lecture - 3.

Relationship between E AND V

Differential form

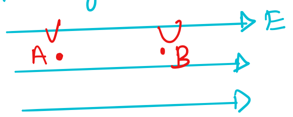
Focus on learning not on writing

$E = -\frac{dV}{dr} \times \frac{1}{\cos\theta}$ ← angle between Electric field and $d\vec{r}$ (displacement)

in most of the cases $\theta = 0°$

where -ve sign represent that → when we move along electric field potential decreases.

$V_A > V_B$



$E = -\frac{dV}{dr}$ ← if $\theta = 0°$

1. V is in the form of x

$E_x = -\frac{\partial V}{\partial x}$

2. V is in the form of y

$E = -\frac{\partial V}{\partial y}$

3. V is in the form of x, y & z.

$\vec{E} = \underbrace{-\frac{\partial V}{\partial x}\hat{i}}_{E_x} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$ ✓

1. In x-y co-ordinate system if potential at a point $P(x, y)$ is given by $V = axy$; where a is a constant, [redacted]

$E = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$

(y & z are const.) (x & z are const.) (x & y are const.)

$V = axy$

$E = -\frac{\partial}{\partial x} axy\,\hat{i} - \frac{\partial}{\partial y} axy\,\hat{j} - \frac{\partial}{\partial z} axy\,\hat{k}$

$E = -ay \times \hat{i} - ax\hat{j}$

$|\vec{E}| = \sqrt{(ay)^2 + (ax)^2}\ \frac{V}{m}$

$$\boxed{\vec{E} = -ay\hat{i} - ax\hat{j}}$$

2. The electric potential V at any point x, y, z (all in *metres*) in space is given by $V = 4x^2$ *volt*. The electric field at the point (1m, 0, 2m) in *volt/metre* is

(a) 8 along negative X-axis ✓

(b) 8 along positive X-axis

(c) 16 along negative X-axis

(d) 16 along positive Z-axis

$E = -\frac{\partial V}{\partial x}\hat{i} = -\frac{\partial}{\partial x} 4x^2\hat{i} = -8x\hat{i}$

$\vec{E} = -8\hat{i}$ V/m

3. The electric potential V is given as a function of distance x (*metre*) by $V = (5x^2 + 10x - 9)$ *volt*. Value of electric field at $x = 1m$ is

(a) $-20\ V/m$ (b) $6\ V/m$ (c) $11\ V/m$ (d) $-23\ V/m$

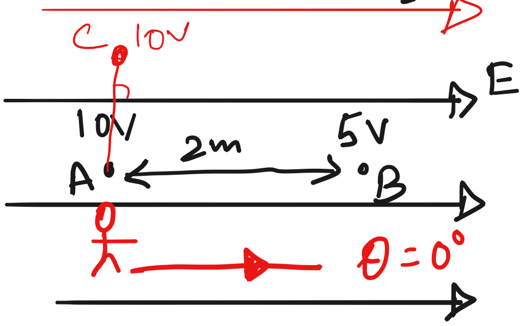
$$E = -\frac{\partial}{\partial x}(5x^2 + 10x - 9) =$$

NEET

diffrence in potential

2.Discreet form $E = -\frac{dV}{dr} \times \frac{1}{\cos\theta}, \Rightarrow E = -\frac{(V_2 - V_1)}{r_2 - r_1} \times \frac{1}{\cos\theta}$

disp.



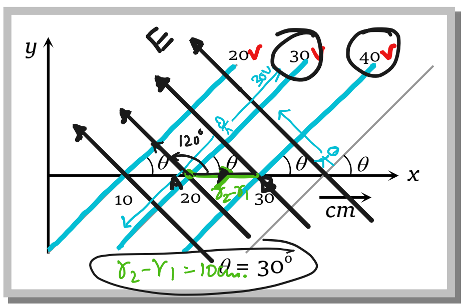
$$E = -\frac{(V_B - V_A)}{2} \times \frac{1}{\cos 0}$$

$$E = -\frac{(5-10)}{2} = 2.5\ V/m.$$

4. Some equipotential surface are shown in the figure. The magnitude and direction of the electric field is

when we move ⊥r to electric field potential remains same.

IIT Adv.



(a) $100\ V/m$ making angle 120° with the x-axis (b) $100\ V/m$ making angle 60° with the x-axis

(c) $200\ V/m$ making angle 120° with the x-axis (d) None of the above

$$E = -\frac{(V_2 - V_1)}{r_2 - r_1} \times \frac{1}{\cos\theta} = -\frac{(40-30)}{0.1m} \times \frac{1}{\cos 120^\circ}$$

$$E = \frac{-100}{0.1} \times \frac{1}{-1/2} = 2000\ \frac{\text{volts}}{\text{meter}}$$

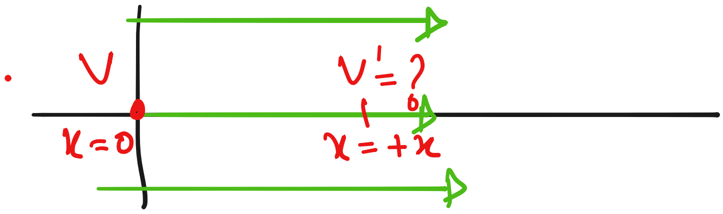
5. A uniform electric field having a magnitude E_0 and direction along the positive X-axis exists. If the electric potential V, is zero at $X = 0$, then, its value at $X = +x$ will be

H.W. (a) $V(x) = +xE_0$ (b) $V(x) = -xE_0$ (c) $V(x) = x^2E_0$ (d) $V(x) = -x^2E_0$

NEET

$$E = -\frac{(V_2 - V_1)}{r_2 - r_1} \times \frac{1}{\cos\theta^\circ}$$

E_0



Tricky example: 6

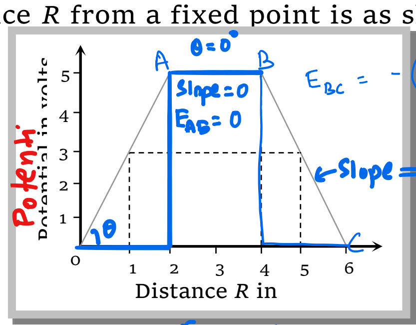
The variation of potential with distance R from a fixed point is as shown below. The electric field at $R = 5\,m$ is

(a) 2.5 volt/m −ve slope of V vs r graph gives Electric field NEET tanθ

(b) − 2.5 volt/m

(c) $\frac{2}{5}$ volt/m

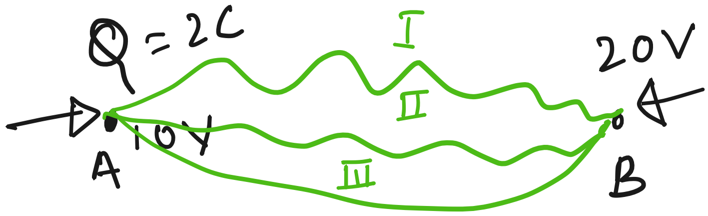
(d) $-\frac{2}{5}$ volt/m



Slope = tanθ = $\frac{5}{2}$ = 2.5

$E_{0A} = -2.5\ V/m$.

Work Done in Displacing a Charge



$W_I = W_{II} = W_{III}$

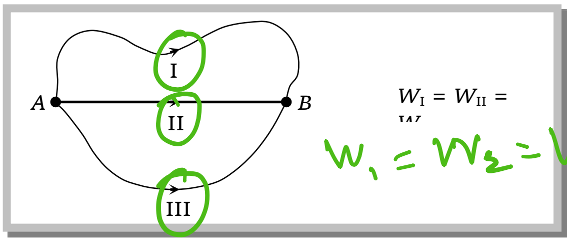
work = $Q\Delta V = Q(V_B - V_A)$

to displace Q from A to B work = $Q(V_B - V_A)$

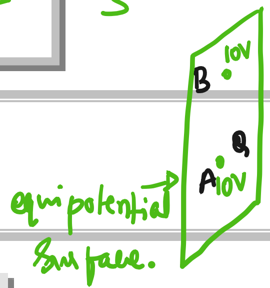
$W = 2(20-10) = 20\,J.$

Conservation of Electric Field

As electric field is conservation, work done and hence potential difference between two point is path independent and depends only on the position of points between. Which the charge is moved.



$W_1 = W_2 = W_3$

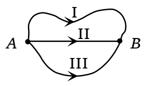


$W = Q(10-10)$
$W = 0$

Concept

☞ No work is done in moving a charge on an equipotential surface.

$W_I = W_{II} =$



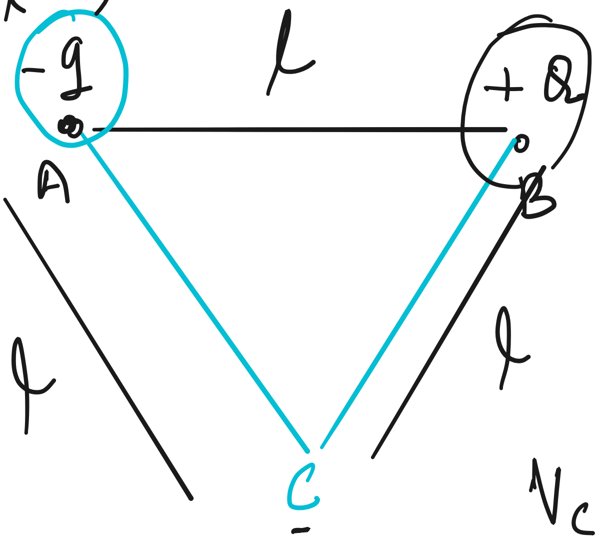
Examples based on work

NEET.

7. A charge $(-q)$ and another charge $(+Q)$ are kept at two points A and B respectively. Keeping the charge $(+Q)$ fixed at B, the charge $(-q)$ at A is moved to another point C such that ABC forms an equilateral triangle of side l. The network done in moving the charge $(-q)$ is

(a) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Qq}{l}$ (b) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Qq}{l^2}$ (c) $\dfrac{1}{4\pi\varepsilon_0}Qql$ (d) Zero

$W = q\left(\dfrac{KQ}{l} - \dfrac{KQ}{l}\right) = 0$



← Fixed

Due to Q (Fixed) potential at A

$V_A = \dfrac{KQ}{l}$

$V_c = \dfrac{KQ}{l}.$

8. The work done in bringing a 20 *coulomb* charge from point *A* to point *B* for distance 0.2 *m* is 2 *Joule*. The potential difference between the two points will be (in *volt*)

(a) 0.2 (b) 8 (c) 0.1 (d) 0.4

$W = q\Delta V$

$2 = 20\,\Delta V$

$\Delta V = 0.1$ volts

9. A charge $+q$ is revolving around a stationary $+Q$ in a circle of radius r. If the force between charges is F then the work done of this motion will be

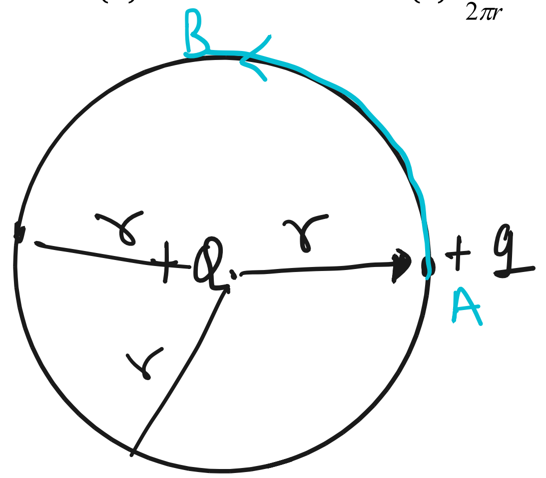
[CPMT 1975, 90, 91, 97; NCERT 1980, 83; EAMCET 1994; MP PET 1993, 95; MNR 1998; AIIMS 1997; DCE 1995; RPET 1998]

(a) $F \times r$ (b) $F \times 2\pi r$ (c) $\frac{F}{2\pi r}$ (d) 0

$W = q(\Delta V)$

$W = q \times 0$

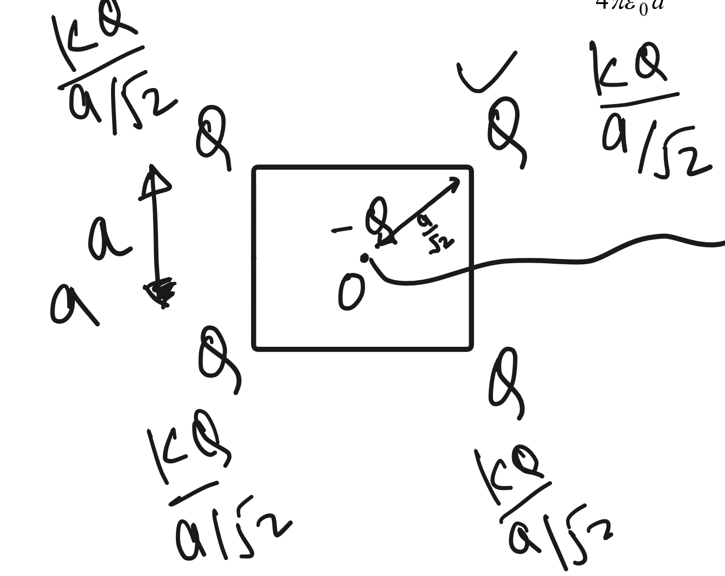
$W = 0$



$V_A = \frac{kQ}{r} = V_B$

10. Four equal charge Q are placed at the four corners of a body of side '*a*' each. Work done in removing a charge $-Q$ from its centre to infinity is

(a) 0 (b) $\frac{\sqrt{2}Q^2}{4\pi\varepsilon_0 a}$ (c) $\frac{\sqrt{2}Q^2}{\pi\varepsilon_0 a}$ (d) $\frac{Q^2}{2\pi\varepsilon_0 a}$



$W = -Q\left(0 - \frac{\cancel{4}\sqrt{2}Q}{\cancel{4}\pi\varepsilon_0 a}\right)$ ∞ O

$W = -Q(V_\infty - V_0)$

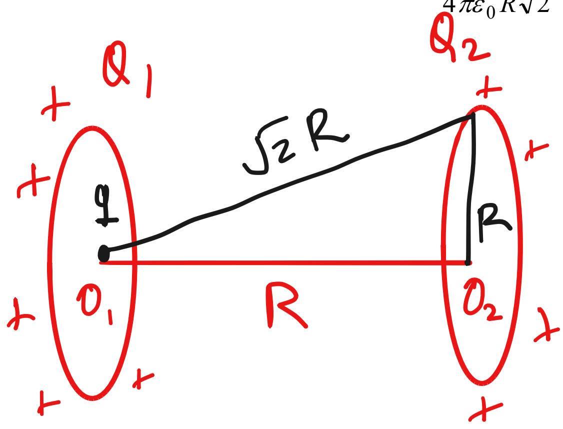
$V_\infty = 0$

$(V_0)_{total} = \frac{4kQ}{a/\sqrt{2}} = \frac{4\sqrt{2}kQ}{a}$

11.. Two identical thin rings each of radius R, are coaxially placed a distance R apart. If Q_1 and Q_2 are respectively the charges uniformly spread on the two rings, the work done in moving a charge q from the centre of one ring to that of the other is

(a) Zero (b) $\dfrac{q(Q_1 - Q_2)(\sqrt{2}-1)}{4\pi\varepsilon_0 R\sqrt{2}}$ (c) $\dfrac{q(Q_1 + Q_2)\sqrt{2}}{4\pi\varepsilon_0 R}$ (d) $\dfrac{q\left(\dfrac{Q_1}{Q_2}\right)(\sqrt{2}-1)}{4\pi\varepsilon_0 R\sqrt{2}}$

H.W.



$$W = q\,(V_{O_2} - V_{O_1})$$

$$V_{O_1} = \frac{KQ_1}{R} + \frac{KQ_2}{\sqrt{2}R}$$

$$V_{O_2} = \frac{KQ_2}{R} + \frac{KQ_1}{\sqrt{2}R}$$

Tricky example: 12

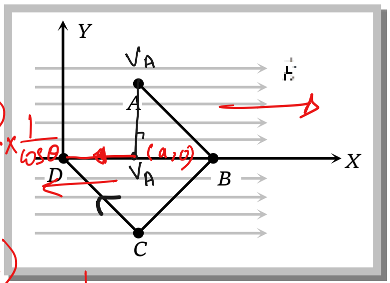
A point charge q moves from point A to point D along the path $ABCD$ in a uniform electric field. If the co-ordinates of the points A, B, C and D are $(a, b, 0)$, $(2a, 0, 0)$, $(a, -b, 0)$ and $(0, 0, 0)$ then the work done by the electric field in this process will be

(a) $-qEa$

(b) Zero

(c) $2E(a + b)q$

(d) $\dfrac{qEa}{2b}$



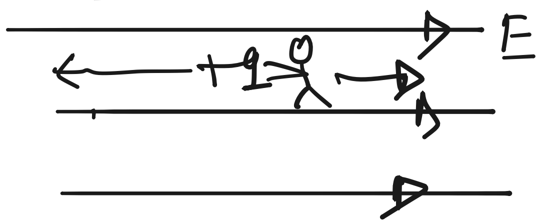
$$E = -\frac{(V_D - V_A)}{a} \times \frac{1}{\cos\theta}$$

$$E = -\frac{(V_D - V_A)}{a} \times \frac{1}{-1}$$

$$Ea = V_D - V_A$$

$$W = q\,\Delta V$$

$$W = qEa$$ work done by external agent.

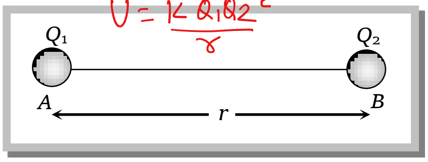


Electric Potential Energy

(1) **Potential energy of a charge :** Work done in bringing the given charge from infinity to a point in the electric field is known as potential energy of the charge. Potential can also be written as potential energy per unit charge. *i.e.* $V = \frac{W}{Q} = \frac{U}{Q}$.

(2) **Potential energy of a system of two charges :** Since work done in bringing charge Q_2 from ∞ to point B is $W = Q_2 V_B$, where V_B is potential of point B due to charge Q_1 i.e. $V_B = \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{r}$

$U = \frac{kQ_1Q_2}{r} \leftarrow$ Scalar



$-Q_1 \quad \underline{\qquad r \qquad} \quad Q_2$

So, $$W = U_2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_1Q_2}{r}$$

This is the potential energy of charge Q_2, similarly potential energy of charge Q_1 will be $U_1 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_1Q_2}{r}$

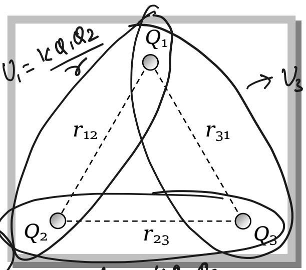
$U' = -\frac{kQ_1Q_2}{r}$

Hence potential energy of Q_1 = Potential energy of Q_2 = potential energy of system $U = k\frac{Q_1Q_2}{r}$ (in C.G.S. $U = \frac{Q_1Q_2}{r}$)

Note : ❑ Electric potential energy is a scalar quantity so in the above formula take sign of Q_1 and Q_2.

(3) **Potential energy of a system of *n* charges :**

$U_1 = \frac{kQ_1Q_2}{r}$



$\rightarrow V_3 = \frac{kQ_1Q_3}{r}$

$V_L = \frac{kQ_2Q_3}{r}$

$$\text{Potential energy } = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1Q_2}{r_{12}} + \frac{Q_2Q_3}{r_{23}} + \frac{Q_3Q_1}{r_{31}}\right]$$

While potential energy of any of the charge say Q_1 is $\frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1Q_2}{r_{12}} + \frac{Q_3Q_1}{r_{31}}\right]$

Note : ❑ For the expression of total potential energy of a system of n charges consider $\frac{n(n-1)}{2}$ number of pair of charges.

$\Delta KE = W = q\Delta V$

(4) **Electron volt (*eV*) :** $1eV = 1.6\times10^{-19}\,C \times \frac{1J}{C} = 1.6\times10^{-19}\,J$ = 1.6×10^{-12} *erg*

Energy acquired by a charged particle in *eV* when it is accelerated by *V volt* is *E* = (charge in quanta) × (p.d. in *volt*)

$W = q\Delta V = e\times1 = 1.6\times10^{-19}\,J$

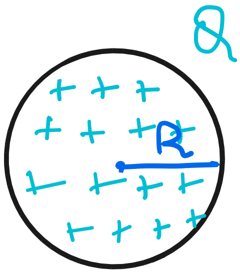
1 eV is unit of energy $1\,eV = 1.6\times10^{-19}\,J$

Commonly asked examples : 1.6×10^{-19}

S.No.	Charge	Accelerated by p.d.	Gain in K.E. $\Delta KE = W = q\Delta V$
(i)	Proton	5×10^4 V	$K = e \times 5 \times 10^4 V = 5 \times 10^4 eV = 8 \times 10^{-15} J$ [JIPMER 1999]
(ii)	Electron	100 V	$K = e \times 100\ V = 100\ eV = 1.6 \times 10^{-17}\ J$ [MP PMT 2000; AFMC 1999]
(iii)	Proton	1 V	$K = e \times 1\ V = 1\ eV = 1.6 \times 10^{-19}\ J$ [CBSE 1999]
(iv)	0.5 C	2000 V	$K = 0.5 \times 2000 = 1000\ J$ [JIPMER 2002]
(v)	α-particle	10^6 V	$K = (2e) \times 10^6\ V = 2\ MeV$ [MP PET/PMT 1998]

(5) **Electric potential energy of a uniformly charged sphere :** Consider a uniformly charged sphere of radius R having a total charge Q. The electric potential energy of this sphere is equal to the work done in bringing the charges from infinity to assemble the sphere.

Mains /NEET $U = \dfrac{3Q^2}{20\pi\varepsilon_0 R}$ learn.



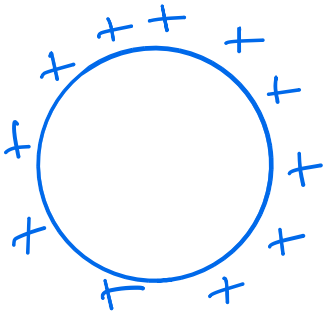
Q_1 Q_2 r

$\dfrac{KQ_1Q_2}{r}$

(6) **Electric potential energy of a uniformly charged thin spherical shell :**

$$U = \frac{Q^2}{8\pi\varepsilon_0 R}$$

$U = \dfrac{KQ}{2R}$



(7) **Energy density :** The energy stored per unit volume around a point in an electric field is given by

$U_e = \dfrac{U}{\text{Volume}} = \dfrac{1}{2}\varepsilon_0 E^2$. If in place of vacuum some medium is present then $U_e = \dfrac{1}{2}\varepsilon_0\varepsilon_r E^2$

in capacitor.

based on electric potential energy

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13. If the distance of separation between two charges is increased, the electrical potential energy of the system

[AMU 1998]

(a) May increases or decrease (b) Decreases

(c) Increase (d) Remain the same

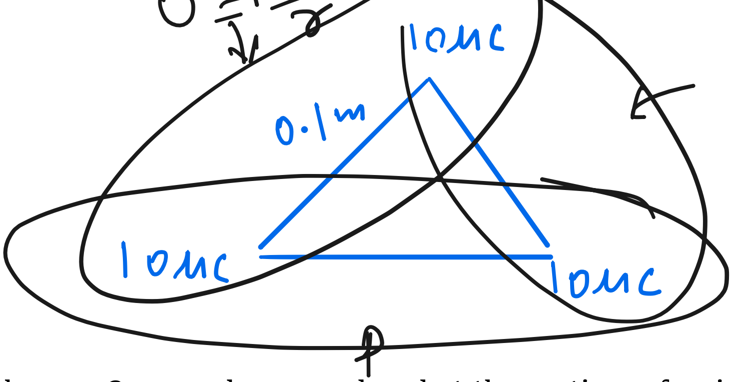
$U = -\frac{KQ_1Q_2}{r\uparrow}$ $\quad +Q_1 \underset{r}{\longleftrightarrow} +Q_2 \quad$ $\downarrow U = \frac{KQ_1Q_2}{r\uparrow}$

14. Three particles, each having a charge of $10\mu C$ are placed at the corners of an equilateral triangle of side $10cm$. The electrostatic potential energy of the system is (Given $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ N-m^2/C^2$)

[AMU 1998]

(a) Zero (b) Infinite (c) $27\,J$ (d) $100\,J$

$U = \frac{KQ^2}{r}$



$3\,\frac{KQ_1\times Q_2}{r} = U_{total}$

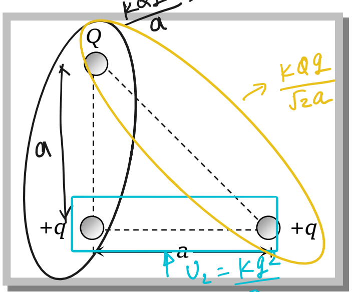
15. Three charges Q, $+q$ and $+q$ are placed at the vertices of a right-angled isosceles triangle as shown. The net electrostatic energy of the configuration is zero if Q is equal to

(a) $\frac{-q}{1+\sqrt{2}}$

(b) $\frac{-\sqrt{2}q}{1+\sqrt{2}}$

(c) $-2\,q$

(d) $+q$



$\frac{KQq}{a} + \frac{Kq^2}{a} + \frac{KQq}{\sqrt{2}a} = 0$

Motion of Charged Particle in an Electric Field

(1) **When charged particle initially at rest is placed in the uniform field :**

Let a charge particle of mass m and charge Q be initially at rest in an electric field of strength E

$F_{net} = ma = qE, \quad a = \frac{qE}{m}$

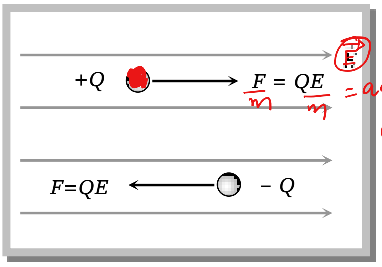


Fig.

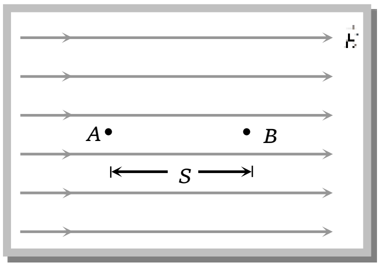


Fig.

(i) **Force and acceleration :**

$$a = \frac{F}{m} = \frac{QE}{m}$$

Since the field E in constant the acceleration is constant, thus motion of the particle is uniformly accelerated.

use $s = ut + \frac{1}{2}at^2$ along x axis

$a_x = 0$

$u_x = V, \quad S = L$

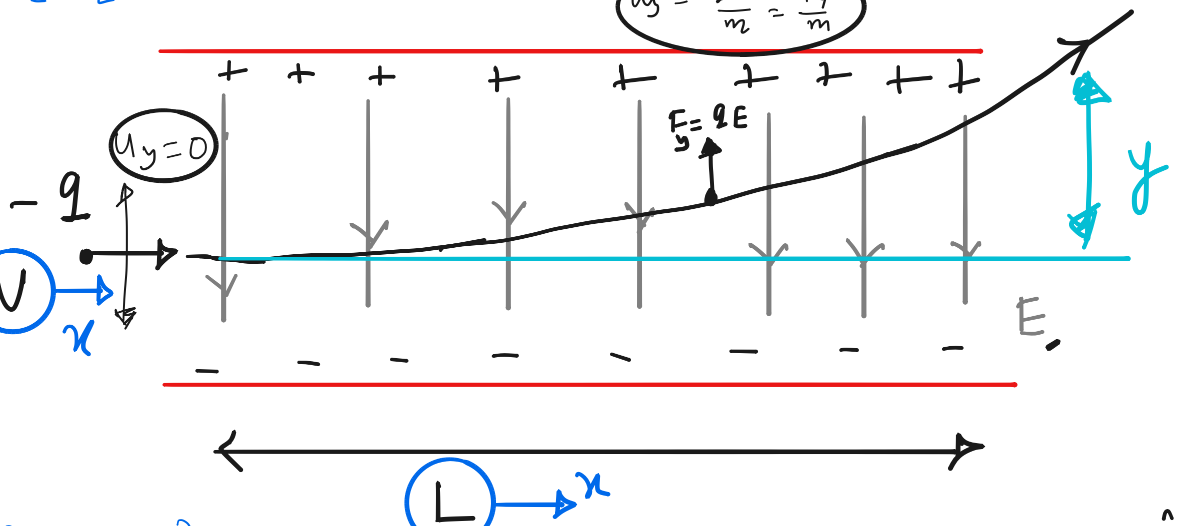
$L = ut$

$L = Vt$

$t = \frac{L}{V}$

$v = u + at, \quad s = ut + \frac{1}{2}at^2, \quad v^2 = u^2 + 2as.$

$a_y = \frac{qE}{m} = \frac{F_y}{m}$



$y = \frac{1}{2}\frac{qE}{m}\left(\frac{L}{V}\right)^2$

$s = ut + \frac{1}{2}at^2$ use along y axis

$y = 0 + \frac{1}{2}\frac{qE}{m}t^2$

$y = \frac{qEL^2}{2\left(\frac{mV^2}{2}\right) \times 2}$

$y = \frac{qEL^2}{\ldots}$

$y = \frac{\quad}{4KE}$

16. An electron (mass = $9.1 \times 10^{-31}\ kg$ and charge = $1.6 \times 10^{-19}\ coul.$) is sent in an electric field of intensity $1 \times 10^{6}\ V/m$. How long would it take for the electron, starting from rest, to attain one–tenth the velocity of light

$c = 3 \times 10^{8}\ m/s.$

(a) $1.7 \times 10^{-12}\ sec$ (b) $1.7 \times 10^{-6}\ sec$ (c) $1.7 \times 10^{-8}\ sec$ (d) $1.7 \times 10^{-10}\ sec$

E

$q = e$

$u = 0\ m/s$

$F = qE = eE$

$a = \frac{eE}{m}$

$V = u + at$

$c/10 = 0 + \frac{eE}{m} t$

(2, 10, 21, 15)

17. Two protons are placed $10^{-10}\ m$ apart. If they are repelled, what will be the kinetic energy of each proton at very large distance

(a) $23 \times 10^{-19}\ J$ (b) $11.5 \times 10^{-19}\ J$ (c) $2.56 \times 10^{-19}\ J$ (d) $2.56 \times 10^{-28}\ J$

at rest at rest.

e^+ e^+

$10^{-10}\ m$

by conservation of energy

$= U_i + KE_i = U_f + KE_f.$

$= \frac{k e \times e}{10^{-10}} + 0 = \frac{k \times e \times e}{\infty} + \frac{1}{2}mv^2 + \frac{1}{2}mv^2$

$\frac{9 \times 10^{9}}{10^{-10}} \times (1.6 \times 10^{-19})^2 = mv^2$

V e^+ ∞ e^+ V

18. A particle A has a charge $+q$ and particle B has charge $+4q$ with each of them having the same mass m. When allowed to fall from rest through the same electrical potential difference, the ratio of their speeds $\frac{v_A}{v_B}$ will becomes

(a) 2 : 1 (b) 1 : 2 (c) 1 : 4 (d)

$+q$ ΔV

A m

$q\Delta V = \frac{m V_A^2}{2}$

$4q$ ΔV

B m

$4q\Delta V = \frac{m V_B^2}{2}$

19. How much kinetic energy will be gained by an $\alpha -$particle in going from a point at 70 V to another point at 50 V

(a) 40 eV (b) 40 keV (c) 40 MeV (d) 0 Ev

20. A particle of mass 2g and charge $1\mu C$ is held at a distance of 1 metre from a fixed charge of $1 mC$. If the particle is released it will be repelled. The speed of the particle when it is at a distance of 10 metres from the fixed charge is

(a) 100 m/s (b) 90 m/s (c) 60 m/s (d) 45 m/s

21. An electric dipole is placed along the x-axis at the origin O. A point P is at a distance of 20 cm from this origin such that OP makes an angle $\frac{\pi}{3}$ with the x-axis. If the electric field at P makes an angle θ with x-axis, the value of θ would be

(a) $\frac{\pi}{3}$ (b) $\frac{\pi}{3} + \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$ (c) $\frac{2\pi}{3}$ (d) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

22. An electric dipole in a uniform electric field experiences

(a) Force and torque both (b) Force but no torque (c) Torque but no force (d) No force and no torque

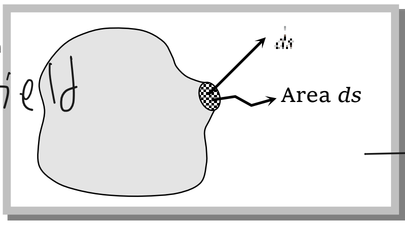
Electric Flux

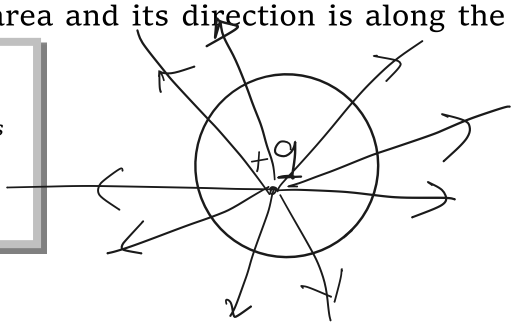
(1) **Area vector :** In many cases, it is convenient to treat area of a surface as a vector. The length of the vector represents the magnitude of the area and its direction is along the outward drawn normal to the area.

$\phi \propto$ No. of electric field lines.

$\phi = \oint \vec{E}\cdot\vec{ds} = \oint E\,ds\cos\theta$

Closed surface. Angle b/w Area vector and electric field

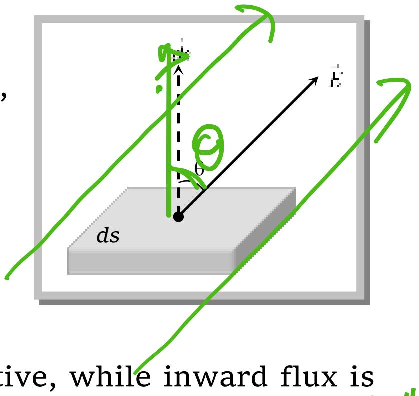




(2) **Electric flux**

Electric flux through an elementary area $\vec{ds}$ is defined as the scalar product of area of field i.e. $d\phi = \vec{E}\cdot\vec{ds} = E\,ds\,\cos\theta$

Hence flux from complete area (S) $\phi = \int E\,ds\cos\theta = ES\cos\theta$



If $\theta = 0^o$, *i.e.* surface area is perpendicular to the electric field, so flux linked with it will be max.

i.e. $\phi_{max} = E\,ds$ and if $\theta = 90^o$, $\phi_{min} = 0$

(3) **Unit and Dimensional Formula**

S.I. unit – $(volt \times m)$ or $\frac{N-C}{m^2}$

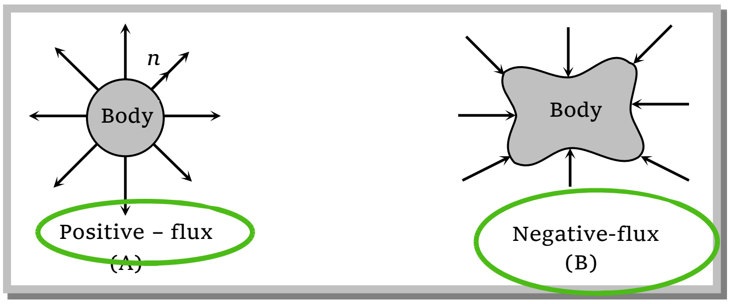
It's Dimensional formula – $(ML^3T^{-3}A^{-1})$

(4) **Types :** For a closed body outward flux is taken to be positive, while inward flux is to be negative

$\phi = \oint E\,ds\cos\theta$

Small Area

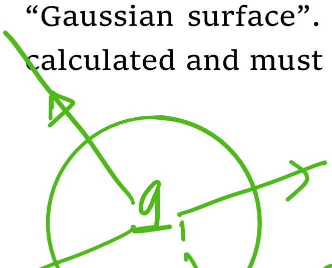
electric Field



Gauss's Law

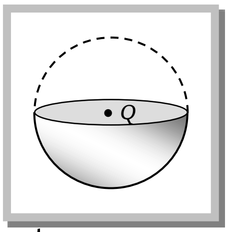
(1) **Definition :** According to this law, total electric flux through a closed surface enclosing a charge is $\frac{1}{\varepsilon_0}$ times the magnitude of the charge enclosed i.e. $\phi = \frac{1}{\varepsilon_0}(Q_{enc.})$

(2) **Gaussian Surface :** Gauss's law is valid for symmetrical charge distribution. Gauss's law is very helpful in calculating electric field in those cases where electric field is symmetrical around the source producing it. Electric field can be calculated very easily by the clever choice of a closed surface that encloses the source charges. Such a surface is called "Gaussian surface". This surface should pass through the point where electric field is to be calculated and must have a shape according to the symmetry of source.



$\phi = \frac{\text{Charge enclosed}}{\varepsilon_0} = \frac{q_1}{\varepsilon_0}$

e.g. If suppose a charge Q is placed at the centre of a hemisphere, then to calculate the flux through this body, to encloses the first charge we will have to imagine a Gaussian surface. This imaginary Gaussian surface will be a hemisphere as shown.



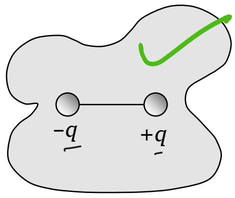
Net flux through this closed body $\phi = \dfrac{Q}{\varepsilon_0}$

Hence flux coming out from given hemisphere is $\phi = \dfrac{Q}{2\varepsilon_0}$.

(3) **Zero flux :** The value of flux is zero in the following circumstances

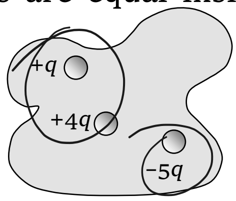
(i) If a dipole is enclosed by a surface

$\phi = 0; Q_{enc} = 0$



$\phi = 0$

(ii) If the magnitude of positive and negative charges are equal inside a closed surface

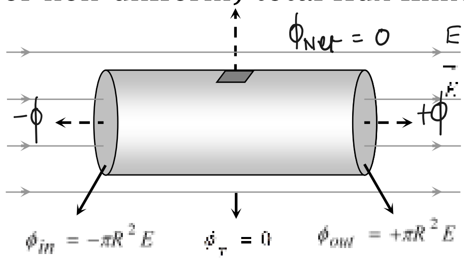


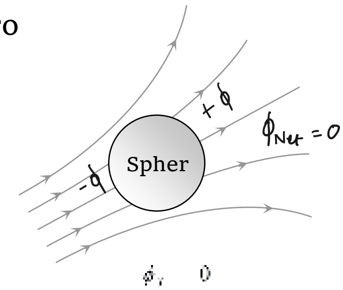
$\phi = 0$

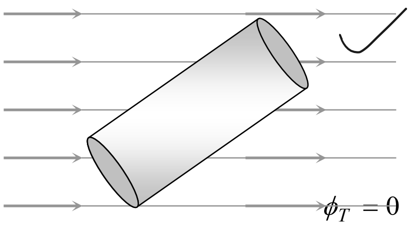
$Q_{enc} = 0,$

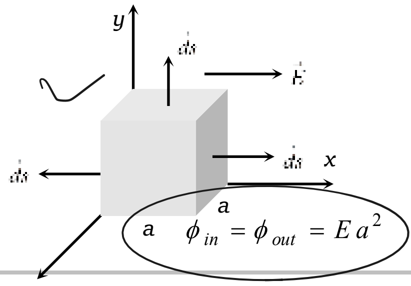
so, $\phi = 0$

(iii) If a closed body (not enclosing any charge) is placed in an electric field (either uniform or non-uniform) total flux linked with it will be zero

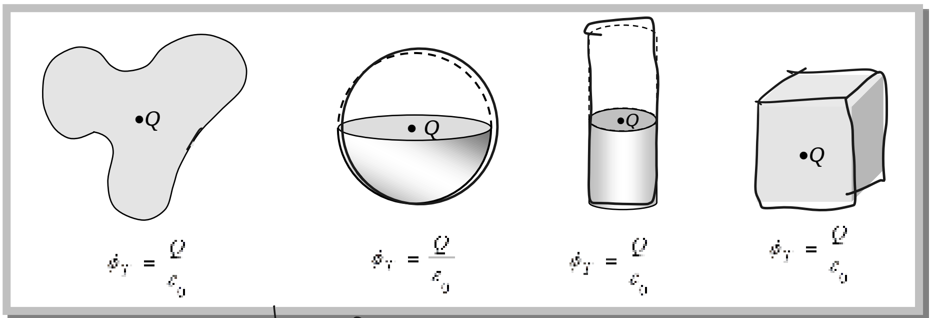






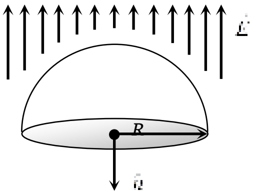


(4) **Flux emergence :** Flux linked with a closed body is independent of the shape and size of the body and position of charge inside it



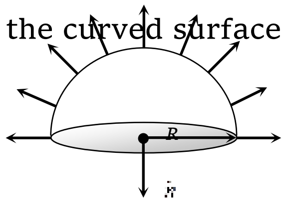
$\phi = \dfrac{Q}{\varepsilon_0}$

(i) If a hemispherical body is placed in uniform electric field then flux linked with the curved surface



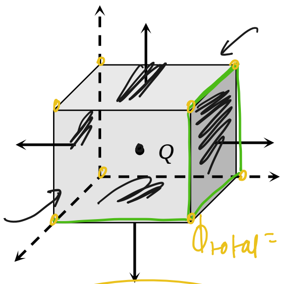
$\phi_{curved} = +\pi R^2 E$

(ii) If a hemispherical body is placed in non-uniform electric field as shown below. then flux linked with the curved surface.



$\phi_{curved} = 2\pi R^2 E$

(v) If charge is kept at the centre of cube



total 12 edges

$\phi_{total} = \frac{1}{\varepsilon_0}.(Q)$

$\phi_{face} = \frac{Q}{6\varepsilon_0}$

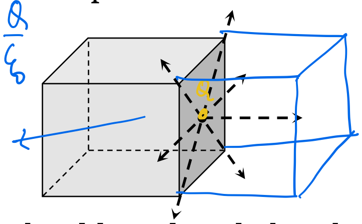
$\phi_{total} = \frac{Q}{\varepsilon_0}$

$\phi_{corner} = \frac{Q}{8\varepsilon_0}$

$\phi_{edge} = \frac{Q}{12\varepsilon_0}$

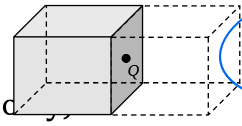
(iv) If charge is kept at the centre of a face

$\phi_{total} = \frac{Q}{\varepsilon_0}$



First we should enclosed the charge by assuming a Gaussian surface (an identical imaginary cube)

$\phi_{total} = \frac{Q}{\varepsilon_0}$



$\phi_{cube} = \frac{Q}{2\varepsilon_0}$ (i.e. from 5 face

$\phi_{face} = \frac{1}{5}\left(\frac{Q}{2\varepsilon_0}\right) = \frac{Q}{10\varepsilon_0}$.

Example based on electric flux and Gauss's

23. Electric charge is uniformly distributed along a long straight wire of radius 1 *mm*. The charge per *cm* length of the wire is *Q coulomb*. Another cylindrical surface of radius 50 *cm* and length 1 *m* symmetrically encloses the wire as shown in the figure. The total electric flux passing through the cylindrical surface is

(a) $\frac{Q}{\varepsilon_0}$

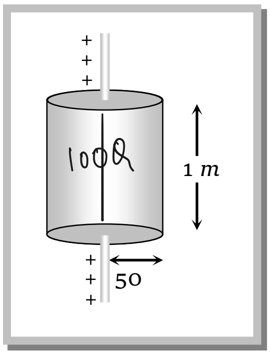
(b) $\frac{100\,Q}{\varepsilon_0}$

(c) $\frac{10\,Q}{(\pi\varepsilon_0)}$

(d) $\frac{100\,Q}{(\pi\varepsilon_0)}$

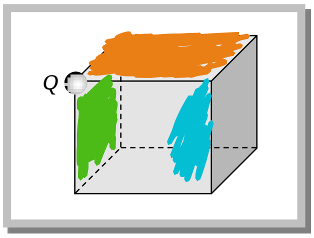
In 1cm → Q charge

In 100cm → 100 Q



$\phi = \frac{100Q}{\varepsilon_0}$

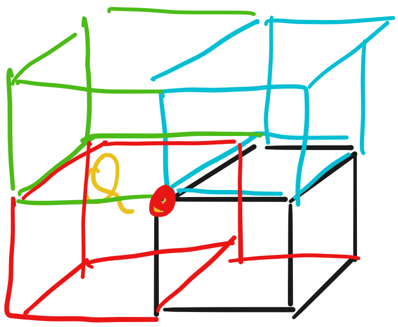
24. A charge Q is situated at the corner A of a cube, the electric flux through the one face of the cube is ____________ **[CPMT 2000]**



$\phi_{cube} = \frac{Q}{8\varepsilon_0}$

$\phi_{one\ face} = \frac{Q}{24\varepsilon_0}$

(a) $\frac{Q}{6\varepsilon_0}$ (b) $\frac{Q}{8\varepsilon_0}$ (c) $\frac{Q}{24\varepsilon_0}$ (d) $\frac{Q}{2\varepsilon_0}$



$\phi_{total} = \frac{Q}{\varepsilon_0}$

$\phi_{one\ cube} = \frac{Q}{8\varepsilon_0}$

25. A square of side 20 *cm* is enclosed by a surface of sphere of 80 *cm* radius. Square and sphere have the same centre. Four charges + 2 × 10^{-6} *C*, – 5 × 10^{-6} *C*, – 3 × 10^{-6} *C*, +6 × 10^{-6} C are located at the four corners of a square, then out going total flux from spherical surface in $N\text{–}m^2/C$ will be **[RPMT 1989]**

(a) Zero (b) $(16\pi) \times 10^{-6}$ (c) $(8\pi) \times 10^{-6}$ (d) $36\pi \times 10^{-6}$

26. In a region of space, the electric field is in the x-direction and proportional to x, *i.e.*, $\vec{E} = E_0 x\hat{i}$. Consider an imaginary cubical volume of edge a, with its edges parallel to the axes of coordinates. The charge inside this cube is

(a) Zero (b) $\varepsilon_0 E_0 a^3$ (c) $\frac{1}{\varepsilon_0} E_0 a^3$ (d) $\frac{1}{6}\varepsilon_0 E_0 a^2$

Tricky example: 26

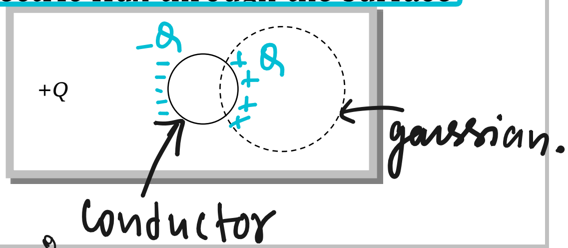
In the electric field due to a point charge + Q a spherical closed surface is drawn as shown by the dotted circle. The electric flux through the surface drawn is zero by Gauss's law. A conducting sphere is inserted intersecting the previously drawn Gaussian surface. The electric flux through the surface

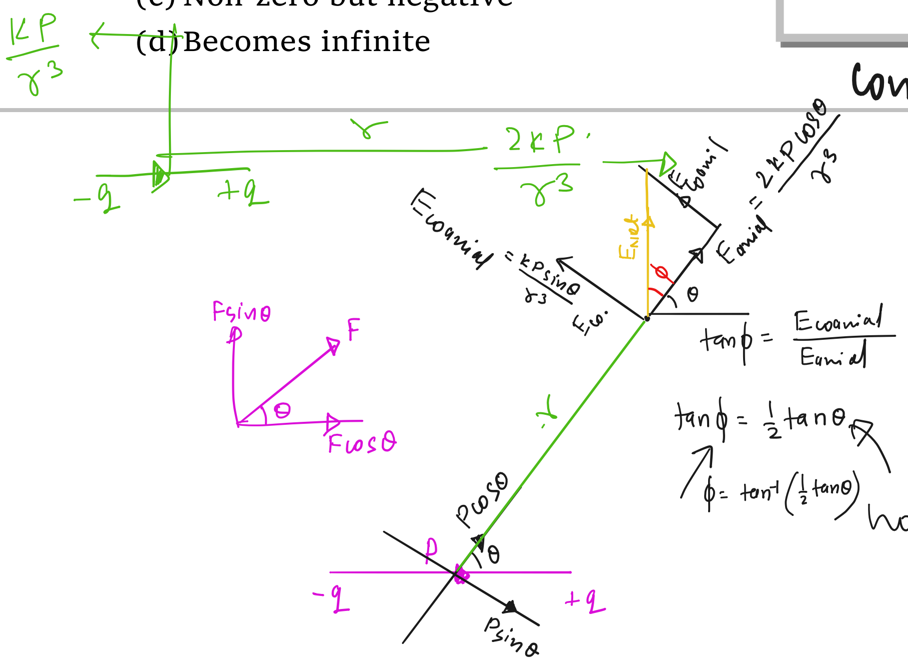
(a) Still remains zero

✓(b) Non zero but positive

(c) Non-zero but negative

(d) Becomes infinite





$\tan\phi = \frac{E_{coaxial}}{E_{axial}}$

$\tan\phi = \frac{1}{2}\tan\theta$

$\phi = \tan^{-1}\left(\frac{1}{2}\tan\theta\right)$

horizontal ∠ r

Angle between horizontal ∠ E_{net}

is $\phi + \theta$

$= \tan^{-1}\left(\frac{1}{2}\tan\theta\right) + \theta$