6\hat{j}$

$4\hat{i}\,(4\hat{i} - (3y+6)\hat{j})$ $\qquad 0$

$16\hat{i}$

$(4\hat{j})(4\hat{i} - (3y+6)\hat{j}$

$-12y\,\hat{j} - 24\,\hat{j}$

Applied Physics

educative

$E = \frac{\lambda}{2\pi\varepsilon_0 r}$ by infinite wire

Gaussian law $\Phi = q_{net}/\varepsilon_0$ $\Phi = \oint \vec{E}\cdot d\vec{A} = \frac{q_{encl}}{\varepsilon_0}$

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

$d = 4,\ n = 2$

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

$$\oint_S \vec{E}\cdot d\vec{A} = \frac{q_{encl}}{\varepsilon_0} \quad -①$$

Field on the surface, Area of Gaussian surface (Imaginary), charge enclosed by the

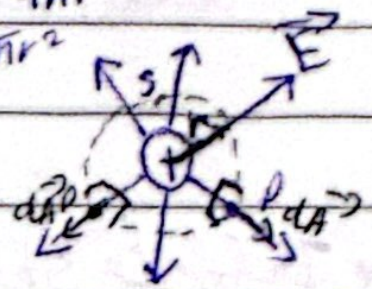
3

3, 7

Prove that Gauss law (by point charge) is equivalent to Coulomb's law (only point charge) :-

Sphere $4\pi r^2$

circle πr^2



$$\oint_S \vec{E}\cdot d\vec{A} = \frac{q_{encl}}{\varepsilon_0}$$

$$\oint_S E\,dA\cos 0^\circ = \frac{q_{encl}}{\varepsilon_0}$$

for all patches

as E is constant

$$E\oint_S dA = \frac{q}{\varepsilon_0}$$

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

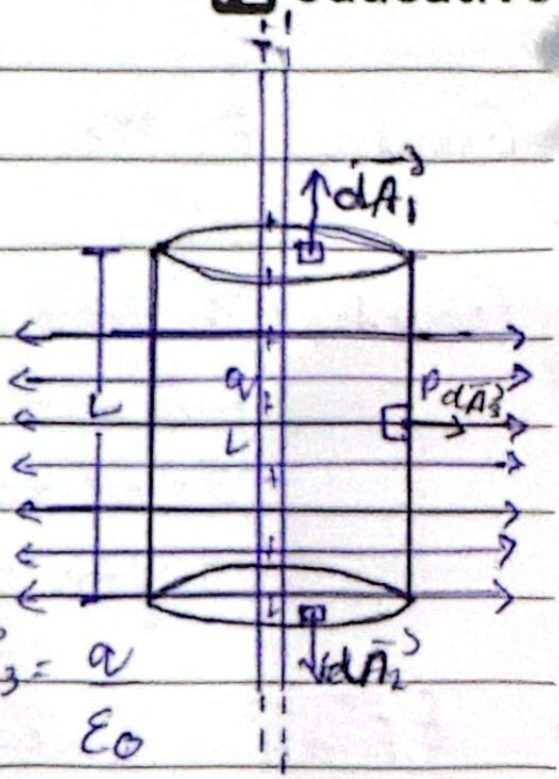
And

$$E = \frac{q}{4\pi\varepsilon_0 r^2}$$ Coulomb's law

Scanned with CamScanner

In coulomb path for charge
In gauss path for area vector

Application of Gauss' law



• Infinite line of charge :- charge in fence / charge in fence

E is constant and uniform

$$\lambda = \frac{q}{L}$$

$$q = \lambda L$$

$$\oint_S \vec{E}\cdot d\vec{A} = \oint_{S_1} \vec{E}\cdot d\vec{A}_1 + \oint_{S_2} E\, d\vec{A}_2 + \oint_{S_3} \vec{E}\, d\vec{A}_3 = \frac{q}{\varepsilon_0}$$

Area circle cap, Area circle cap, $\cos 90$, $\cos 90°$

$$\oint_S \vec{E}\cdot d\vec{A} = 0 + 0 + E\oint_S d\vec{A}_3$$

∵ Area of cylinder side

∵ A = circumference × length

$$\therefore A_3 = (2\pi r)L$$

$$\phi = \frac{q}{\varepsilon_0} \qquad \lambda = \frac{q}{L}$$

$$\frac{q \times L}{L\varepsilon_0}$$

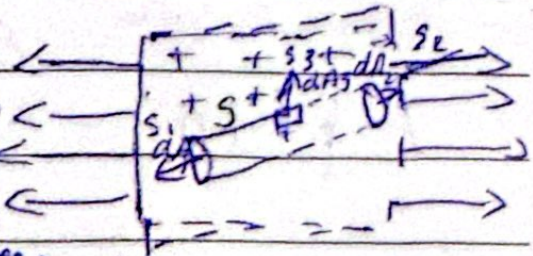
$$E\, 2\pi r L = \frac{\lambda L}{\varepsilon_0}$$

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

ring + ring + ... = disc

if disc radius = ∞, sheet

• Infinite sheet of charge :-



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

$$= EA + EA + 0 = \frac{q}{\varepsilon_0}$$

$$\therefore q = \sigma A \qquad q = \sigma A$$

charge density

$$\sigma = q/A$$

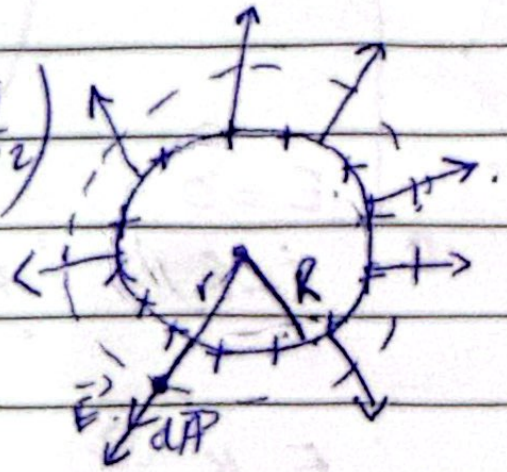
$$2EA = \frac{\sigma A}{\varepsilon_0} \quad \text{so} \quad E = \frac{\sigma}{2\varepsilon_0}$$

Scanned with CamScanner

educative

A uniform spherical shell of charges

For external Points $(r \geq R)$ $\left(E \propto \frac{1}{r^2}\right)$



$$\oint_S \vec{E} \cdot d\vec{A} = \frac{q_{encl}}{\varepsilon_0} \quad -①$$

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

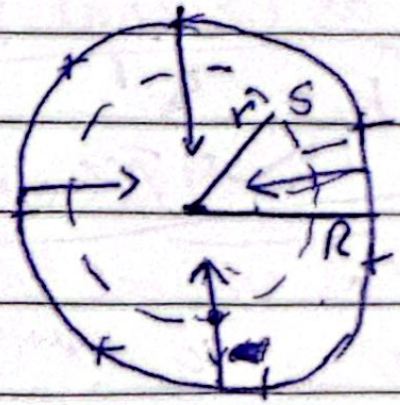
$$E \oint_S dA = \frac{q}{\varepsilon_0}$$

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

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

For external points a spherical shell behaves Just like a point charge.

For Internal Point, $r < R$



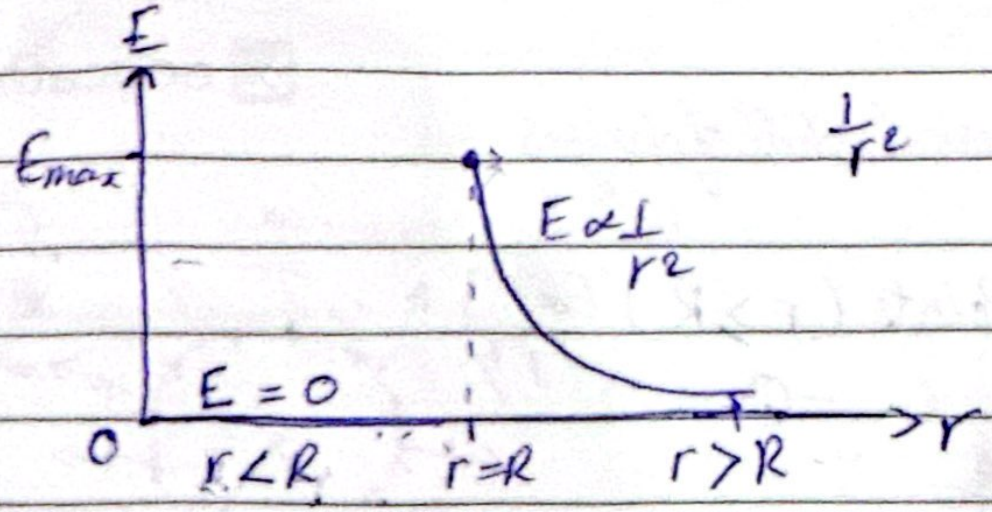
$$\oint_S E\, dA \cos\theta = 0$$

$$\oint_S dA \neq 0$$

$$\cos\theta \neq 0$$

$$E = 0$$

Scanned with CamScanner



Field distance graph for internal & external points on sphere

$E = k \frac{q}{r^2}$

Spherically symmetric charge distribution

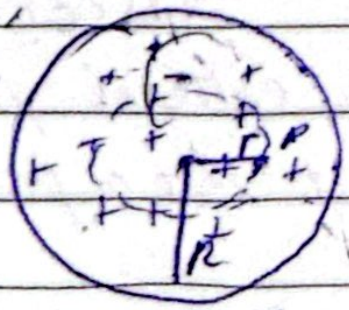
part of charge and part of volume

non uniform distribution in sphere

volume density = ρ

$\rho = \rho'$ / shows gaussian surface

$\frac{q}{\frac{4}{3}\pi R^3} = \frac{q'}{\frac{4}{3}\pi r^3}$



P as external point $r > R$

$$\boxed{E = \frac{q'}{4\pi\varepsilon_0 r^2}} \quad (1)$$

$E \propto \frac{1}{r^2}$

P is external to inner sphere gaussian

P as internal $r < R$

$\frac{q}{V} = \frac{q'}{V}$

whole sph $\frac{q}{\frac{4}{3}\pi R^3} = \frac{q'}{\frac{4}{3}\pi r^3}$ / gaussian

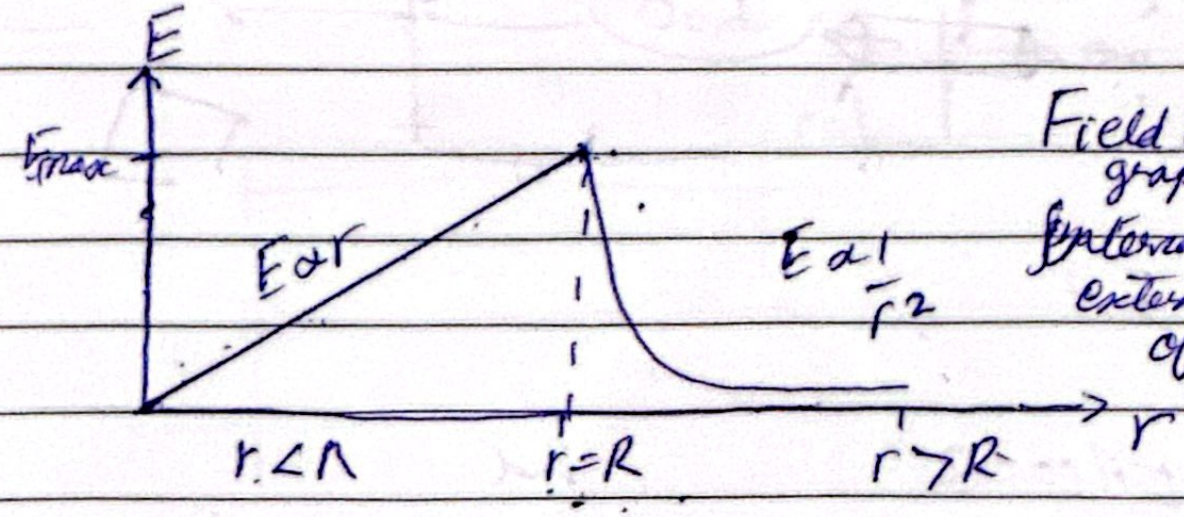
$$q' = \frac{r^3}{R^3} q$$

put in eq (1)

$$E = \frac{r^3}{R^3} \frac{q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{q}{4\pi\varepsilon_0 R^3} r \quad (r < R)$$

$$(E \propto r)$$



Field distance graph for internal and external point of sphere

Charge density $\frac{q}{A}$

anything 1/L 1/A 1/V density

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

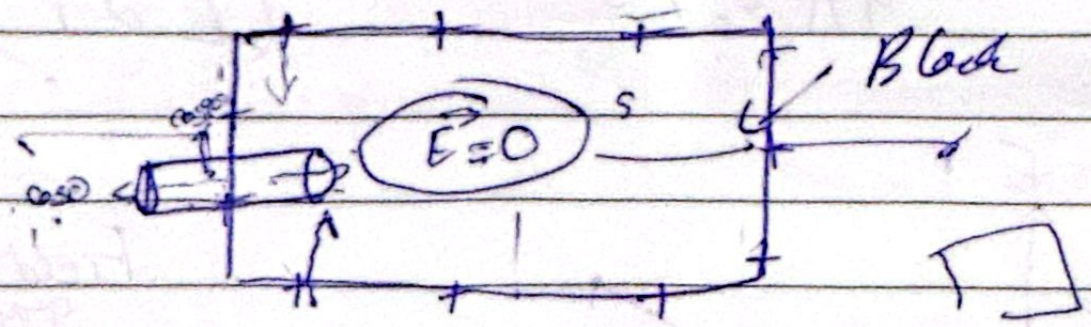
$$E = \frac{kq}{r^2} \hat{r} \frac{\vec{r}}{r}$$

$$= \frac{1}{4\pi\varepsilon_0 r^3} r$$

Excess charges in conductor goes to surface

if Sphere charge distribution but conductor so it will behave like shell

Net charge by gaussian surface in conductor is 0



$E = EA$

$\phi_E = EA\cos\theta$

First problem

2nd

$E = 3\hat{i} + 7\hat{j}$

$A = (2m)^2\hat{j} = 4\hat{j}$

$E \cdot A = 12\hat{i}\hat{j} + 28\hat{j}\hat{j}$

$= 28$

$\hat{i}\times\hat{i} = \hat{j}\times\hat{j} = \hat{k}$.

10-12 M.C.Qs

1 numerical Sums

educative

$E = K + U^{Pot}$

$\Delta E = \Delta K + \Delta U$ as $\Delta E = 0$

$\Delta U = -\Delta K$

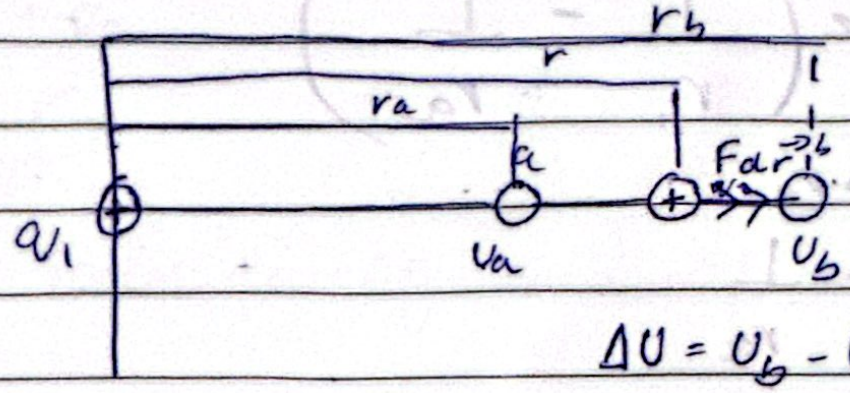
Work done on system energy ↑ U

Work done by system system energy ↓ −U

$\Delta U = -W$ work done changes energy of

$\Delta U = -\vec{F} \cdot \vec{S}$

$= -\int_a^b \vec{F} \cdot d\vec{S} = -\int_{r_a}^{r_b} \vec{F} \cdot d\vec{r}$



$\Delta U = U_b - U_a$

$= -\int_{r_a}^{r_b} F dr \cos\theta$

$= -\int_{r_a}^{r_b} F dr \cos 0$ $F = q_0 E$ done against radial force

$= -\int_{r_a}^{r_b} F dr$

$= -\int_{r_a}^{r_b} \frac{K q_1 q_2 dr}{r^2} = -K q_1 q_2 \int_{r_a}^{r_b} \frac{dr}{r^2}$

Scanned with CamScanner

$$-Kq_1q_2 \int_{r_a}^{r_b} r^{-2}\,dx$$

educative

Power Rule:

$$\int x^n\,dx = \frac{x^{n+1}}{n+1}$$

$$U = -Kq_1q_2 \left.\frac{r^{-2+1}}{-2+1}\right|_{r_a}^{r_b}$$

Negative

$U-$

$$= -Kq_1q_2 \left.\frac{1}{r}\right|_{r_a}^{r_b}$$

upper - lower

$$= +Kq_1q_2\left(\frac{1}{r_b} - \frac{1}{r_a}\right)$$

if $r_b > r_a$

then $\frac{1}{r_b} < \frac{1}{r_a}$

so $\Delta U < 0$

In attraction

$\cos 180°$

as $d\vec{r}$ will be

opposite 2 $\vec{F}$

Scanned with CamScanner

Infinity of particle is place where its Field is 0

$E = 0$ $F = 0$ $U = 0$ $V = 0$] ∞ of charge

Energy stored in bringing a charge from ∞ to a particular point

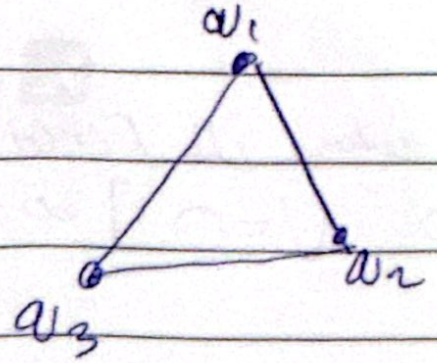
At ∞ $r_a \to \infty$ and $U_a = 0$

as $r_b = r$
$r_a = \infty$

$$U = Kq_1q_2\left(\frac{1}{r_b} - \frac{1}{\infty}\right)$$

$$U = \frac{Kq_1q_2}{r}$$

When scalar quantity we have to deal with sign



Energy & Force are property of system

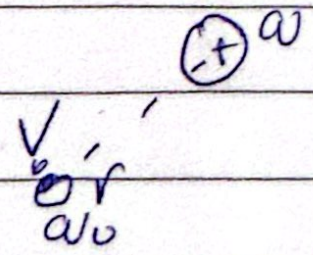
$$U = \frac{Kq_1q_2}{r_{12}} + \frac{Kq_1q_3}{r_{13}} + \frac{Kq_2q_3}{r_{23}}$$

Charge bringing from ∞ to a place

$$\underset{\text{System Empty}}{0} + \underset{\text{One charge}}{0} + \underset{\text{Second charge}}{\frac{Kq_1q_2}{r_{12}}} + \underset{\text{Third Charge Brought}}{\frac{Kq_1q_3}{r_{13}}} + \frac{Kq_2q_3}{r_{23}} = U$$

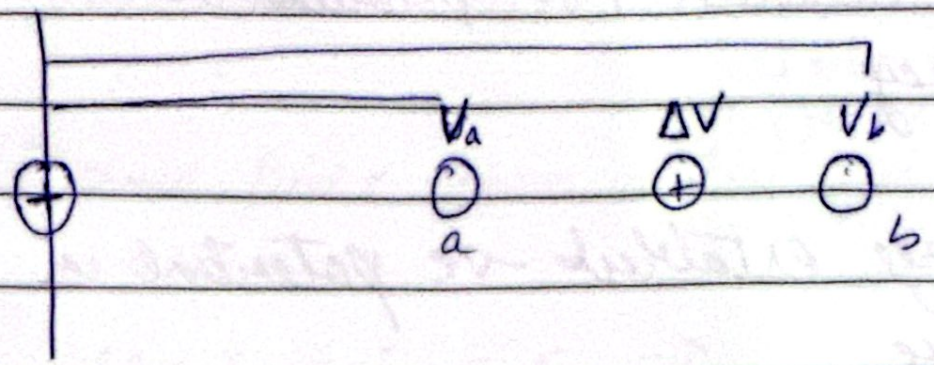
$$U = \frac{Kqq_0}{r}$$ as $U \propto qq_0$

$$\frac{U}{q_0} = \frac{Kq}{r} = V$$



$$V = \frac{Kq}{r}$$

potential at r by q



U → Joule
q → Coulomb

$$V = \frac{U}{q_0} \qquad W = -q_0 V$$

As

$$W = -\Delta U$$

$$W = -(U_b - U_a)$$ absolute value of U

$$W = -q_0 (V_b - V_a)$$

$$W = -q_0 \Delta V$$

$$V = \frac{U}{q_0}$$ Joule Coulomb^{-1}

$$\frac{\Delta U}{q_0} = Kq\left(\frac{1}{r_b} - \frac{1}{r_a}\right)$$

Jo Use hota
Uo Use karne
ki zarurat
ni

Potential depends upon charge

educative

A +ve charge establish +ve potential in surrounding

And

A -ve charge establish -ve potential in surrounding

$= (1.602 \times 10^{-19} C)(1V)$

$1 eV = 1.602 \times 10^{-19} J$

Superposition

sign depends upon direction

$k \left(\Sigma \frac{q_1}{r_1} + \frac{q_2}{r_2} \right.$

Potential is scalar

Scanned with CamScanner

Potential due to dipole $V = \frac{Kq}{r}$

if q +ve ~~B.O~~ +q
r for -ve -q

we should find r shows distance from centre of dipole

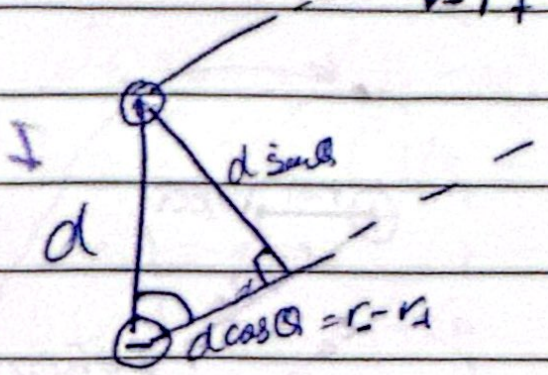
$d <<< r$

so $r_+ \cong r_- \cong r$ —①

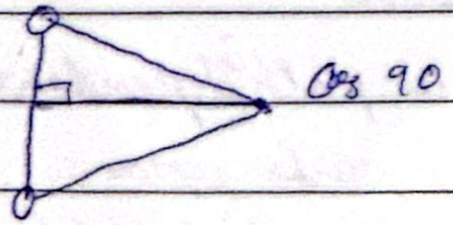
$V_+ + V_- = K[q/r_+ + -q/r_-]$ by this it will become zero

$V = Kq\left(\frac{r_- - r_+}{r_- r_+}\right)$ for numerator we assume

for denominator —①



$V = Kq \frac{d\cos\theta}{r^2} = \frac{KP\cos\theta}{r^2}$ general

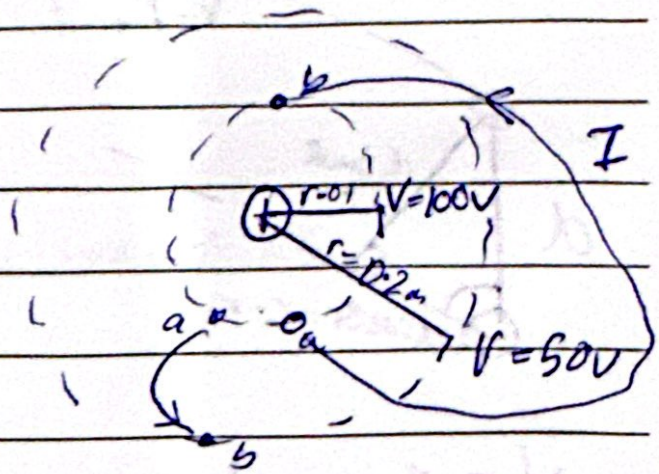


$E = (\ )$
$F = q_0 E$

Potential due to continuous charge distribution
Have to Find $E \Leftrightarrow V$

$E \Leftrightarrow V \longrightarrow U$ as $U = q_0 V$

- Equipotential Surfaces — same potential



$q = 1.11\,nC$
$r_1 = 0.1m$
$r_2 = 0.2m$
$V_1 = \frac{Kq}{r}$

$V_2 = \frac{1}{2}\left(\frac{Kq}{r}\right)$ half if r is double

Path I

$\Delta U = q_0 \Delta V$
$-W_{ab} = q_0 \Delta V$
$W_{ab} = -q_0 (V_b - V_a)$
$= -q_0 (100V - 100V)$
$= 0$

Work
W is path independent
it depends upon initial and final

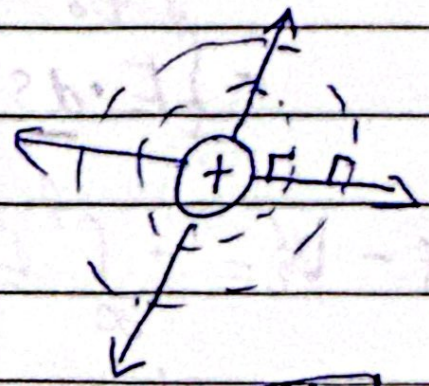
Conservative

for Path 2

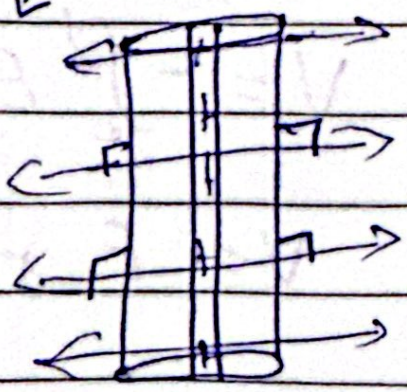
$W_{ab} = q_0(50 - 100)$
$= 50 q_0$

Slide 35

$W_1 = -q_0 (V_1 - V_1)$
$W_2 = -q_0 (V_3 - V_3)$ shows path independence
$W_3 = -q_0 (V_2 - V_1)$
$W_4 = -q_0 (V_2 - V_1)$



The electric field lines are perpendicular to equipotential surfaces



Relation b/w V and E

calculating V from E

$\Delta U = q_0 \Delta V$

$$\Delta V = \frac{\Delta U}{q_0}$$

$$\Delta V = \frac{-W_{ab}}{q_0}$$

$\because \Delta U = -W_{ab}$

$W = \int \vec{F} \cdot d\vec{r}$

$U \leftrightarrow F$

r

$\frac{\Delta U}{r} = F$

$F = q_0 E$

$$= \frac{\int_i^f \vec{F} \cdot d\vec{S}}{q_0}$$

$$-\frac{\int_i^f F \, dS}{q_0} = -\frac{\int_i^f q_0 \vec{E} \cdot d\vec{S}}{q_0}$$

$$-\frac{q_0 \int_i^f \vec{E} \cdot dS}{q_0}$$

$$-\int_i^f E \cdot \underline{dS}$$ dependent of design

for absolute

$$V_f - V_i = -\int_\infty^f \vec{E} \cdot \underline{d\vec{S}}$$

$$V = -\int_\infty^f E \cdot d\vec{S}$$

$$V = E\,r$$

educative

Summary :-

	Vector description	Scalar description
It has q_0 Interaction b/w two or more charges (system) Effect of one charge or group of charges at a point q_0 (Individual)	$\vec{F}$ q_0 E	U q_0 V

$$F = \frac{Kq}{r^2} = \frac{F}{q_0}$$

ε_0 8.85×10^{-12}

m_e 9.11×10^{-31}

m_p 1.67×10^{-27}

charge of p

charge of e 1.602×10^{-19}

$$V = \frac{Kq}{r} \qquad \Delta U = \Delta q_0$$

$$-W = q_0 \Delta V$$

$$W = -q_0 \Delta V$$

$$W = -q_0 (V_f - V_i)$$

For dipole's electric field

$$E = \frac{KP}{r^3} \quad \text{or} \quad E = \frac{KP}{x^3}$$

at z-axis $E_p = \frac{2Kqd}{z^3} = 2\frac{KP}{z^3}$

continuous charge distribution

$$E_y = \frac{K\lambda}{y}\left(\frac{L}{y^2 + \frac{L^2}{4}}\right)$$

Potential due to dipole

$$V = \frac{KP\cos\theta}{r^2}$$

add both potential