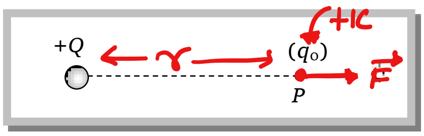
good morning everyone

ELECTRIC FIELD AND POTENTIAL

(1) **Electric field intensity** $(\vec{E})$**:** The electric field intensity at any point is defined as the force experienced by a unit positive charge placed at that point. $\vec{E} = \dfrac{\vec{F}}{q_0}$



$\vec{F} = \vec{E} = \dfrac{KQ}{r^3}\vec{r}$ $F = \dfrac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$

$|\vec{E}| = \dfrac{KQ}{r^2}$ $F = \dfrac{KQ \times 1}{r^2}$

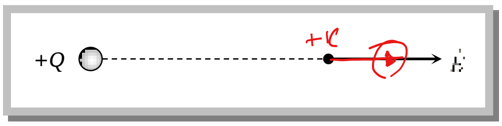
$\dfrac{N}{C}$ or $\dfrac{\text{Volt}}{\text{meter}}$

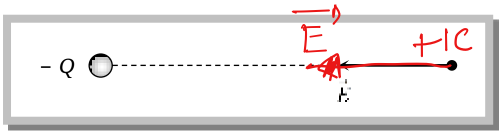
(2) **Unit and Dimensional formula :** It's S.I. unit – $\dfrac{Newton}{coulomb} = \dfrac{volt}{meter} = \dfrac{Joule}{coulomb \times meter}$ and

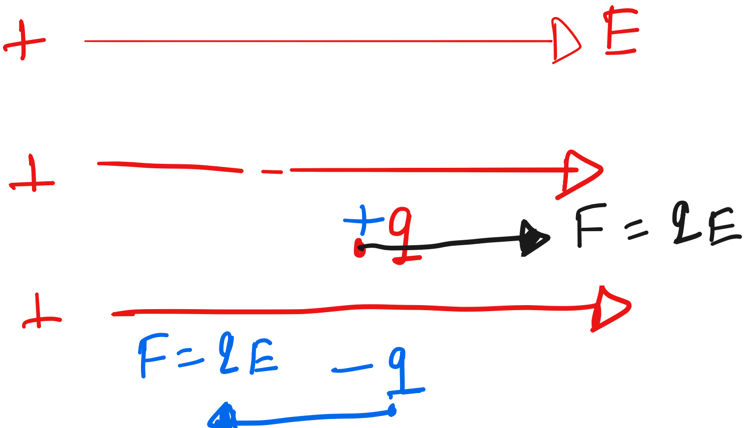
C.G.S. unit – *Dyne/stat coulomb*.

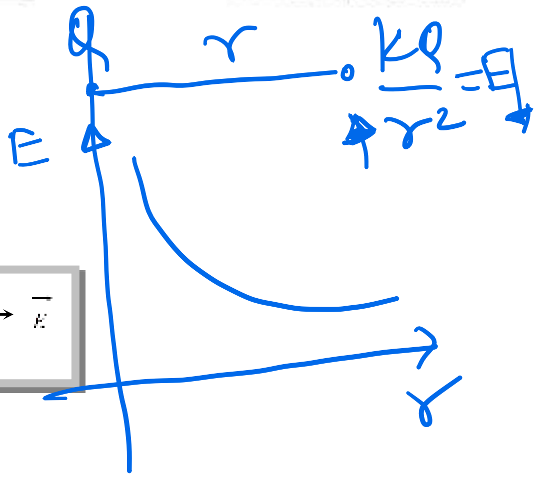
Dimension : $[E] = [MLT^{-3}A^{-1}]$

(3) **Direction of electric field :** Electric field (intensity) $\vec{E}$ is a vector quantity. Electric field due to a positive charge is always away from the charge and that due to a negative charge is always towards the charge



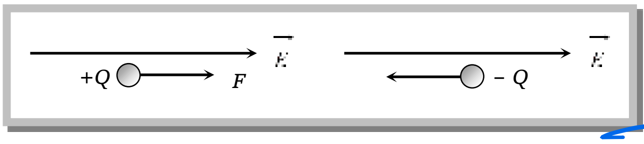






$$\frac{kQ}{r^2} = E$$

(4) **Relation between electric force and electric field :**



Electric field due to continuous distribution of charge

Ring

$$E = \frac{KQx}{(R^2+x^2)^{3/2}}$$

$x = 0$

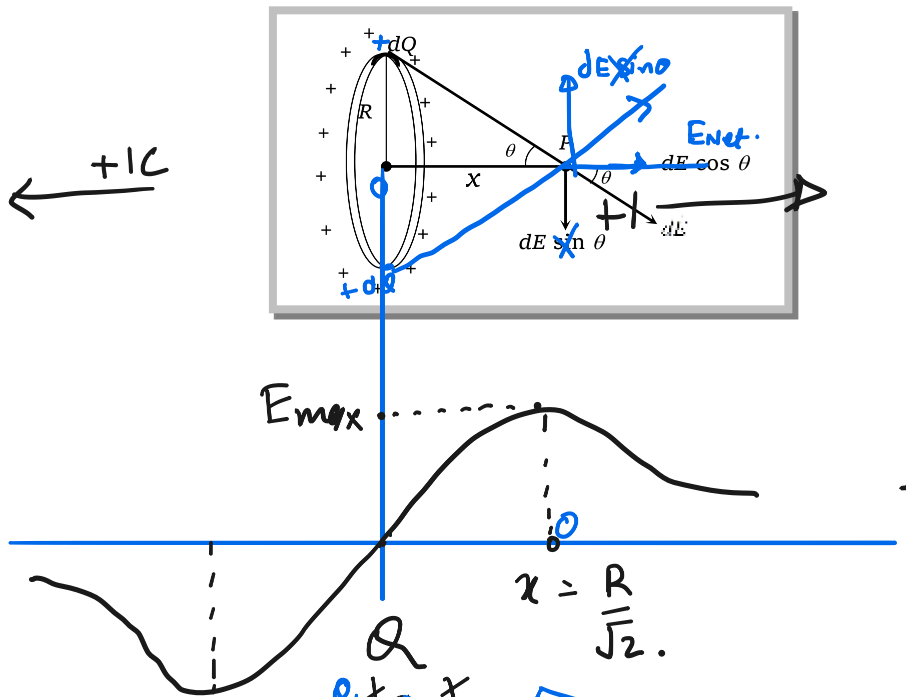
$E_{centre} = 0$

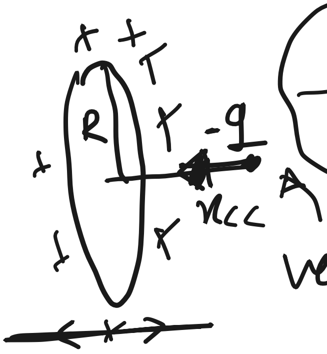
$R^2 >>> x^2$

$R^2 + x^2 \simeq R^2$

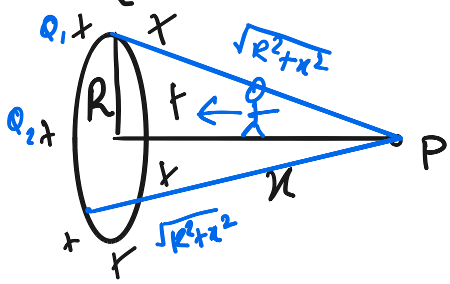
$$\frac{KQx}{R^3} = E$$

very close.





$$F = \frac{KQxq}{R^3}$$

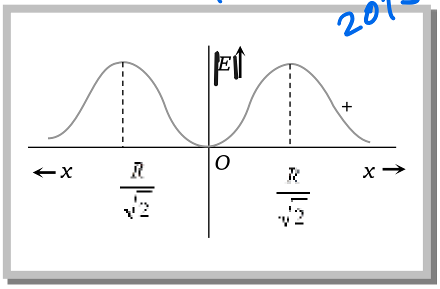


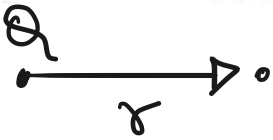
$$V = \frac{KQ}{\sqrt{R^2+x^2}}$$

$= \frac{KQx}{(R^2+x^2)^{3/2}}$ at $x = \frac{R}{\sqrt{2}}$

$E_{max} = ?$

IIT main 2019.

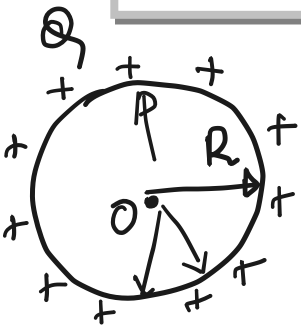


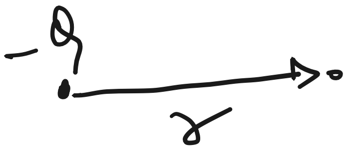


$\frac{KQ}{r}$

potential is a scalar quantity.

$V = \frac{KQ}{R}$

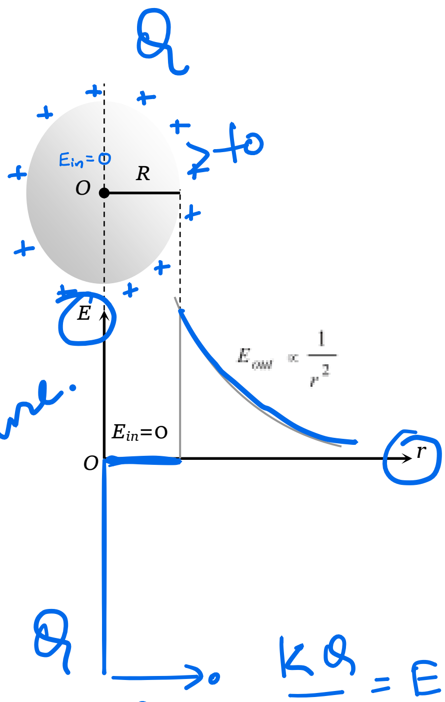




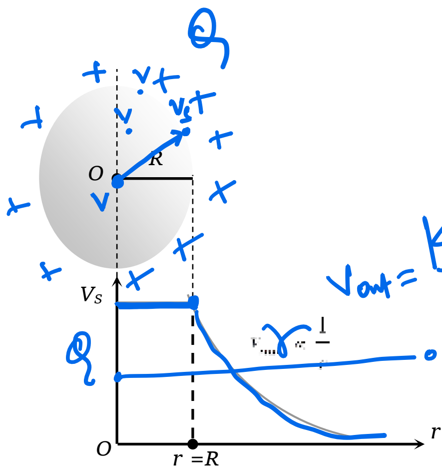
$V = \frac{-KQ}{r}$

Counding Sphere-

E - r graph



V - r graph



dis continous in nature.

$V_{out} = \frac{KQ}{r}$

$V_{in} = V_s = \frac{KQ}{R} = V_{centre}.$

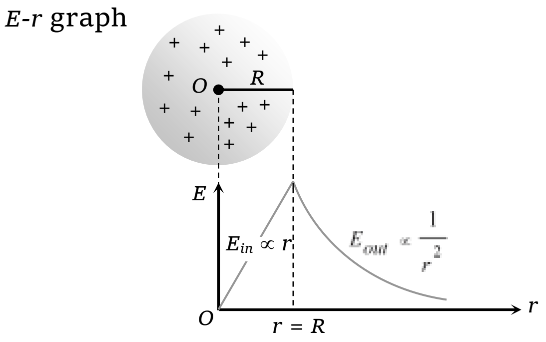
$\frac{KQ}{R^2} = E_{surface}.$

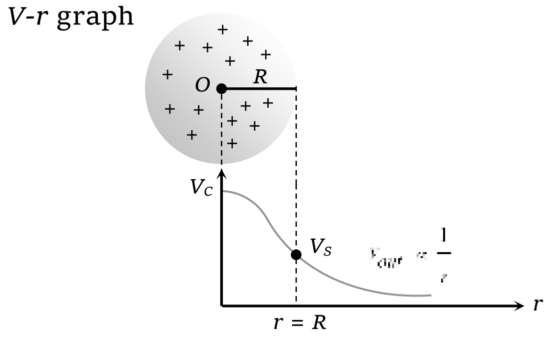
$E_{out} = \frac{KQ}{r^2} \quad r > R.$

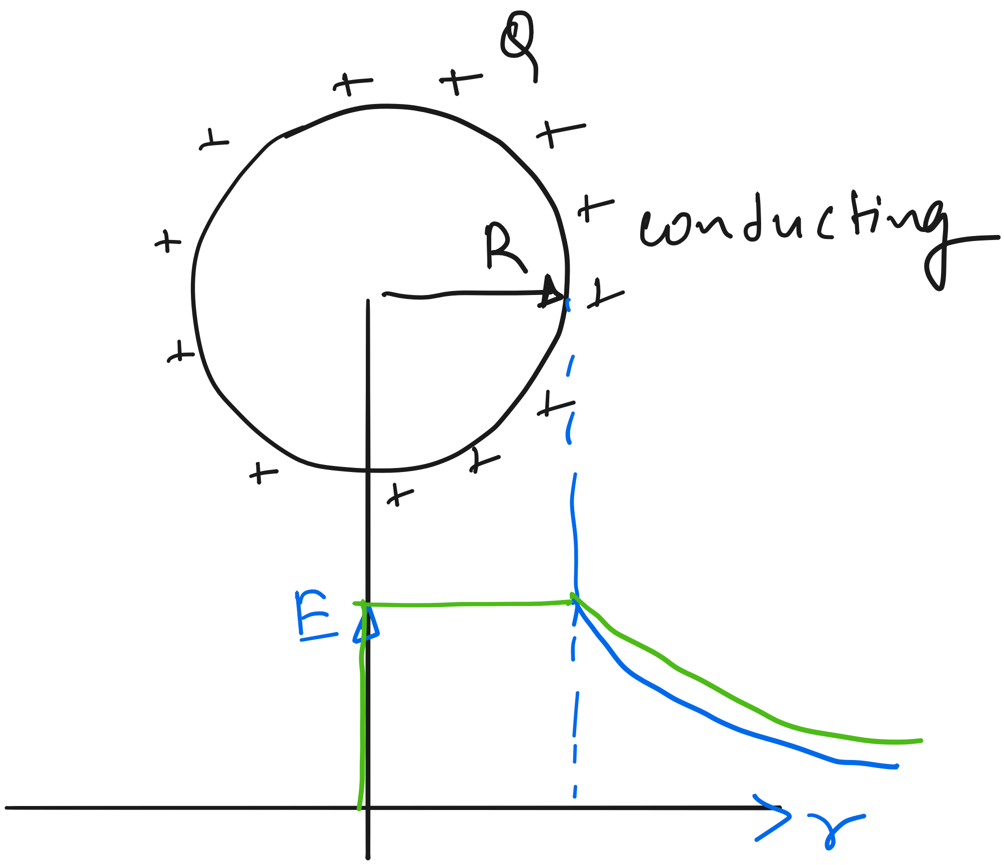
Note Potential on surface of conductor and inside conductor everywhere is same.

Non conducting sphere-

- Graphical variation of electric field and potential with distance

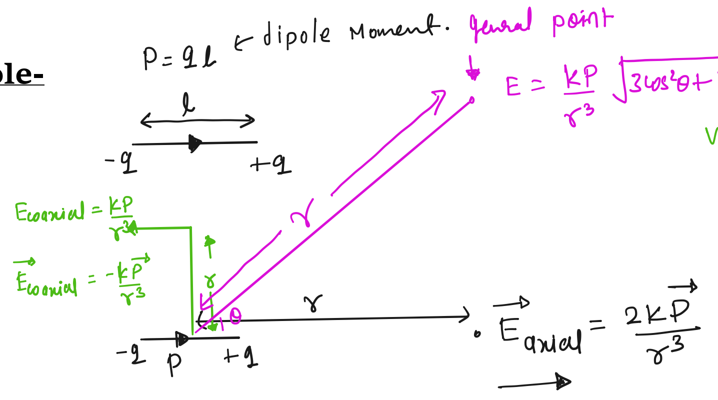






Dipole-

$p = q\ell$ ← dipole Moment.



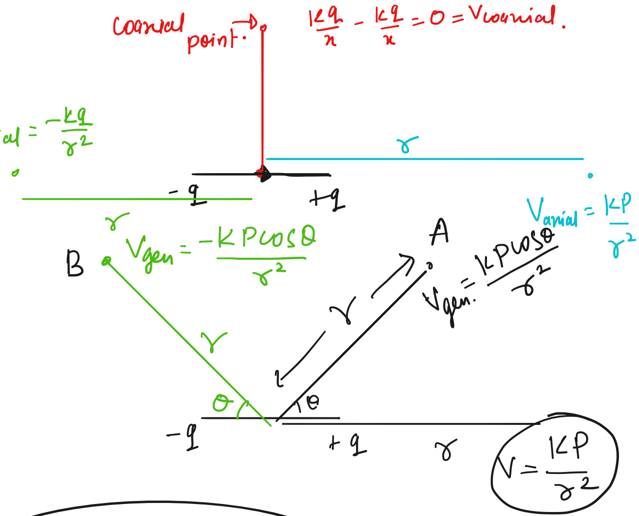
$E = \frac{KP}{r^3}\sqrt{3\cos^2\theta + 1}$

$E_{coaxial} = \frac{KP}{r^3}$

$\vec{E}_{coaxial} = -\frac{K\vec{P}}{r^3}$

$\vec{E}_{axial} = \frac{2K\vec{P}}{r^3}$

Potential due to dipole



$\frac{Kq}{r} - \frac{Kq}{r} = 0 = V_{coaxial}$.

$V_{axial} = -\frac{Kq}{r^2}$

$V_{axial} = \frac{KP}{r^2}$

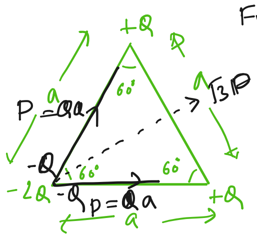
$V_{gen} = -\frac{KP\cos\theta}{r^2}$

$V_{gen.} = \frac{KP\cos\theta}{r^2}$

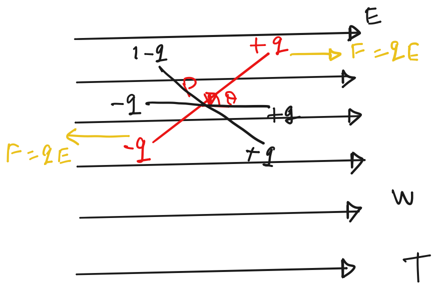
$V = \frac{KP}{r^2}$

$V_A - V_B = \frac{2KP\cos\theta}{r^2}$

Find eq. dipole Moment of sys.



$P_{Net} = \sqrt{3}qa$



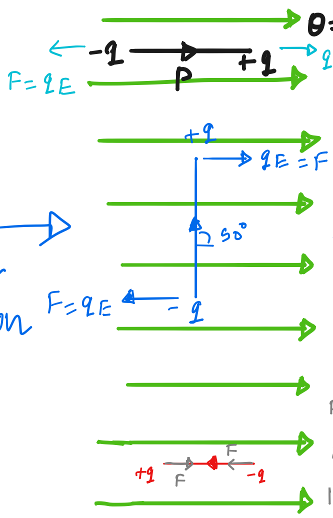
$F_{Net} = 0$

$\tau_{Net} = PE\sin\theta$

$U = -PE\cos\theta$

$W = PE(\cos\theta_1 - \cos\theta_2)$

$T = 2\pi\sqrt{\frac{I}{PE}}$



$\theta = 0°$, $F_{Net} = 0$, $\tau_{Net} = PE\sin 0 = 0$

Condition of equilibrium

$U = -PE\cos 0°$

$U = -PE$

minimum Energy.

Stable equilibrium.

also known as ref. position of Standard position

$F_{Net} = 0$

$\tau = PE\sin 50°$

$\tau_{max} = PE$

Not in equilibrium.

$U = -PE\cos 90° = 0$

$F_{Net} = 0$

$\tau_{Net} = PE\sin 180° = 0$

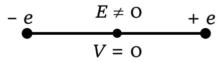
It's in equilibrium

$U = -PE\cos 180° = U = PE$ ← maximum

It represent unstable equilibrium.

Ifinite long wire-

Due to sheet

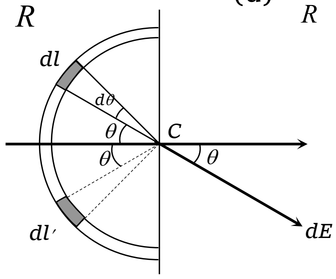


Examples based on electric field and electric

Q1. A half ring of radius R has a charge of λ per unit length. The electric field at the centre is $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

[CPMT 2000; CBSE PMT 2000; REE 1999]

(a) Zero (b) $\frac{k\lambda}{R}$ (c) $\frac{2k\lambda}{R}$ (d) $\frac{k\pi\lambda}{R}$



Q2. What is the magnitude of a point charge due to which the electric field 30 cm away has the magnitude 2 *newton/coulomb* $[1/4\pi\varepsilon_0 = 9\times10^{9}\ Nm^2]$ **[MP PMT 1996]**

(a) 2×10^{-11} *coulomb* (b) 3×10^{-11} *coulomb* (c) 5×10^{-11} *coulomb* (d) 9×10^{-11} *coulomb*

Q3. Two point charges Q and $-3Q$ are placed at r distance apart. Find electric field at centre?

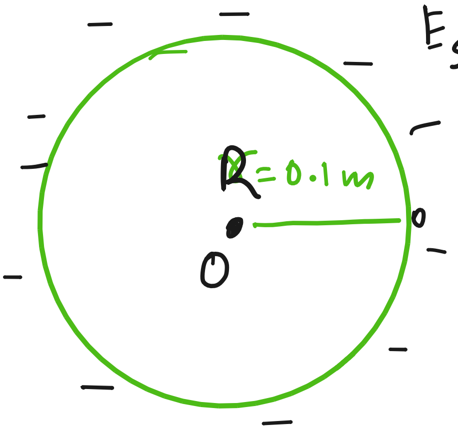
Q4. Two charged spheres of radius R_1 and R_2 respectively are charged and joined by a wire. The ratio of electric field of the spheres is

(a) $\frac{R_1}{R_2}$ (b) $\frac{R_2}{R_1}$ (c) $\frac{R_1^2}{R_2^2}$ (d) $\frac{R_2^2}{R_1^2}$

Q5. The number of electrons to be put on a spherical conductor of radius 0.1m to produce an electric field of 0.036 N/C just above its surface is

(a) 2.7×10^5 (b) 2.6×10^5 (c) 2.5×10^5 (d) 2.4×10^5

$Q = ne$



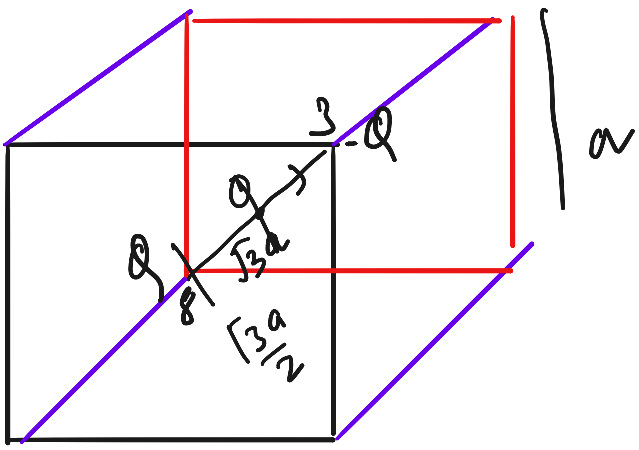
$$E_s = \frac{KQ}{R^2} = \frac{K\,ne}{R^2}$$

$$0.036 = \frac{9 \times \cancel{10^9} \times n \times 1.6 \times \cancel{10^{-19}}}{\cancel{10^{-2}}}$$

$$\frac{0.036}{9 \times 1.6} \times 10^{+8} = n.$$

Q6. Eight equal charges each $+Q$ are kept at the corners of a cube. Net electric field at the centre will be $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(a) $\frac{kQ}{r^2}$ (b) $\frac{8kQ}{r^2}$ (c) $\frac{2kQ}{r^2}$ (d) Zero



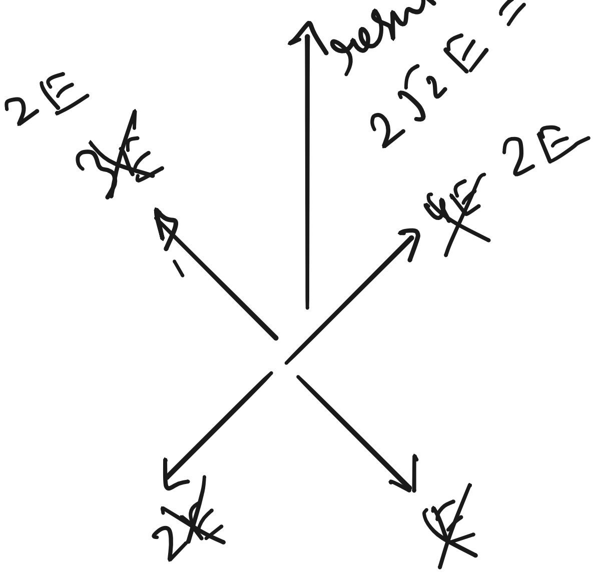
IIT mains.

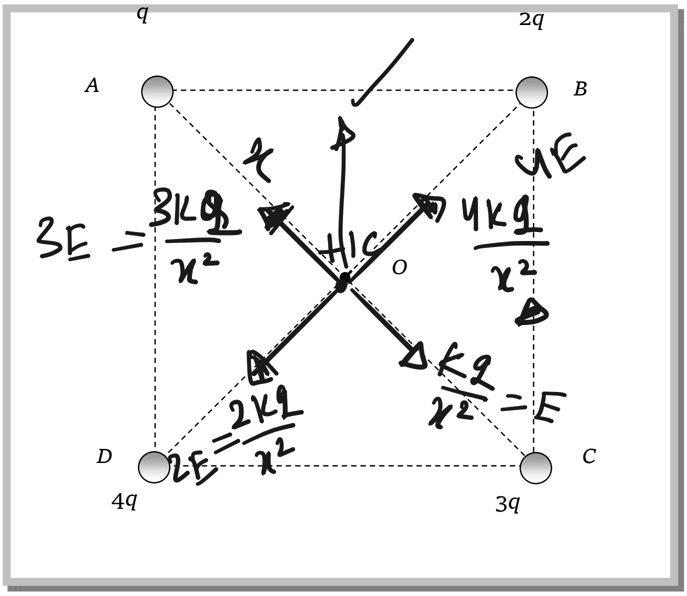
$$E_8 + E_3 = \frac{KQ}{\left(\frac{\sqrt{3}a}{2}\right)^2} \times 2$$

$E_8 = E_3$, $E_6 \cancel{=} E_1$, $E_2 \cancel{=} E_5$, $E_4 \cancel{=} E_7$

Q7. q, $2q$, $3q$ and $4q$ charges are placed at the four corners A, B, C and D of a square. The field at the centre O of the square has the direction along. **[CPMT 1989]**

resultant $2\sqrt{2}E = 2\sqrt{2}\dfrac{kq}{\left(\frac{a}{\sqrt{2}}\right)^2}$

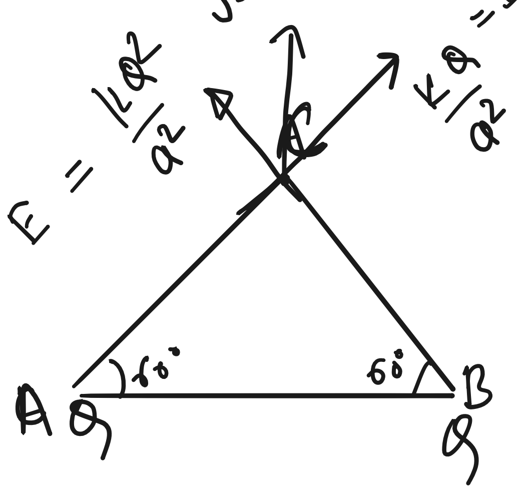




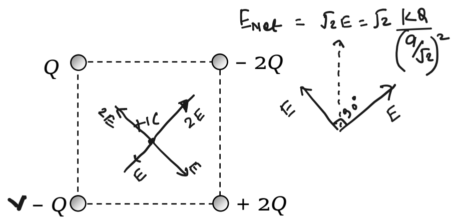
(a) AB (b) CB (c) AC (d) BD

Q8. Equal charges Q are placed at the vertices A and B of an equilateral triangle ABC of side a. The magnitude of electric field at the point ~~A~~ C is

(a) $\frac{Q}{4\pi\varepsilon_0 a^2}$ (b) $\frac{\sqrt{2}Q}{4\pi\varepsilon_0 a^2}$ (c) $\frac{\sqrt{3}Q}{4\pi\varepsilon_0 a^2}$ (d) $\frac{Q}{2\pi\varepsilon_0 a^2}$



Q9. Four charges are placed on corners of a square as shown in figure having side of 5 cm. If Q is one micro coulomb, then electric field intensity at centre will be



(a) $1.02\times10^{7}\,N/C$ upwards

(b) $2.04\times10^{7}\,N/C$ downwards

(c) $2.04\times10^{7}\,N/C$ upwards

(d) $1.02\times10^{7}\,N/C$ downwards

Q10. Infinite charges are lying at x = 1, 2, 4, 8...*meter* on X-axis and the value of each charge is Q. The value of intensity of electric field and potential at point x = 0 due to these charges will be respectively

(a) $12\times10^9 Q$ N/C, 1.8×10^4 V

(b) Zero, $1.2\times10^4 V$

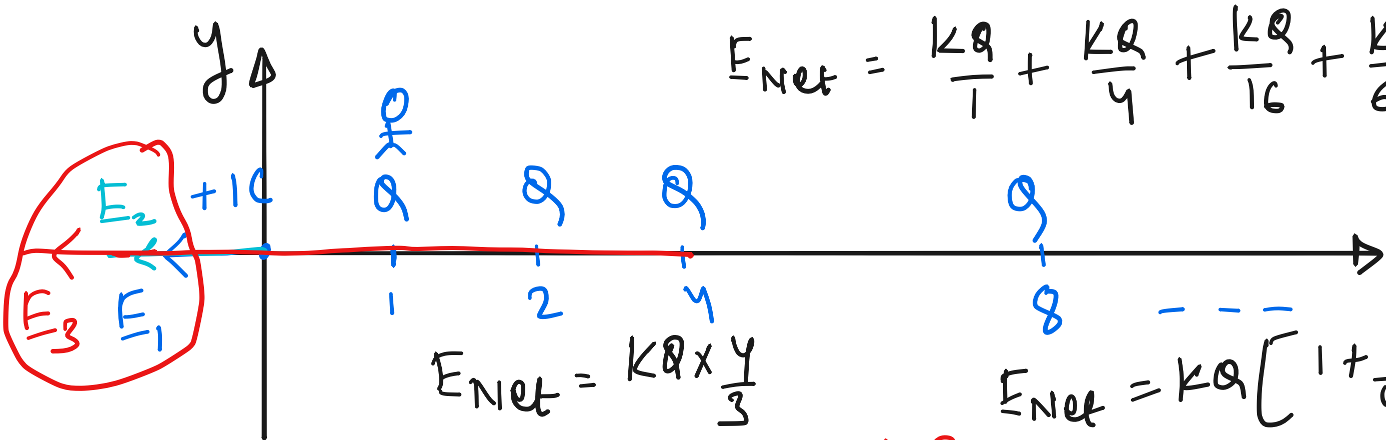
(c) $6\times10^9 Q$ N/C, 9×10^3 V

(d) $4\times10^9 Q$ N/C, 6×10^3 V

$E_{Net} = 3\cancel{9}\times10^9\times\frac{4}{\cancel{3}} = 12\times10^9 Q$

$E_{Net} = E_1 + E_2 + E_3 + \cdots\infty$

$E_{Net} = \frac{KQ}{1} + \frac{KQ}{4} + \frac{KQ}{16} + \frac{KQ}{64} + \cdots$



$E_{Net} = KQ\times\frac{4}{3}$

$E_{Net} = KQ\left[1+\frac{1}{4}+\frac{1}{16}+\cdots\right]$

$4/3$

$E_1 = \frac{KQ}{1^2}$, $E_2 = \frac{KQ}{2^2}$, $E_3 = \frac{KQ}{4^2}$

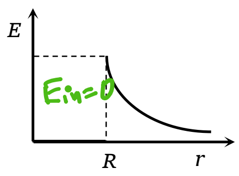
$r = 1/4$

$\frac{4}{3} = \frac{1}{3/4} = S_\infty = \frac{a}{1-r} = \frac{1}{1-1/4}$

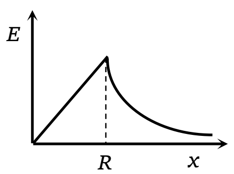
Q11. Which of the following graphs shows the variation of electric field E due to a hollow spherical conductor of radius R as a function of distance from the centre of the sphere

[AMU 2001]

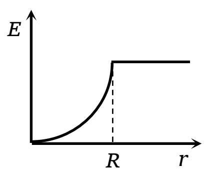
(a)



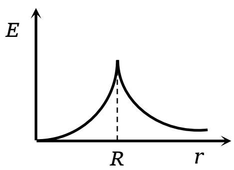
(b)



(c)



(d)



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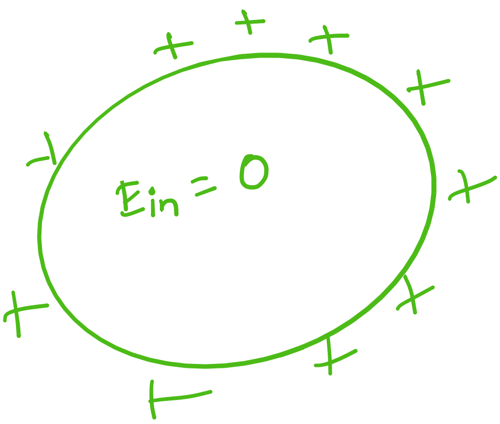
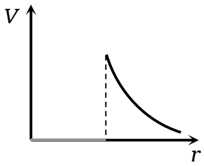
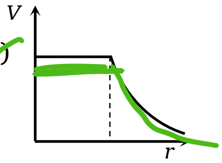
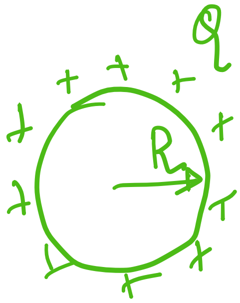


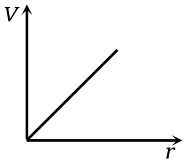
Inside conductors Net Electric field is always zero.

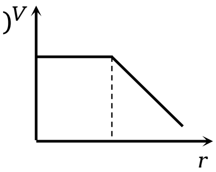
Q12. In a hollow spherical shell potential (V) changes with respect to distance (r) from centre
[DCE 2001, 03]

(a) 

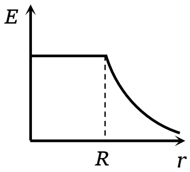
(b) 

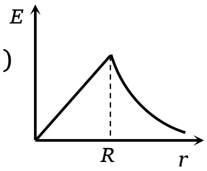


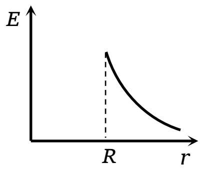
(c) 

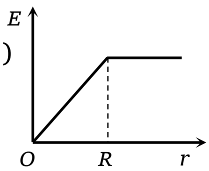
(d) 

Q13. The electric field due to a uniformly charged sphere of radius R as a function of the distance from its centre is represented graphically by **[AIIMS 2004]**

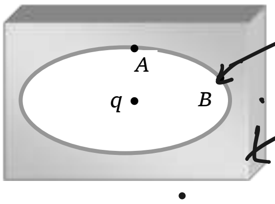
(a) 

(b) 

(c) 

(d) 

Q14. An ellipsoidal cavity is carved within a perfect conductor. A positive charge q is placed at the centre of the cavity. The points A and B are on the cavity surface as shown in the figure. Then
[IIT-JEE (Screening) 1999]



Surface.

conductor.

(a) Electric field near A in the cavity = Electric field near B in the cavity
(b) Charge density at $A =$ Charge density at B
(c) Potential at $A =$ Potential at B
(d) ~~Total electric field flux through~~ the surface of the cavity is q/ε_0

q

$$\phi = \frac{q}{\epsilon_0}$$

Q15. A solid metallic sphere has a charge $+3Q$. Concentric with this sphere is a conducting spherical shell having charge $-Q$. The radius of the sphere is a and that of the spherical shell is $b(b > a)$. What is the electric field at a distance $R(a < R < b)$ from the centre **[MP PMT 1995]**

(a) $\frac{Q}{2\pi\varepsilon_0 R}$ (b) $\frac{3Q}{2\pi\varepsilon_0 R}$

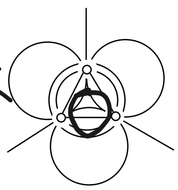
(c) $\frac{3Q}{4\pi\varepsilon_0 R^2}$ (d) $\frac{4Q}{4\pi\varepsilon_0 R^2}$

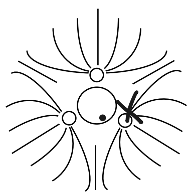
Q16. Two infinitely long parallel wires having linear charge densities λ_1 and λ_2 respectively are placed at a distance of R metres. The force per unit length on either wire will be $\left(K = \frac{1}{4\pi\varepsilon_0}\right)$ **[MP PMT/PET 1998; DPMT 2000]**

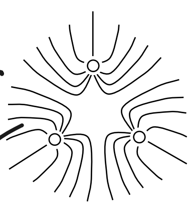
(a) $K\frac{2\lambda_1\lambda_2}{R^2}$ (b) $K\frac{2\lambda_1\lambda_2}{R}$

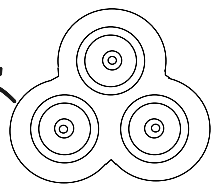
(c) $K\frac{\lambda_1\lambda_2}{R^2}$ (d) $K\frac{\lambda_1\lambda_2}{R}$

Q17. Three positive charges of equal value q are placed at the vertices of an equilateral triangle. The resulting lines of force should be sketched as in **[IIT-JEE (Screening) 2001]**

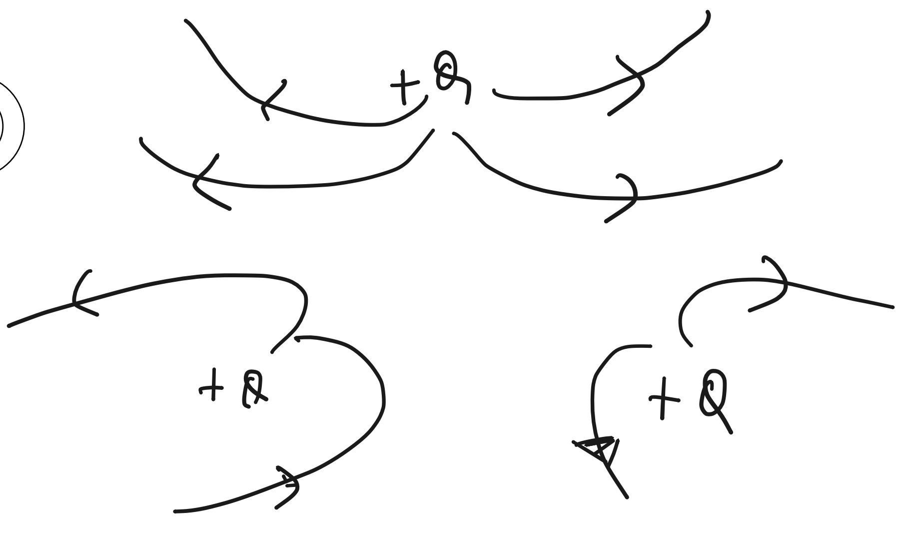
(a) 

(b) 

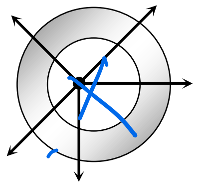
(c) 

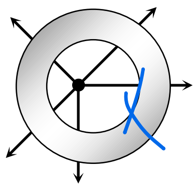
(d) 

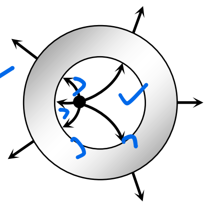
IIT main 2019

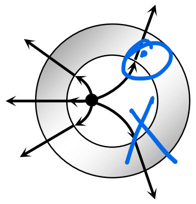


Q18. A metallic shell has a point charge 'q' kept inside its cavity. Which one of the following diagrams correctly represents the electric lines of forces **[IIT-JEE (Screening) 2003]**

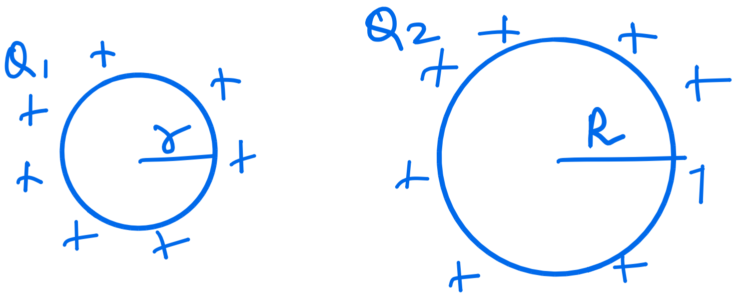
(a) 

(b) 

(c) 

(d) 

hint



H.W.

Q19. If on the concentric hollow spheres of radii r and $R(>r)$ the charge Q is distributed such that their surface densities are same then the potential at their common centre is

[IIT 1981]

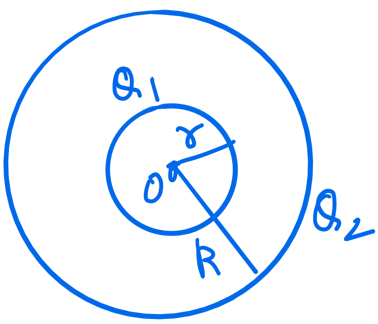
(a) $\frac{Q(R^2+r^2)}{4\pi\varepsilon_0(R+r)}$

(b) $\frac{QR}{R+r}$

(c) Zero

(d) $\frac{Q(R+r)}{4\pi\varepsilon_0(R^2+r^2)}$

$Q_1 + Q_2 = Q$ — A



$$\frac{Q_1}{\cancel{4\pi} r^2} = \frac{Q_2}{\cancel{4\pi} R^2}$$

$$Q_1 = \frac{r^2}{R^2} Q_2 \quad \text{— B}$$

$V_{small} = \frac{KQ_1}{r}, \quad V_{big} = \frac{KQ_2}{R}$

total potential at centre

$$V = \frac{KQ_1}{r} + \frac{KQ_2}{R}$$

Q20. Two equal negative charge $-q$ are fixed at the fixed points $(0,a)$ and $(0,-a)$ on the Y-axis. A positive charge Q is released from rest at the point $(2a,0)$ on the X-axis. The charge Q will

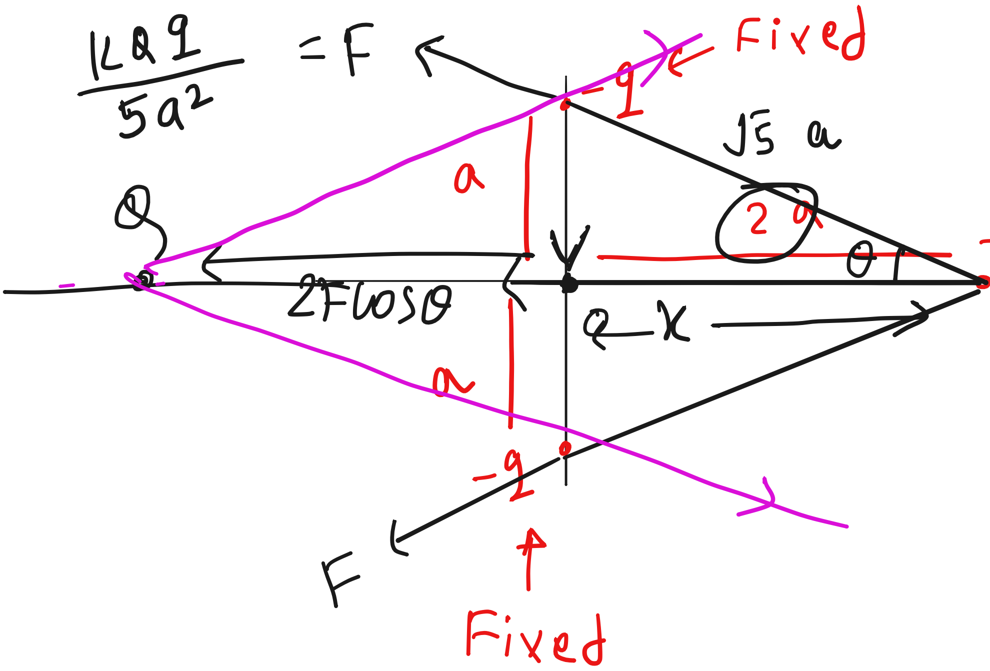
(a) Execute simple harmonic motion about the origin

(b) Move to the origin and remain at rest

(c) Move to infinity

(d) Execute oscillatory but not simple harmonic motion

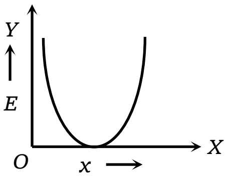
$$F_{Net} = 2F\cos\theta$$
$$= 2 \times \frac{KQq}{5a^2} \cdot \frac{2a}{\sqrt{5}a}$$

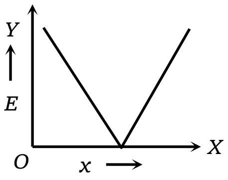


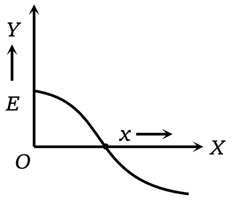
$$F_{Net} = \frac{4KQq}{5\sqrt{5}a^2}$$

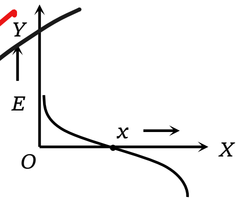
it will perorm osillatory motion.

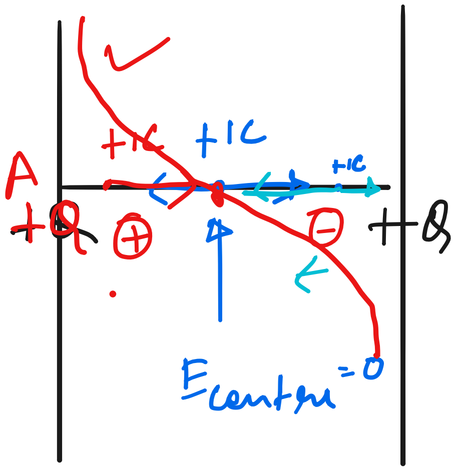
Q21. Two identical point charges are placed at a separation of d. P is a point on the line joining the charges, at a distance x from any one charge. The field at P is E, E is plotted against x for values of x from close to zero to slightly less than d. Which of the following represents the resulting curve

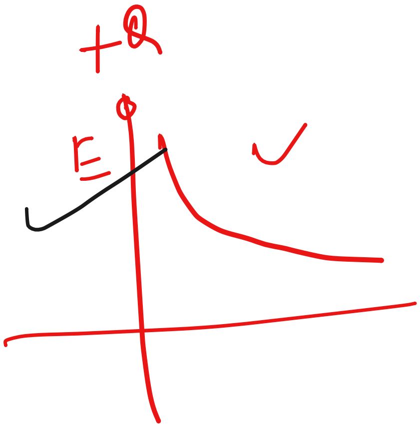
(a)


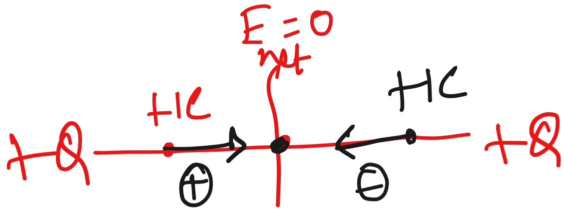
(b)


(c)


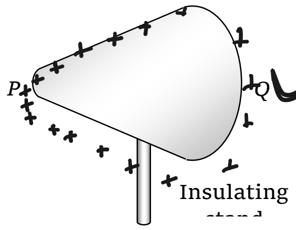
(d)








Q22. Figure shows a charged conductor resting on an insulating stand. If at the point P the charge density is σ, the potential ~~is V and~~ the electric field strength is E, what are the values of these quantities at point Q



potential same every-where on conductor.

	Charge density	Potent ial	Electric intensity
(a)	$>\sigma$	$>V$	$>E$
(b)	$>\sigma$	V	$>E$
(c)	$<\sigma$	V	E
(d)	$<\sigma$	V	$<E$

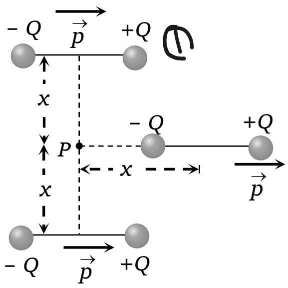
For Q poin

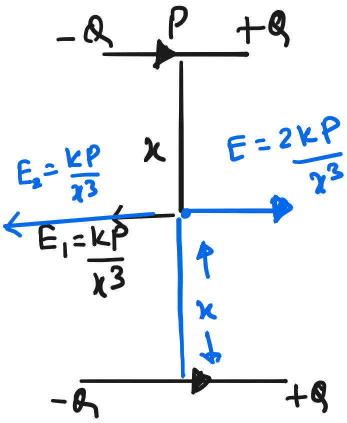
$E_P > E_Q$

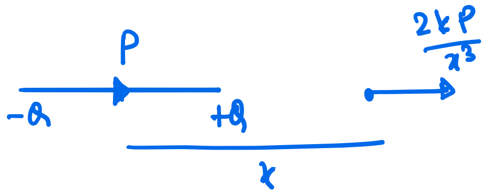
$\sigma_P > \sigma_Q$

$V_P = V_Q$

Q23. \Three identical dipoles are arranged as shown below. What will be the net electric field at P $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$







(a) $\frac{k.p}{x^3}$ (b) $\frac{2kp}{x^3}$

(c) Zero (d) $\frac{\sqrt{2}\, kp}{x^3}$

Q24. A conducting sphere of radius R, and carrying a charge q is joined to a conducting sphere of radius $2R$, and carrying a charge $-2q$. The charge flowing between them will be

(a) $\frac{q}{3}$ (b) $\frac{2q}{3}$

(c) q (d) $\frac{4q}{3}$

Q25. ABC is an equilateral triangle. Charges $+q$ are placed at each corner. The electric intensity at O will be

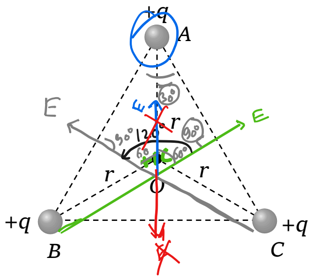
[CPMT 1985; AIEEE 2002]

(a) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

(b) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

(c) Zero

(d) $\frac{1}{4\pi\varepsilon_0}\frac{3q}{r^2}$



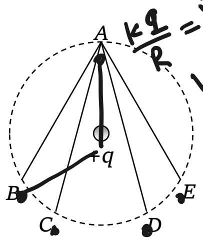
Q26. In the electric field of a point charge q, a certain charge is carried from point A to B, C, D and E. Then the work done **[NCERT 1980]**

(a) Is least along the path AB

(b) Is least along the path AD

(c) Is zero along all the ~~paths~~ AB, AC, AD and AE

(d) Is least along AE



$\frac{Kq}{R} = V_A$

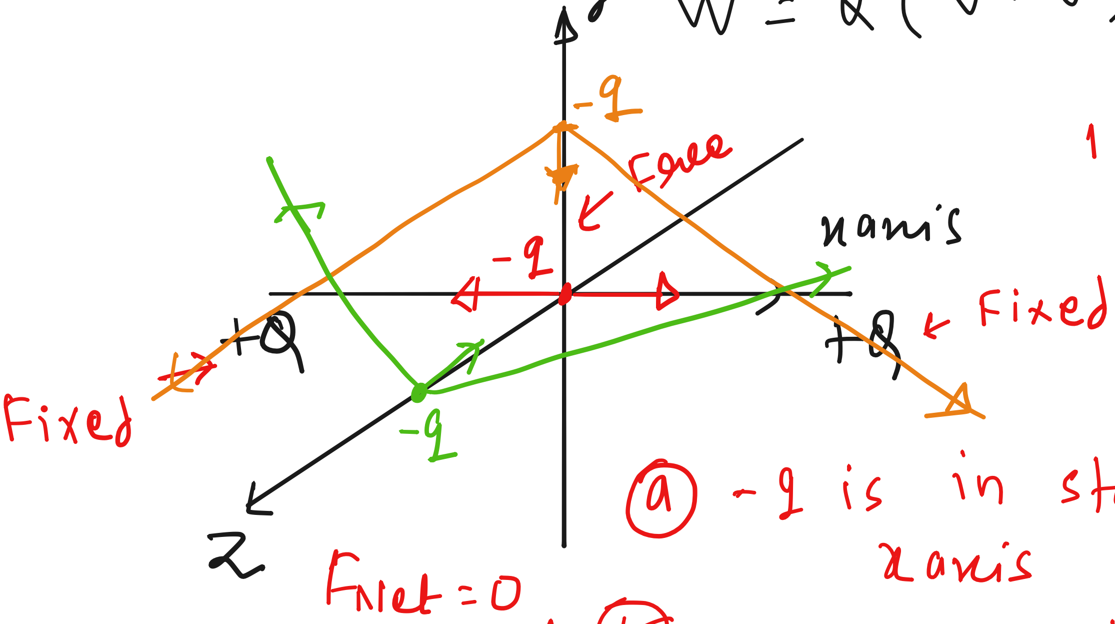
$V_B = \frac{Kq}{R}$

$V_C = \frac{Kq}{R}$

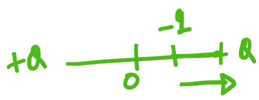
$V_D = \frac{Kq}{R}.$

$W = Q\Delta V$

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



11T Adv.



(a) $-q$ is in stable eq. along x axis

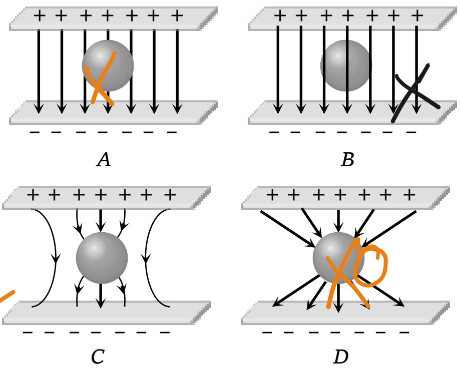
(b) $-q$ is in unstabe eq. along x axis

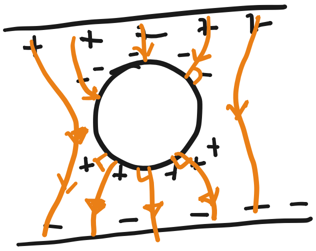
(e) −q is in stable eq° along y

(d) −q is ~~stable~~ along z axis

Q27. An uncharged sphere of metal is placed in between two charged plates as shown. The lines of force look like

[MP PMT 1985; KCET 2004]



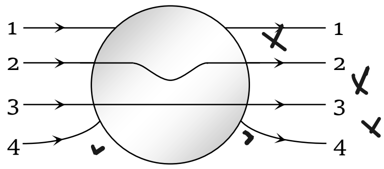


Electric field lines make 90° with surface of conductor.

Electric field lines never enter into surface of conductor.

Q28. A metallic solid sphere is placed in a uniform electric field. The lines of force follow the path(s) shown in figure as

[IIT 1996]



(a) 1 (b) 2

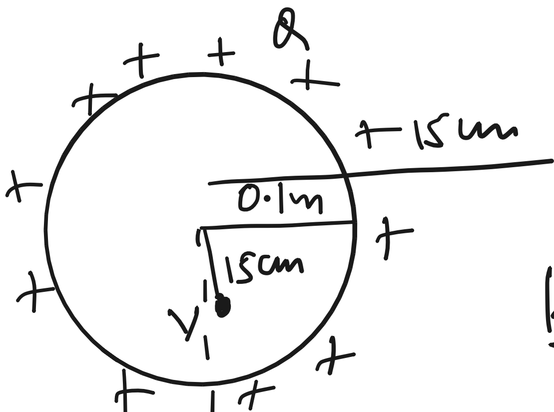
(c) 3 (d) 4

Q29. If a charged spherical conductor of radius $10\,cm$ has potential V at a point distant $5\,cm$ from its centre, then the potential at a point distant $15\,cm$ from the centre will be

[SCRA 1998; JIPMER 2001, 02]

(a) $\frac{1}{3}V$ (b) $\frac{2}{3}V$

(c) $\frac{3}{2}V$ (d) $3V$



$$\frac{KQ}{R} = \frac{KQ}{0.1} = V$$

$$KQ = 0.1V \quad \text{— (A)}$$

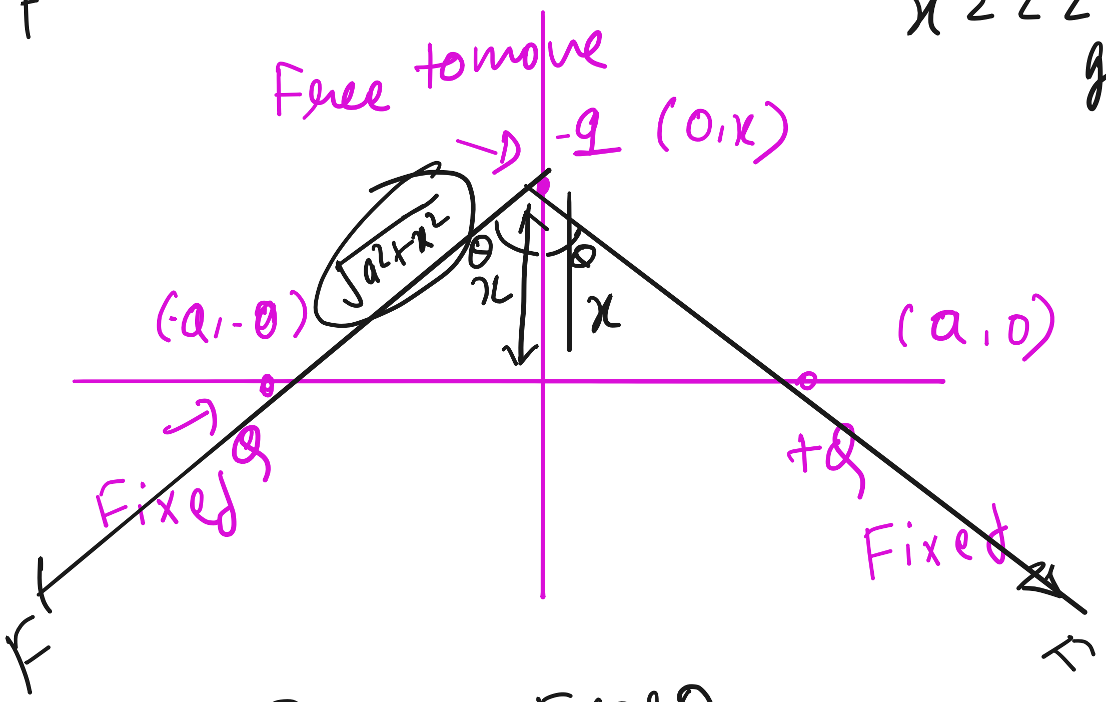
$$\frac{KQ}{0.15} = V_{out}.$$

$+Q$ 15cm 0.15m

$$\frac{0.1V}{0.15} = V_{out} = \frac{2V}{3}$$

it will perform S.H.M.

$x <<< a$
given



$$F_{Net} = 2F\cos\theta$$

$$= 2 \times \frac{kQq}{(a^2+x^2)} \frac{x}{\sqrt{a^2+x^2}}$$

$$m\,acc = \frac{2kQqx}{a^3}$$

$$acc. = \frac{2kQqx}{ma^3}$$

$$= \frac{2kQqx}{(a^2+x^2)^{3/2}} = \frac{2kQqx}{a^3}$$

$$T = 2\pi\sqrt{\frac{x}{acc}}$$

$$\boxed{F_{Net} \propto x}$$

$$T = 2\pi\sqrt{\frac{\cancel{x}}{\frac{2kQq\cancel{x}}{ma^3}}} = 2\pi\sqrt{\frac{ma^3}{2kQq}}$$