ELECTROSTATICS - 1

EXERCISE – I

SINGLE CORRECT

1. D

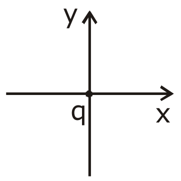
$$|\vec{E}| = \frac{kq}{|\vec{r}|^2}$$

$$\vec{r} = (8-2)\hat{i} + (-5-3)\hat{j}$$

Now $E = \frac{9\times10^9 \times 50\times10^{-6}}{100}$

E = 4500 v/m

2. **C**



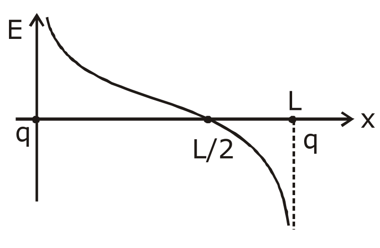
$$\vec{E}_A = \frac{Kq(\hat{i}+2\hat{j}+2\hat{k})}{(\sqrt{14})^3}$$

$$\vec{E}_B = \frac{Kq(\hat{i}+\hat{j}-\hat{k})}{(\sqrt{13})^3}$$

$$\vec{E}_c = \frac{Kq(2\hat{i}+2\hat{j}+2\hat{k})}{(\sqrt{12})^3}$$

Now $\vec{E}_A.\vec{E}_B = 0 \Rightarrow \vec{E}_A \perp \vec{E}_B$

3. **D**



4. **B**

Force on charge = qE = qE_0sin ωt

acceleration = $\frac{q\varepsilon_0}{m}$ sin ωt ...(1)

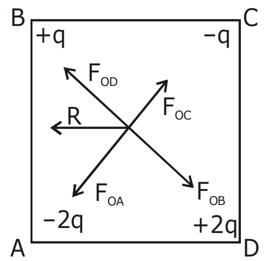
In SHM a = $A\omega^2$ sin ωt ...(2)

Comare (1) & (2)

$$A\omega^2 = \frac{q\varepsilon_0}{m} \Rightarrow A = \frac{q\varepsilon_0}{m\omega^2}$$

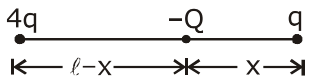
5. **D**

Length of the arrow showes magnitude



Resultant R is ⊥ to surface AB

6. Negative charge is placed to achieve equilibrium.



Net force on Q is zero

$$\Rightarrow \frac{K4qQ}{(\ell - x)^2} = \frac{kqQ}{x^2}$$

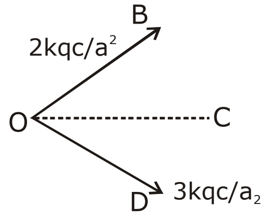
$\Rightarrow$ x = ℓ/3

Net force on q is also zero

$$\Rightarrow \frac{kQq}{(\ell/3)^2} = \frac{k4qq}{\ell^2}$$

$$Q = \frac{4q}{9}$$

7. **D**



Resultant lie in between region COD

8. $a = \frac{qE}{m}$

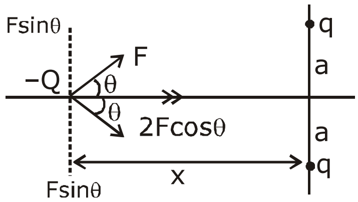
After time t

$$v = \frac{qE}{m}t$$

$$KE = \frac{1}{2}mv^2$$

$$= \frac{E^2q^2t^2}{2m}$$

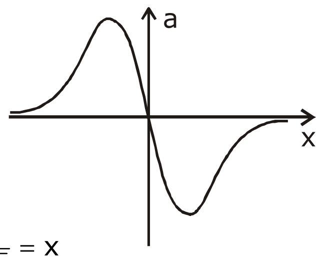
9. **B**



Net force on –Q charge = 2F cos θ

$$a = \frac{2F\cos\theta}{m}$$

$$a = \frac{2kqQx}{m(a^2 + x^2)}$$



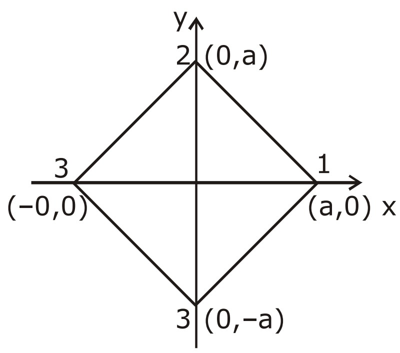
for a_{max} $\frac{da}{dx} = 0$

which gives $\pm\frac{a}{\sqrt{2}} = x$

at $x \to \infty$ $a = 0$

$x \to 0$ $a = 0$

10. **D**



E.f at (0, 0, z)

$$\vec{E}_1 = \frac{kq(z\hat{k} - a\hat{i})}{(\sqrt{a^2 + z^2})^3}$$

$$\vec{E}_2 = \frac{kq(z\hat{k} - a\hat{i})}{(\sqrt{a^2 + z^2})^3}$$

$$\vec{E}_3 = \frac{kq(z\hat{k} + a\hat{i})}{(\sqrt{a^2 + z^2})^3}$$

$$\vec{E}_4 = \frac{kq(z\hat{k} + a\hat{i})}{(\sqrt{z^2 + a^2})^3}$$

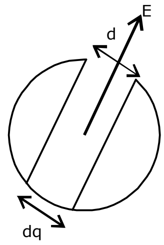
$$E_{net} = \frac{4kqz\hat{k}}{(\sqrt{z^2 + a^2})^3}$$

$$\text{Magnitude } E = \frac{4kqz}{(\sqrt{z^2 + a^2})^{3/2}}$$

for maxima $\frac{dE}{dz} = 0$

which gives $z = \frac{L}{2}$

11.

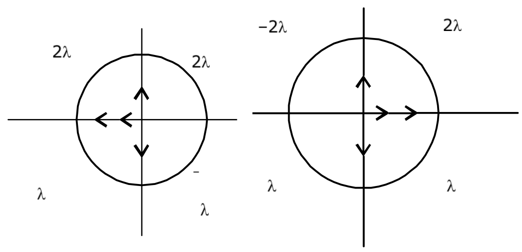


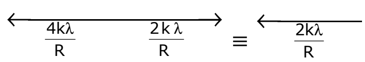
$$E = \frac{Kdq}{R^2}$$

$$dq = \frac{d}{2\pi R}.d$$

$$E = \frac{K\phi}{2\pi R^3}.d \Rightarrow E \times \frac{1}{R^3}$$

12.

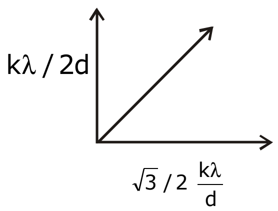




$$\vec{E} = \frac{-2k\lambda\hat{i}}{R}$$

$$= = \frac{-\lambda}{2\pi\epsilon_0 R}\hat{i}$$

13. **A**



$\theta_1 = 0,\ \theta_2 = 60°$

$$E_{\perp} = \frac{k\lambda}{d}[\sin 60° + \sin 0°] = \frac{\sqrt{3}}{2}\frac{k\lambda}{d}$$

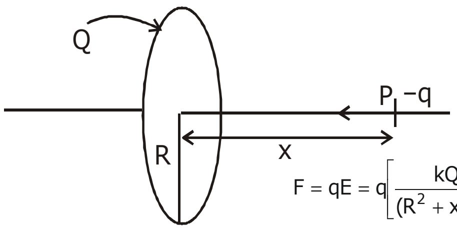
$$E_{||} = \frac{k\lambda}{d}[\cos 60° - \cos 0°] = \frac{-k\lambda}{2d}$$

$$\tan\theta = \frac{1}{\sqrt{3}}$$

$\theta = 30°$

14. **D**
think !!
x is not small

15.



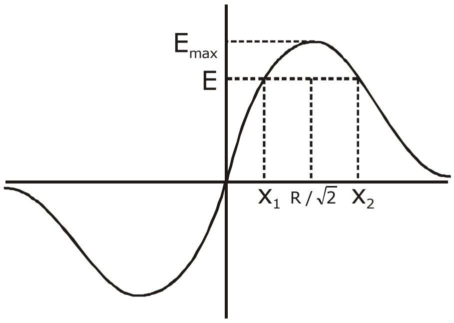
$$F = qE = q\left[\frac{kQx}{(R^2 + x^2)^{3/2}}\right]$$

$\because x << R$

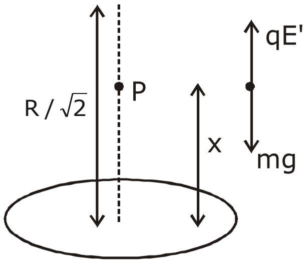
$$\Rightarrow F = q\frac{KQx}{R^3}$$

$$\omega = \sqrt{\frac{qQk}{R^2 m}}$$

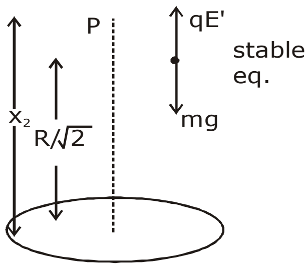
16.



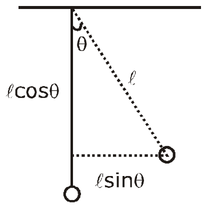
As we displaced upward qE′ ↑
qE′ > mg So particle move upward
⇒ Unstable equilibrium



(b) As we displace upward qE′ ↓
mg > qE′ particle comes at point P again
Now we displace down ward from x_2 qE′ > mg
so particle comes at point P again
⇒ stable equilibrium



17.



$$(W.D)_E + (W.D.)_{mg} = \Delta K$$

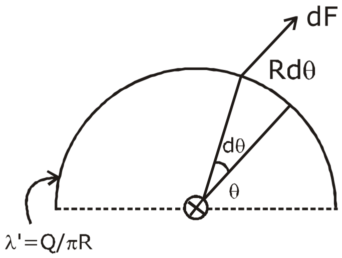
$$(qE\,\ell\sin\theta) + (\ell - \ell\cos\theta)mg = \frac{1}{2}mv^2$$

$$q\left(\frac{mg}{R}\right)\frac{\ell}{\sqrt{2}} + mg\ell\left[1 - \frac{1}{\sqrt{2}}\right] = \frac{1}{2}mv^2$$

$$v = \sqrt{2g\ell}$$

$$\omega = \frac{v}{R} = \sqrt{\frac{2g}{\ell}}$$

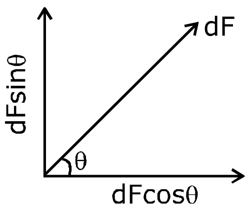
18. **B**



dF = dqE

$dF = \lambda' R d\theta \dfrac{2k\lambda}{R}$

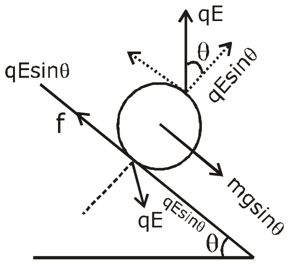
$dF = \dfrac{2k\lambda}{R} Q \dfrac{d\theta}{\pi}$



$F_{net} = \int_0^{\pi} dF \sin\theta = \dfrac{2k\lambda Q}{\pi R} \int_0^{\pi} \sin\theta d\theta$

$F = \dfrac{\lambda Q}{\pi^2 \varepsilon_0 R}$

19. **B**



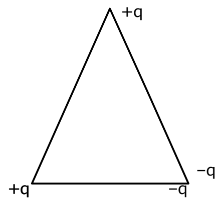
At equilibrium f = mgsinθ

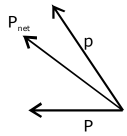
Net τ is also 0

⇒ 2qE sin θ = f.R.

$E = \dfrac{mg}{2q}$

20.

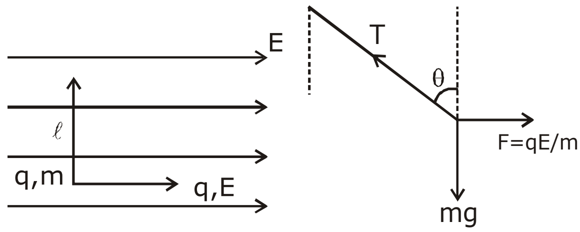




(0, 0, L) is ⊥ to p_{net}

⇒ component along z-direction is zero

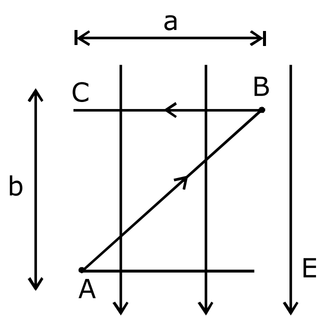
21. **D**



$g_{eff} = \left[g^2 + \left(\dfrac{qE}{m}\right)^2 \right]^{1/2}$

$T = 2\pi \sqrt{\dfrac{\ell}{g_{eff}}}$

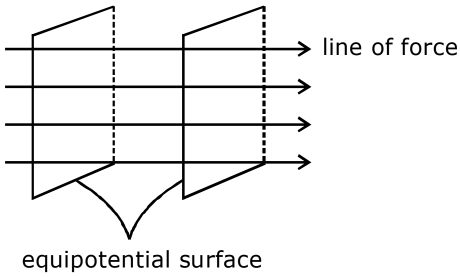
22. **C**



dr = $-\vec{E}.\vec{dr}$

$V_A - V_B = E_b$

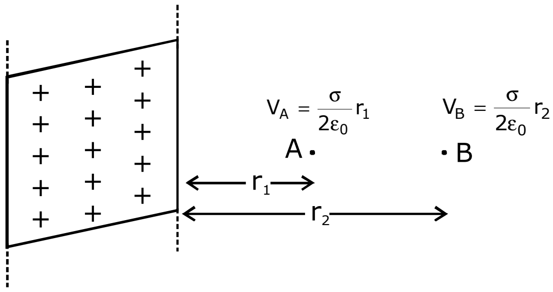
23.



Angle between both = 90°

24. B

25.

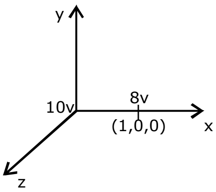


Given $V_B - V_A = 5$ V

$\frac{\sigma}{2\varepsilon_0}(r_2 - r_1) = 5V$

$r_2 - r_1 = 0.88$ mm

26. $\because\ E_x = E_y = E_z$



$E_x = \frac{10-8}{t} = 2v/m$

Now $\vec{E} = 2\hat{i} + 2\hat{j} + 2\hat{k}$

$dv = -E.dr = (2\hat{i} + 2\hat{j} + 2\hat{k})(dx\hat{i} + dy\hat{j} + d\hat{k})$

$v_f - v_i = \left[\int_0^1 2dx + \int_0^1 2dy \int_0^1 2dz\right]$

$v_f - 10 = -\left[2+2+2\right]$

$v_f = 4v$

27. **B**

$E = \frac{Kq}{r^2}$; $V = \frac{Kq(n-1)}{r}$

$\frac{V}{E} = r(n-1)$

28. $V = k(2x^2 - y^2 + z^2)$

$E = -\left[\frac{dV}{dx}\hat{i} + \frac{dV}{dy} j + \frac{dV}{dz}\hat{k}\right]K$

$E = -\left[4x\hat{i} - 2y\hat{j} + 2z\hat{k}\right]K$

$E_{(1,1,1)} = = -\left[4x\hat{i} - 2y\hat{j} + 2z\hat{k}\right]K$

$|E| = 2k\sqrt{6}$

29. **D**

$q_1 \leftarrow d \rightarrow q_2$

Seperation increase then

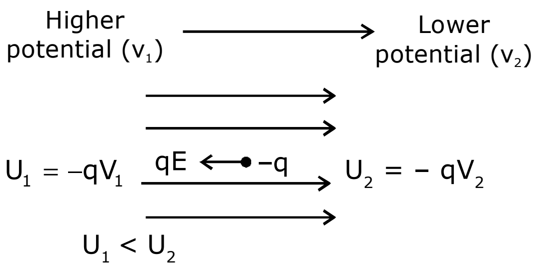
$U = \frac{Kq_1q_2}{d} \downarrow$

But

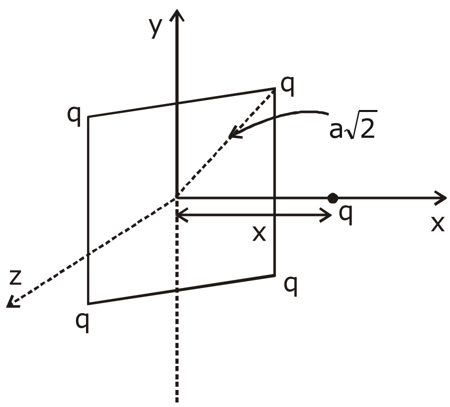
$q_1 \leftarrow d \rightarrow -q_2$

if d ↑ then $U = \frac{-kq_1q_2}{d} \uparrow$

30.



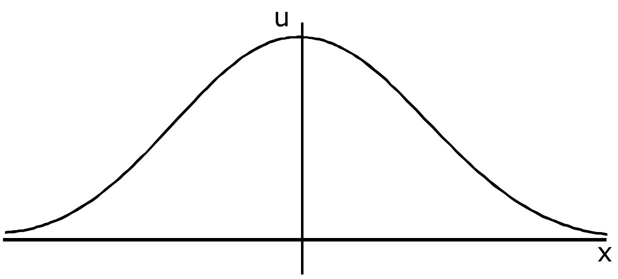
31. **B**



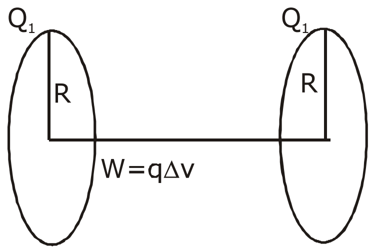
$U = \frac{Kq^2}{r^2} + \frac{Kq^2}{r^2} + \frac{Kq^2}{r^2} + \frac{Kq^2}{r^2}$

$r^2 = x^2 + \frac{a^2}{2}$

$$U = \frac{4kq^2}{x^2 + a^2/2}$$



32. **B**



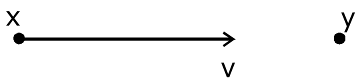
$v_A = \frac{KQ_1}{R} + \frac{KQ_2}{\sqrt{2}R}$ $\qquad$ $v_B = \frac{KQ_2}{R} + \frac{KQ_1}{\sqrt{2}R}$

$$W = q\left[\frac{kQ_2}{R} + \frac{KQ_1}{\sqrt{2}R} - \frac{kQ_1}{R} - \frac{kQ_2}{\sqrt{2}R}\right]$$

$$W = \frac{q}{R4\pi\varepsilon_0}\left[\left(Q_2 + \frac{Q_1}{\sqrt{2}}\right) - \left(Q_1 + \frac{Q_2}{\sqrt{2}}\right)\right]$$

$$W = q(Q_1 - Q_2)(\sqrt{2} - 1)|(\sqrt{2}\, 4\pi\varepsilon_0 R)$$

33. **B**



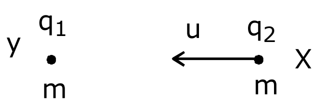
Either y is fixed or not E is conserved but when y is fixed $F_{net} \neq 0$

$\Rightarrow$ P not conserved

when y is free $F_{net} = 0$

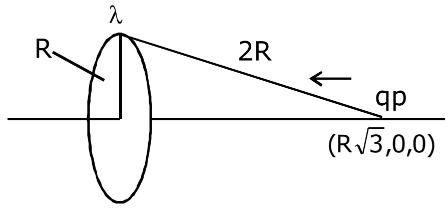
$\Rightarrow$ P = conserved

34. **A**



After long time y will move with velocity u and $v_x = 0$ becouse momentum is conserved

35. **C**



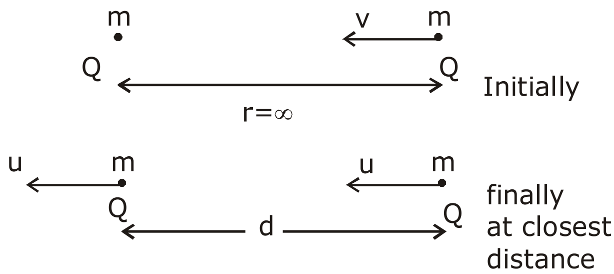
$$\text{Energy at Point P} = \frac{\lambda q}{4\varepsilon_0} + q\left(\frac{K\lambda 2\pi R}{2R}\right)$$

$$= \frac{\lambda q}{4\varepsilon_0} + \frac{q\lambda}{4\varepsilon_0} = \frac{q\lambda}{2\varepsilon_0}$$

$$\text{Energy at point 0} = \frac{qk\lambda(2\pi R)}{R} = \frac{q\lambda}{2\varepsilon_0}$$

i.e. particle will reach just point 0.

36. **B**



from E.C.

$$\frac{1}{2}mv^2 = 2(1/2\,mv^2) + \frac{kq^2}{d} \quad ...(1)$$

from

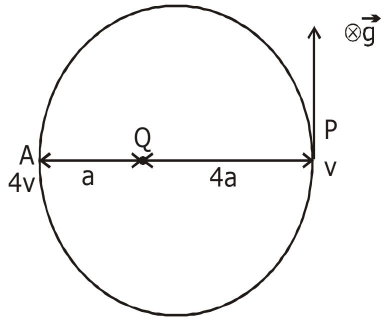
M.C. $\quad mv = 2mu \Rightarrow u = v/2 \quad ...(2)$

from (1) and (2)

$$\frac{1}{2}mv^2 = \frac{mv^2}{4} + \frac{kq^2}{d}$$

$$d = \frac{4kq^2}{mv^2}$$

37. **A**

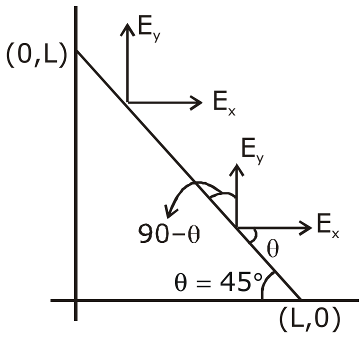


Energy conservation
between point P & A

$\Rightarrow \; qv + \frac{1}{2}mv^2 = 4qv$

$\frac{1}{2}mv^2 = 3qV \;\Rightarrow\; v = \sqrt{\frac{6qv}{m}}$

38. D



As ring move downward Ex ↑ Ey ↓
so at point where $qE_y \sin\theta = qE_x \cos\theta$
After wards ring com reach (L,0) easily (automotic)

$\tan\theta = x/y \;\Rightarrow\; x = y$

x = y = L/2
So energy concervativs between point A and B

$\frac{1}{2}mv^2 = qV$

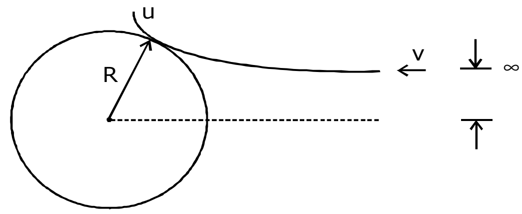
$v = \int_0^{L/2} x\,dx + \int_0^{L/2} y\,dy \;\Rightarrow\; \left[\frac{x^2}{2}\right]_0^{L/2} + \left[\frac{y^2}{2}\right]_0^{L/2}$

$v = \frac{L^2}{8} + \frac{L^2}{8} = \frac{L^2}{4}$

$\frac{1}{2}mv^2 = q\left[\frac{L^2}{4}\right]$

$v^2 = \frac{2qL^2}{4m} \;\Rightarrow v = \left(\frac{qL^2}{2m}\right)^{1/2}$

39. B



from AME about point 0
$\Rightarrow$ mvd = mvR

$u = \frac{vd}{R}$ ...(1)

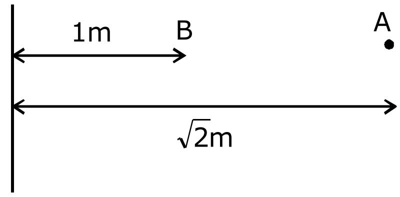
from E.C. $\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + \frac{kq_1q_2}{R}$ ..(2)

from eq. (1) and (2)

$v = 2\sqrt{\frac{2}{3}}$ m/sec.

40. B

Movement is parallel to x-axis
$\therefore$ w.d. by 2λ is zero.



$(W.D.)_{AB} = \int_{\sqrt{2}}^{1} \vec{E}.dr$

$= \int_{\sqrt{2}}^{1} \frac{2k(3\lambda)}{r} dr = 3 \times 2k\lambda \ln\left(\frac{1}{\sqrt{2}}\right)$

$= 3k\lambda \ln 2$

(W.D.) due to wire λ is $k\lambda \ln(2)$

$= \frac{\lambda \ell_n(2)}{\pi\varepsilon_0}$

41. B

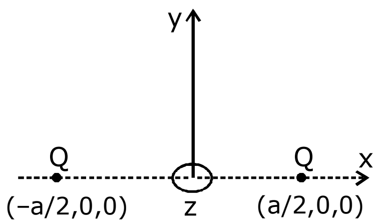
from E.C. $= \frac{EQq}{r} = \frac{EQq}{2r} + \frac{1}{2}mv^2$

$\Rightarrow \frac{kQq}{2r} = \frac{1}{2}mv^2$

$v = \sqrt{\frac{KQq}{mr}}$

Impulse = mv = $\sqrt{\dfrac{kQqm}{r}}$

42. C



Let –Q charge is placed at (0,y,z)
Now total potential energy of the system

$$U = \frac{KQ^2}{a} + \frac{KQ(-Q)}{r} + \frac{KQ(-Q)}{r} = 0$$

$$r = \sqrt{\frac{a^2}{4} + y^2 + z^2}$$

According to problem U = 0

$$\frac{KQ^2}{a} = \frac{KQ^2}{\sqrt{\frac{a^2}{4}+y^2+z^2}} + \frac{KQ^2}{\sqrt{\frac{a^2}{4}+y^2+z^2}}$$

$$\frac{a^2}{4} + y^2 + z^2 = 4a^2$$

$$y^2 + z^2 = \frac{15a^2}{4}$$

43. B
U =– QV

44. D
e.f is perpendicular to equipotential surface

m for e.f = $-\dfrac{1}{2}$

Now check option Ans - D

45. C
Integrate partially one of the term

v = $\int 4a\, xy\sqrt{z}\, dx = \text{const.}$

$4ay\sqrt{z}\,\dfrac{x^2}{2}$ = const.

z = $\dfrac{\text{const.}}{x^4 y^2}$

46. A
F = qE $\Rightarrow$ 3000 = 3E
$\Rightarrow$ E = 1000 N/c
ΔV = E. d = 1000 $\times 10^{-2}$
= 10 volt

47. A
In a given figure
$\vec{E}$ = E Cos Q $\hat{i}$ +E sinθ $\hat{j}$
d = d $\hat{i}$ +d $\hat{j}$
v = $\vec{E}\cdot\vec{d}$ = Ed (Cosθ +Sinθ)

48. D

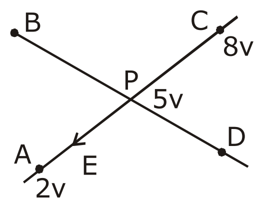
y = 3 + x $\qquad \vec{E} = \dfrac{100}{\sqrt{2}}\left[\hat{i}+\hat{j}\right]$

dv = $-\int \dfrac{100}{\sqrt{2}}\left[\hat{i}+\hat{j}\right].\left[dx\hat{i}+dy\hat{j}\right]$

$= -\dfrac{100}{\sqrt{2}}\left[\int_3^1 dx + \int_1^3 dy\right]$

Δv = 0

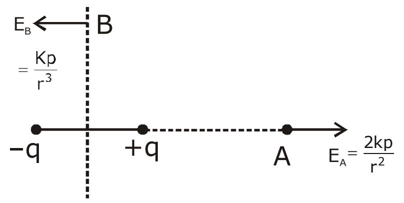
49. B



Δv = $v_A - v_P$ = 3V

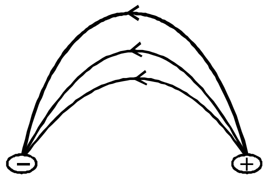
$\Rightarrow$ E = $\dfrac{V}{d} = \dfrac{3}{\sqrt{(0.1)^2+(0.1)^2}} = 15\sqrt{2}$

50. C

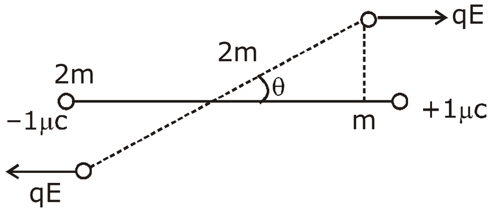


$\vec{E}_A = -2\vec{E}_B$

51. **B**



52. **A**



$\tau_{net} = qE\,2\sin\theta + qE\sin\theta$

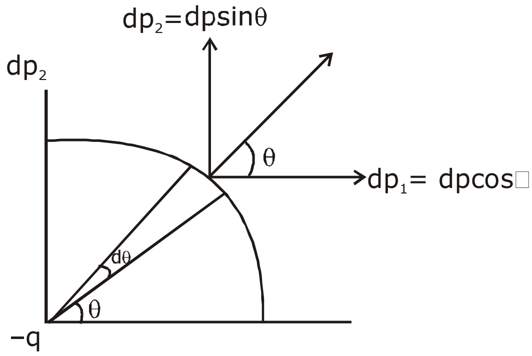
$= 3qE\sin\theta$

$\tau_{net} = 3qE\,\theta$

$W = \sqrt{\dfrac{K_{shm}}{I}} = \sqrt{\dfrac{3\times1\times10^{-6}\times20\times10^{-3}}{6}}$

$= \sqrt{\dfrac{1}{100}}$ = 1 rad /sec

53. **A**



$\lambda = \dfrac{q}{\pi R/2} = \dfrac{2q}{\pi R}$

$dP_1 = \int_0^{\pi/2} dP\cos\theta$

$= \int_0^{\pi/2} (\lambda R d\theta) R\cos\theta$

$= \lambda R^2 \int_0^{\pi/2} \cos\theta\, d\theta = \lambda R^2 \left[\sin\theta\right]_0^{\pi/2}$

$= \lambda R^2 .1 = \dfrac{2q}{\pi R}.R^2 = \dfrac{2qR}{\pi}$

$dP_2 = \int_0^{\pi/2} dP\sin\theta = \dfrac{2qR}{\pi}$

$P = \dfrac{2\sqrt{2}qR}{\pi}$

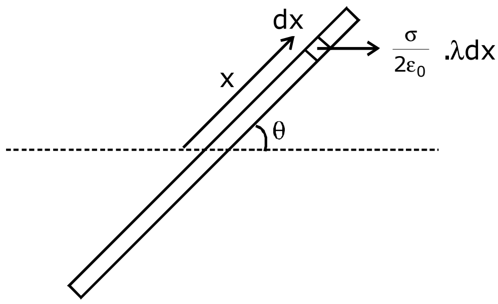
54. **D**

$F = \left|P\dfrac{dE}{dr}\right|$

and $\dfrac{dE}{dr} = 0$ at $r = \dfrac{R}{\sqrt{2}}$

$\Rightarrow F = 0$

55. **B**



$d\tau = \dfrac{2\sigma}{2\varepsilon_0}.\lambda x dx$

$= \dfrac{\sigma}{\varepsilon_0}\lambda\sin\theta\int_0^{l} x.dx$

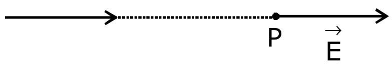
$= \dfrac{\sigma\lambda l^2 \sin\theta}{2\varepsilon_0}$

56. **B**

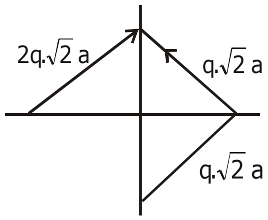
$$q.\frac{dv}{dr}.dr = P_1\frac{dv}{dr}$$

$$= \frac{-2p_1kp_2\cos\theta}{r^3}$$

57. **A**

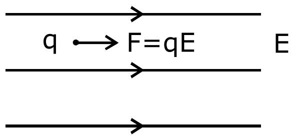


58. **A**

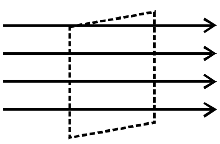


x - axis component will cancel out

59.



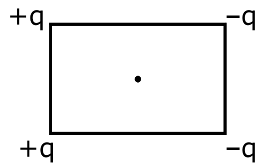
60.



In equipotential surface
v = Constant
but $\in \neq 0$

61. Potential is a scalar quantity Add Pirectly without direction Electric Field is a vector quantity

62.



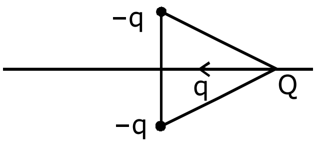
A + C
V = 0
$\in \neq 0$

EXERCISE – II

MULTIPLE CHOICE QUESTIONS

1. **C,D**
By properties of charges

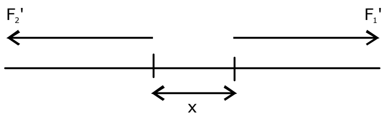
2. **B.D**



$F = \dfrac{-kq}{\left(a^2 + x^2\right)^{\frac{3}{2}}} x$

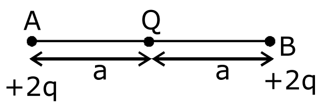
If x is Comparable to a then a above Eqn is not a equation of SHM
At origin P.F. is minimum and K.E +P.E = Const.
$\Rightarrow$ K.E is maximum at origin .

3. If we displaced q lightly then

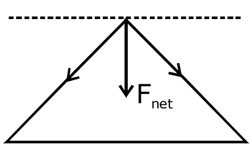


$\because F_2^{1} > f_1^{1}$
$\Rightarrow$ stable equilibrium

4. **C.D**
If we slightly displaced –Q charge towards B thus force on –Q due to B increses

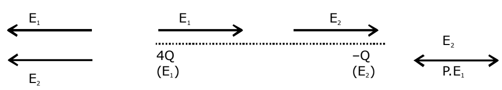


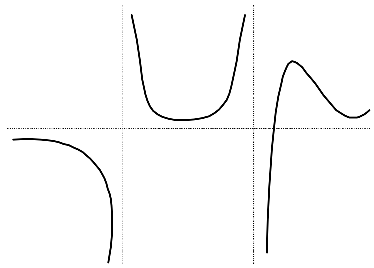
$\Rightarrow$ –Q moves towards BC (unstable equillibrium)
If we displaced to wards y axis



(stable equilibrium)

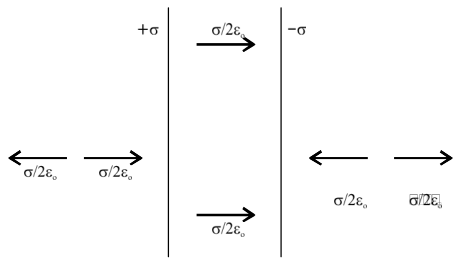
5.





6. **B**
– ve charge may move opposite to line of force

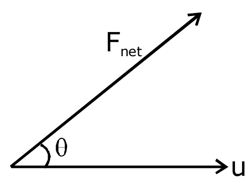
7. **A,C**



8. **A**
A) $V = \dfrac{KQ}{r} = 0$ b/w z $\theta = 0$
B) Depends on distribution of charge .
C) Depends on distribution of charge .
D) F_{net} is zero but τ_{net} may be non zero

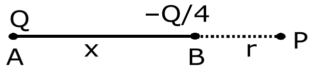
9. **ABD**
Dimension theory

10. **A,C**



In constant force field path may be straight line
Fnet $\rightarrow$
u $\rightarrow$ or Parabola

11. **ABC**



$$V_p = \frac{KQ}{x+r} - \frac{KQ/4}{r} = 0$$

$$\Rightarrow \frac{1}{x+r} - \frac{1}{4r} = 0$$

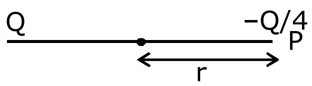
$\Rightarrow 4r - x - r = 0$

$$r = \frac{x}{3}$$

$$v_p = \frac{-KQ/4}{r} + \frac{KQ}{(x-r)} = 0$$

$$\Rightarrow -\frac{1}{4r} + \frac{1}{x-r} = 0$$

$$\Rightarrow r = \frac{x}{5}$$



$$Ep = \frac{KQ}{(x+r)^2} - \frac{K(Q/4)}{r^2} = 0$$

$r > 0$

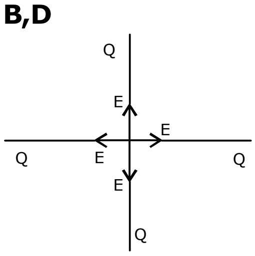
12. **A**

$$\vec{E} = \frac{kq\vec{r}}{|\vec{r}|^3}$$

$$v = \frac{kq}{r}\ \vec{r} = -3\hat{i} - 4\hat{j} + 0\hat{k}$$

$|\vec{r}| = 5$

13. **B,D**



$$v_c = \frac{4KQ}{r}$$

At Z axis horizontal component of E cancelled but vertical is added.

14. $qV = \frac{1}{2}mv^2 = K.E$

$$\Rightarrow V = \sqrt{\frac{2qv}{m}}$$

15. **A,D**

higher density $\Rightarrow$ Higher E

$E_A > E_B$

Electric field lines from higher potential to lower potential.

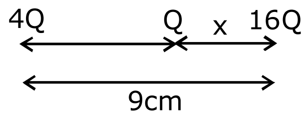
$V_B > V_A$

16. **B,C**

To reduce potential energy

$$F = -\frac{dU}{dx}$$

$F = 0$



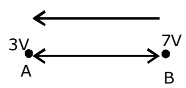
$$\frac{16Q^2K}{x^2} = \frac{4Q^2K}{(9-x)^2}$$

$2(9-x) = x$

$18-2x = x$

$x = 6$ cm

17. **A,C**



$F = eE \rightarrow$

k.E. = e (7−3)

= 4ev

18. **A**

$\rightarrow u$

$$\rightarrow a = \frac{qe}{m}$$

Max. acc = $\frac{1\times10^{-6}\times300}{10^{-3}}$

= 0.3 m/sec^2

$\frac{qe}{m}$

Max. deacc. = –0.3 m/sec^2

So V_{max} = 4+ 0.3×10

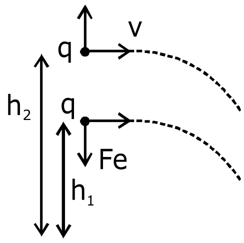
= 7 m/sec.

V_{min} = 4 – 0.3 ×10

= 1 m/sec.

$1\le V\le 7$

19. **D**

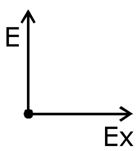


$a_{con.}$ = g

20. **C**

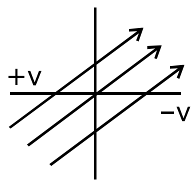
$E = -\frac{dv}{dx}$

21. **B**



in y, $E_y = 0$

$E_x = E_0 = \frac{v}{x_0}$



22. **D**

$Ex = \frac{-\partial v}{\partial x}$

check slope

23. **A,B,D**

$\vec{\tau} = \vec{P}\times\vec{E}$

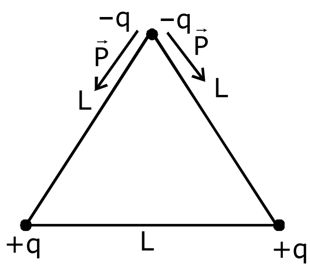
$= \left(2\hat{i}+3\hat{j}\right)\times\left(3\hat{i}+2\hat{k}\right)\times10^{-6}\times10^{5}$

$= (0.6\,\hat{i} - 0.4\,\hat{j} - 0.9\,\hat{k})$

P.E. = $-\vec{P}.\vec{E}$

Max P.E. = $|\vec{P}||\vec{E}|$

24. **A.D**



$P_{net}^2 = P^2 + P^2 + 2P^2 \cos 60$

$= \sqrt{3}\,gL$

25. mA V + mB V = mAV1

E.C $\frac{1}{2}m_A V_2 = \frac{1}{2}(m_A + m_B)V_2 + \frac{kq_1q_2}{r_{min}}$

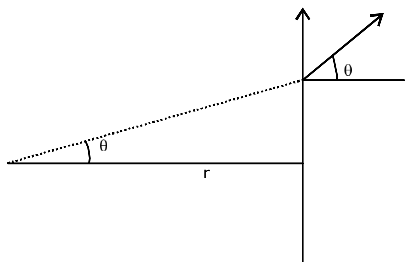
Momentum is concerved because

$F_{net} = 0$

26. F net = 2F sin θ

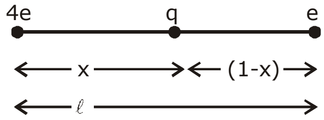
$= 2.\frac{kqQ}{(r^2+d^2)}\times\frac{d}{(r^2+d^2)^{1/2}}$

$= \frac{2\times kqQ}{r^3} = \frac{KPQ}{r^3}$



EXERCISE – III

SUBJECTIVE PROBLEMS

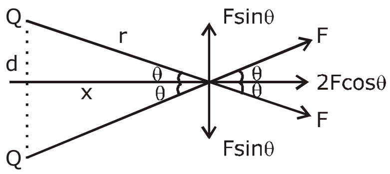
1. 

$\Rightarrow \frac{K4eq}{x^2} = \frac{Kqe}{(\ell - x)^2}$

$2(\ell - x) = x$

$x = \ell/3$

If we more charge q slightly along line joining 4e and e then equilibrium will be stable.

2. 

$F_{net} = 2F\cos\theta = 2x\frac{KQq}{r^2}\cos\theta$

$F_{net} = \frac{2KQq}{(d^2 + x^2)^{3/2}}x$

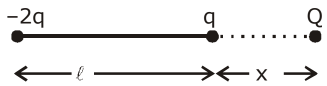
for Maximum

$F_{net}, \frac{dF_{net}}{dx} = 0$

$\Rightarrow x = \frac{d}{2\sqrt{2}}$

put x in eq ....(1)

Then $F_{net} = \frac{16Kq\theta}{3\sqrt{3}d^2}$

3. 

For equilibrium

$\frac{2KqQ}{(\ell + x)^2} = \frac{KqQ}{x^2}$

$\sqrt{2}x = \ell + x$

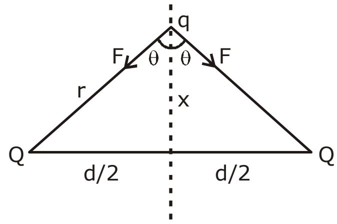
$x = \ell(\sqrt{2} + 1)$

& equilibrium will be stable.

4. $F_{net} = -2F\cos\theta$

$F_{net} = \frac{-2KQq}{r^2}\cos\theta$

$F_{net} = \frac{-2KQqx}{(x^2 + d^2/4)^{3/2}}$

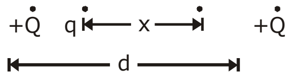


$x << d \quad \Rightarrow \quad F_{net} = \frac{-2KQq}{d^3/Q}x$

$T = 2\Pi\sqrt{\frac{md^2}{(8KQq)^2}}$

$T = \sqrt{\frac{M\Pi^2\varepsilon_0 d^3}{Qq}}$

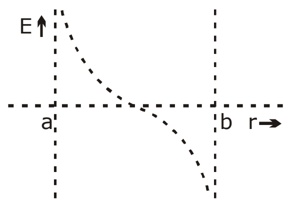
(b) $\frac{KQ^2}{\left(\frac{d}{x} - x\right)^2} \longleftrightarrow \frac{KQ^2}{\left(\frac{d}{x} + x\right)^2}$

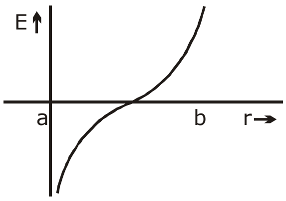


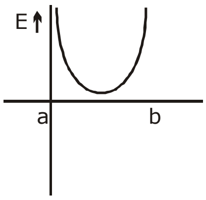
$F_{net} = \frac{KQ^2}{\left(\frac{d}{2} + x\right)^2} - \frac{KQ^2}{\left(\frac{d}{2} - x\right)^2}$

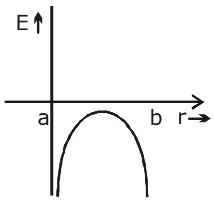
$= \frac{-32KQ^2}{d^3}x = \frac{-8Q^2}{\pi\varepsilon_0 d^3}x$

$T = 2\pi\sqrt{\frac{\pi m\varepsilon_0 d^3}{8Q^2}} = \sqrt{\frac{m\varepsilon_0\pi^3 d^3}{2Q^2}}$

5. (i) 

(ii)


(iii)


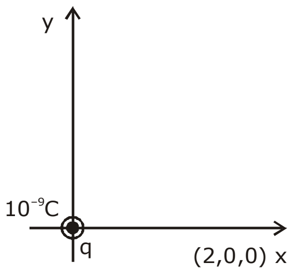
(iv)


6. $E = \frac{Kq\vec{r}}{r^3}$

Electric field at (3,1,1)

$$= \frac{K \times 10^{-9}(3i + j + k)}{(\sqrt{11})^3} + \frac{KQ(i + j + k)}{(\sqrt{3})^3}$$

Given i component is zero.



$$= \left(\frac{K \times 3 \times 10^{-9}}{(\sqrt{11})^3} + \frac{KQ}{(\sqrt{3})^3} \right) \; i = 0$$

$$Q = -\left(\frac{3}{11}\right)^{3/2} 3 \times 10^{-9} \text{c.b.}$$

J component is

$$= \frac{K \times 10^{-9}}{(\sqrt{11})^3} + \frac{KQ}{(\sqrt{3})^3}$$

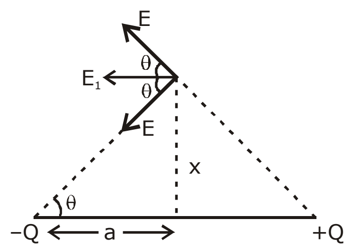
$$= \frac{K \times 10^{-9}}{(\sqrt{11})^3} - \frac{K(\sqrt{3})^3 \, 3 \times 10^{-9}}{(\sqrt{11})^3(\sqrt{3})^3}$$

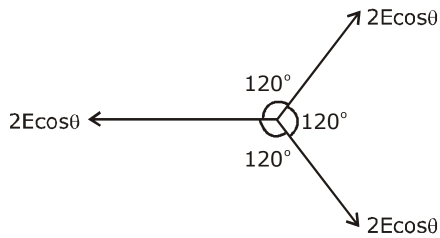
$$\vec{E}\hat{j} = \frac{-2K \times 10^{-9}}{(\sqrt{11})^3}$$

7. $E_1 = 2E\cos\theta$

$$E_1 = \frac{KQ}{\left(\sqrt{x^2 + a^2}\right)^2}$$

$$\cos\theta = \frac{a}{\sqrt{a^2 + x^2}}$$





$E_{net} = 0.$

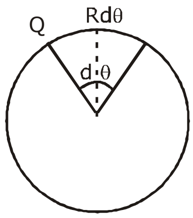
8. $\rightarrow \frac{\sigma}{2\varepsilon_0}$ $\rightarrow \frac{2\sigma}{2\varepsilon_0}$

A.   B.

$\leftarrow \quad \rightarrow$ $\rightarrow \frac{\sigma}{2\varepsilon_0}$

$\frac{2\sigma}{2\varepsilon_0} \quad \frac{\sigma}{2\varepsilon_0}$ $\rightarrow \frac{\sigma}{2\varepsilon_0}$

9. $\lambda = \frac{Q}{2\pi R}$



$$\Rightarrow \frac{K\lambda R d\theta q}{R^2} = 2T\sin d\theta/2$$

$$\Rightarrow T = \frac{qQ}{8\Pi^2\varepsilon_0 r^2}$$

10. Torque on the upper part

$$\int d\tau_1 = \int x(dqE) \qquad \otimes$$

$$\tau_1 = \int_0^{\ell/2} x\lambda dx \frac{\sigma}{2\varepsilon_0} \qquad \otimes$$

$$\tau_1 = \frac{\lambda\sigma}{2\varepsilon_0}\int^{\ell/2} x dx$$

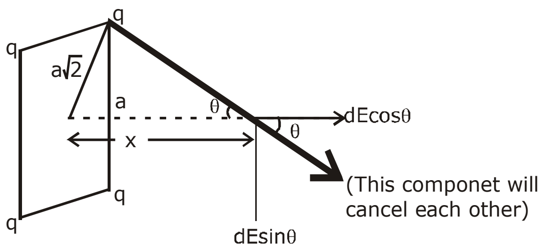
$$\tau_1 = \frac{\sigma\lambda\ell^2}{2\varepsilon_0\theta}$$

Net torque on Rod = Torque on upper part + Torque on lower part

$$= \frac{\sigma\lambda\ell^2 \otimes}{16\varepsilon_0} + \frac{\sigma\lambda\ell^2 \otimes}{16\varepsilon_0}$$

$$= \frac{\sigma\lambda\ell^2}{8\varepsilon_0}$$

$$\therefore \alpha = \frac{3\sigma\lambda}{2M\varepsilon_0}$$

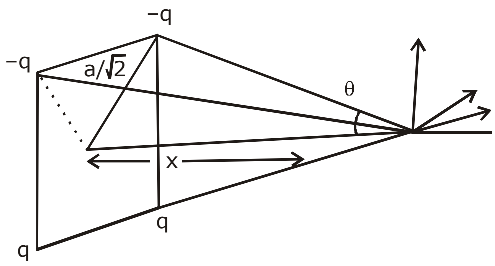
11. 

E_{net} = 4 [dEcosθ]

$$= 4\left[\frac{kq}{(a^2/2 + x^2)} \cdot \frac{x}{(x^2 + a^2/2)^{1/2}}\right]$$

$$E_{net} = \frac{4kqx}{(a^2/2 + x^2)^{3/2}} \quad \text{(Along the axis)}$$

Net E.F. due to four charge is 0.

(iii) 

$$E_y = \frac{4kq}{(a^2/2 + x^2)}\sin\theta\cos 45°$$

$$\Rightarrow E_y = \frac{4kqa}{(a^2/2 + x^2)^{3/2}}$$

12. (a) x = 0
(i) $E_x = 0$, Ey = 0
(ii) $E_x = 0$, Ey = 0
(iii) $E_x = 0$, $E_y = \frac{2kqa}{\left[x^2 + \left(\frac{a}{\sqrt{2}}\right)^2\right]^{3/2}}$

$$Ey = \frac{2kqa}{\frac{a^3}{2\sqrt{2}}} = \frac{4\sqrt{2}kq}{a^2}$$

(i) $Ex = \frac{4kqx}{\left[\left(\frac{a}{\sqrt{2}}\right)^2 + x^2\right]^{3/2}}$

$$Ex = \frac{4kqx}{x^3} = \frac{4kq}{x^2}$$

Ey = 0

(ii) Ex = 0, Ey = 0

(iii) Ex = 0, and $E_y = \frac{2kqa}{\left[x^2 + \left(\frac{a}{\sqrt{2}}\right)^2\right]^{3/2}}$

$\Rightarrow Ey = \dfrac{2kqa}{x^3}$

13. Potential at A $V_A = \dfrac{kq}{r}$

$$= \frac{9\times10^9 \times 8\times10^{-3}}{.03} = 24\times10^8 v$$

Potential at B

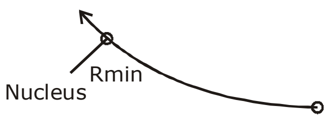
$$V_B = \frac{9\times10^9 \times 8\times10^{-3}}{.04} = 18\times10^8 v$$

W.D. = -2×10^{-9} ($18\times10^8 - 24\times10^8$)
W.D. = 1.2 J

14. From energy conservation

$K = \dfrac{kqQ}{R}$ ......(1)

$R = \dfrac{KqQ}{K}$ $R = \dfrac{Q}{4\Pi\varepsilon_0}\dfrac{q}{K}$



$K = \dfrac{1}{2}mv^2 + \dfrac{KQq}{2R}$

from eq. .....(1)

$\dfrac{KQq}{R} = K$

$\Rightarrow K = \dfrac{1}{2}mv^2 + \dfrac{K}{2}$

$v = \sqrt{\dfrac{K}{m}}$

15. $U = U_{12} + U_{13} + U_{23}$

$$U = \frac{kq(2q)}{a} - \frac{k(4q)q}{a} - \frac{K(4q)(2q)}{a}$$

$$= \frac{Kq^2}{a}[2-4-8]$$

$$\Rightarrow U = \frac{-10\times9\times10^9\times(10^{-7})^2}{0.10}$$

$U = -9\times10^{-3}$ J

16. Total Energy $= \dfrac{nU_1}{2}$

$$= \frac{8}{2}\left[\frac{3Kq^2}{a} + \frac{3Kq^2}{\sqrt{2}a} + \frac{Kq^2}{\sqrt{3}a}\right]$$

$$\Rightarrow \text{Total energy} = \frac{4kq^2}{a}\left[3 + \frac{3}{\sqrt{2}} + \frac{1}{\sqrt{3}}\right]$$

$(W.D.)_{el}$ = –(change in PE) = $-(U_f - U_i)$

$$(W.D.)_{el} = -\left[\frac{4kq^2}{1}\left(\frac{3}{2a} + \frac{3}{2\sqrt{2}a} + \frac{1}{2\sqrt{3}a}\right)\right]$$

$$= -\frac{4kq^2}{1}\left[\frac{3}{2a} + \frac{3}{\sqrt{2}a} + \frac{1}{\sqrt{3}a}\right]$$

$$(W.D.)_{ext} = \frac{-2kq^2}{a}\left[3 + \frac{3}{\sqrt{2}} + \frac{1}{\sqrt{3}}\right]$$

(iii) from previous question
change in potential energy = Increase in K.E.

$$\frac{2kq^2}{a}\left[3 + \frac{3}{\sqrt{2}} + \frac{1}{\sqrt{3}}\right] = \frac{1}{2}(8m)v^2$$

$$v = \sqrt{\frac{Kq^2}{2ma}(3 + \frac{3}{\sqrt{2}} + \frac{1}{\sqrt{3}}}$$

(iv) $\dfrac{1}{2}mv^2 = q(v_A - v_\infty)$

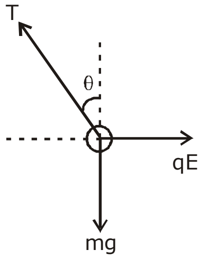
$$\frac{1}{2}mv^2 = q\left[\frac{4Kq}{a}\left(3 + \frac{3}{\sqrt{2}} + \frac{1}{\sqrt{3}}\right)\right]$$

$$v = \sqrt{\frac{2kq^2}{a}\left(3 + \frac{3}{\sqrt{2}} + \frac{1}{\sqrt{3}}\right)}$$

17. at mean position –
T cosθ = mg
T sinθ = qE

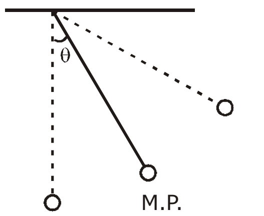
$\tan\theta = \dfrac{qE}{mg}$

$\theta = \tan^{-1}\left[\dfrac{q\sigma}{2\varepsilon_0 mg}\right]$

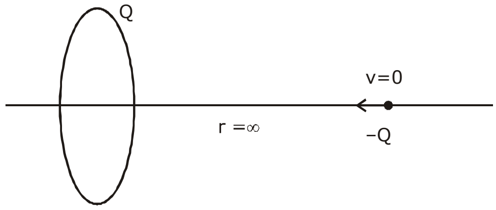


Maximum angle deflected = 2θ

$$= 2\tan^{-1}\left[\frac{q\sigma}{2\varepsilon_0 mg}\right]$$



18.

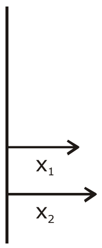


$\Rightarrow$ From E.C. $\frac{1}{2}mv^2 = qv_c$

$$\frac{1}{2}mv^2 = Q\left(\frac{KQ}{R}\right)$$

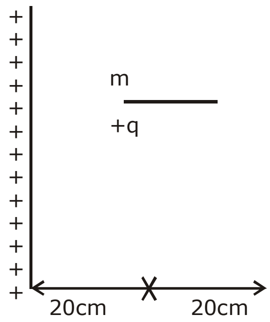
$$\Rightarrow v = \sqrt{\frac{2KQ^2}{Rm}}$$

19.



$$\int_{x_1}^{x_2} E.dr = \frac{1}{2}mv^2$$

Second Method



From qE = 100N

$$q\left[\frac{2K\lambda}{0.20}\right] = 100\text{N}$$

$K q\lambda = 10$

Now $F = \frac{2K\lambda q}{r} \Rightarrow a = \frac{2K\lambda q}{rm}$

$$v\frac{dv}{dr} = \frac{2\times 10}{(0.1)r}$$

$$\int_0^v v\,dv = 200\int_{0.20}^{0.40}\frac{1}{r}dr$$

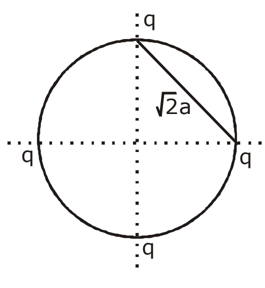
$$\Rightarrow v = 20\sqrt{\ell_n 2}$$

20. Ist Case

$U_0 = U_{12} + U_{23} + U_{13} + U_{14} + U_{24} + U_{34}$

$$U_0 = \frac{Kq^2}{a} + \frac{Kq^2}{a} + \frac{Kq^2}{\sqrt{2}a} + \frac{Kq^2}{a} + \frac{Kq^2}{\sqrt{2}a} + \frac{Kq^2}{a}$$

$$U_0 = \frac{UKq^2}{a} + \frac{2Kq^2}{\sqrt{2}a}$$



IInd Case

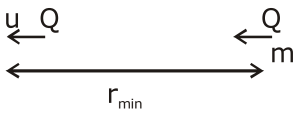
$$U = \frac{4Kq^2}{\sqrt{2}a} + \frac{2Kq^2}{2a}$$

W.D. = $-(\Delta U)$

$$= \left[2\sqrt{2}\frac{Kq^2}{a} + \frac{Kq^2}{a} - \frac{4Kq^2}{a} - \sqrt{2}\frac{Kq^2}{a}\right]$$

$$= \frac{-Kq^2}{a}\left[3 - \sqrt{2}\right]$$

21.



from M.C. $2mu = mv$

$$u = \frac{v}{2}$$

from E.C. $= \frac{1}{2}mv^2 = 2\left(\frac{1}{2}mv^2\right) + \frac{KQ^2}{r_{min}}$

$$= \frac{1}{2}mv^2 = \frac{mv^2}{4} + \frac{KQ^2}{r_{min}}$$

$$r_{min} = \frac{Q^2}{m\pi\varepsilon_0 v^2}$$

22. Range $= \frac{U^2 \sin 2\theta}{a}$

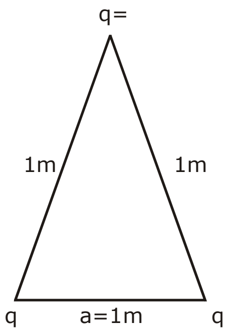
$$a = \frac{q\sigma}{2\varepsilon_0}/m$$

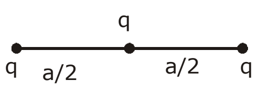
$$\Rightarrow \text{Range} = \frac{U^2 \sin 2\theta}{2\sigma}(2\varepsilon_0 m)$$

For R_{max} $\theta = 45°$

$$\Rightarrow R = \frac{2U^2\varepsilon_0 m}{q\sigma}$$

23.





$$U_1 = \frac{Kq^2}{a} + \frac{Kq^2}{a} + \frac{Kq^2}{a}$$

$$U_1 = \frac{3Kq^2}{a}$$

$$U_2 = \frac{Kq^2}{a/2} + \frac{Kq^2}{a} + \frac{kq^2}{a/2}$$

$$U_2 = \frac{5Kq^2}{a}$$

Change in P.E. $= \frac{2Kq^2}{a}$

$$= \frac{2 \times 9 \times 10^9 \times (0.1)^2}{1}$$

$= 18 \times 10^7$

1000 J Energy is supplied in 1 sec.

$\therefore 18 \times 10^7 \longrightarrow \frac{18 \times 10^7}{1000}$

$= 1.8 \times 10^5$ sec.

24. Total K.E. $= -\Delta U = -(U_f - U_i)$

K.E. $= U_i$

$$\Rightarrow \text{K.E.} = \frac{KQ^2}{a}$$

K.E. of each sphere $= \frac{1}{2}\left(\frac{KQ^2}{a}\right)$

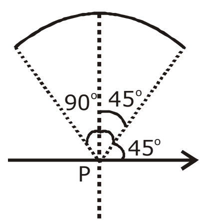
25. $dv = -\vec{E}d\vec{r}$

$$\int_0^v dv = -\int \left(2x^2\hat{i} - 3y\hat{j}\right).\left(dx\,\hat{i} + dy\hat{j}\right)$$

$$v = -\left[\int_0^x 2x^2dx - \int_0^y 3y^2dy\right]$$

$$v = -\frac{2x^3}{3} + y^3 + c$$

26.



Potential at point B due to dipole

$$v_B = \frac{KP\cos 45°}{r^2} = \frac{K}{\sqrt{2}}\frac{P}{r^2}$$

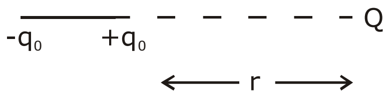
At A

$$v_A = \frac{KP\cos 135^\circ}{r^2} = \frac{-KP}{\sqrt{2}r^2}$$

Total W.D. = $q\,(v_B - v_A)$

$$= \frac{\sqrt{2}KPq}{r^2}\ \text{Joule}$$

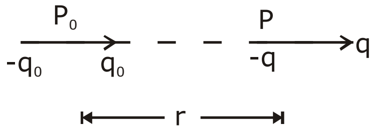
27. $$E = \frac{KQ}{r^2}$$



Force on P_0 due to Q is –ve x direction and

$$F = \left|P\frac{dE}{dr}\right| = \frac{2KP_0Q}{r^3}$$

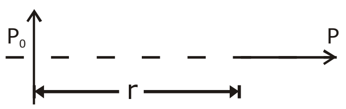
$$\vec{F} = \frac{-2KP_0Q}{r^3}\,\hat{i}$$



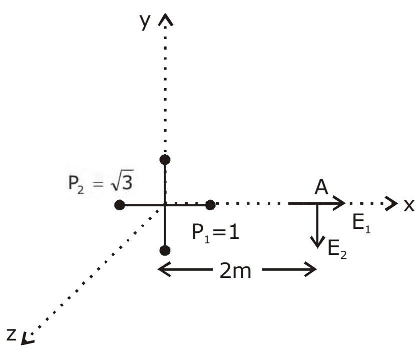
$$\rightarrow E = \frac{2KP}{r^3}\ (\text{due to P})$$

$$F = \left|P_0\frac{dE}{dr}\right| = P_0\frac{6KP}{r^4} = \frac{6KPP_0}{r^4}$$

$$\vec{F} = \frac{6KPP_0}{r^4}(\hat{i})$$



$$\vec{F} = \left[\frac{-KP_0q}{(r-a)^3} + \frac{KP_0q}{(r+a)^3}\right]\left(-\hat{j}\right) = \frac{3KP_0q}{r^4}\,\hat{j}$$

28. 

$$E_1 = \frac{2KP}{r^3} = \frac{2\times1\times K}{8} = \frac{K}{4}$$

$$E_2 = \frac{KP}{r^3} = \frac{\sqrt{3}K}{8}$$

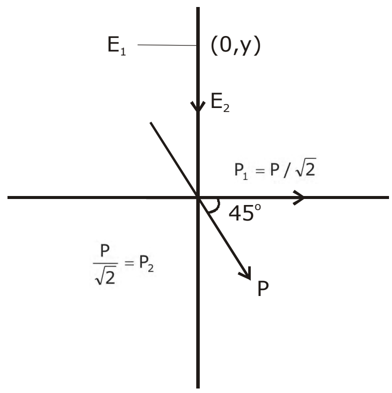
$$E_{net} = \frac{\sqrt{7}k}{8}$$

Potential at $v_A = \frac{KP_1}{r^2} = \frac{K}{4}$

29. $$E_1 = \frac{KP}{\sqrt{2}y^3}$$

$$E_2 = \frac{2KP}{y^3\sqrt{2}}$$

$$\vec{E} = \frac{KP}{\sqrt{2}y^3}\left(-\hat{i} - 2\hat{j}\right)$$



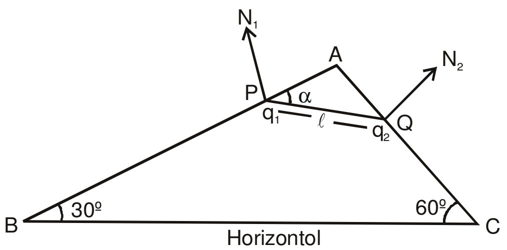
EXERCISE – IV TOUGH SUBJECTIVE PROBLEMS

1 $N_1 \cos 30^\circ + N_2 \cos 60^\circ = 2Mg$

and $N_1 \cos 60^\circ = N_2 \cos 30^\circ$

$\Rightarrow \quad N_1 = \dfrac{2Mg\cos 30^\circ}{(\cos^2 30^\circ + \cos^2 60^\circ)} = \sqrt{3}\,Mg$

$\left[\because \text{ on solving } \cos^2 30^\circ + \cos^2 60^\circ = 1\right]$



$\left(T - \dfrac{kq_1q_2}{\ell^2}\right)\cos\alpha = Mg\sin 30^\circ$

and $\left(T - \dfrac{kq_1q_2}{\ell^2}\right)\sin\alpha + Mg\cos 30^\circ = N_1$

$\Rightarrow \quad \tan\alpha = \sqrt{3} \Rightarrow \alpha = 60^\circ$

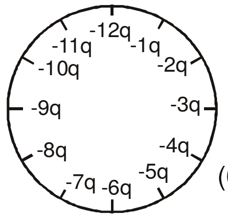
$\Rightarrow \quad T = \dfrac{kq_1q_2}{\ell^2} + Mg$

For Beads remain in equilibrium

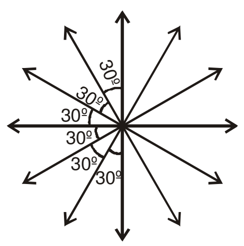
$N_1 = \sqrt{3}\,Mg$ and $N_2 = Mg$

and for, T = 0 $\Rightarrow \quad q_1q_2 = \dfrac{-mg\,\ell^2}{k}$

2



$(6kq/r^2)$ $\Rightarrow$



$\Rightarrow \quad \vec{E} \longleftarrow$

Bysymmetry

$\vec{E} = \left[\dfrac{6kq}{r^2} + 2\left(\dfrac{6kq}{r^2}\right)\cos 30^\circ + 2\left(\dfrac{6kq}{r^2}\right)\cos 60^\circ + 2\left(\dfrac{6kq}{r^2}\right)\cos 90^\circ\right](-\hat{i})$

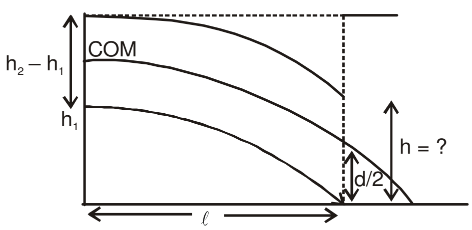
$\vec{E} = \dfrac{6kq}{r^2} + (1 + \sqrt{3} + 1)\,(-\hat{i})$

3 $\dfrac{1}{2}mv^2 = \dfrac{KQq}{R} - \dfrac{KQq}{\sqrt{R^2 + (\sqrt{3}R)^2}}$

$V^2 = \left(\dfrac{1}{4\pi\varepsilon_0}\right) \times \dfrac{Qq(2\pi R\lambda)}{mR} \Rightarrow V = \left(\dfrac{Qq\lambda}{2\varepsilon_0 m}\right)^{1/2}$

4 $\Rightarrow \quad v \times t = \ell \quad \Rightarrow t = \dfrac{\ell}{v}$

$\Rightarrow \quad h = 2\left[\dfrac{h_1 + h_2}{2} - \dfrac{1}{2}g\left(\dfrac{\ell}{v}\right)^2\right]$ from C.M.

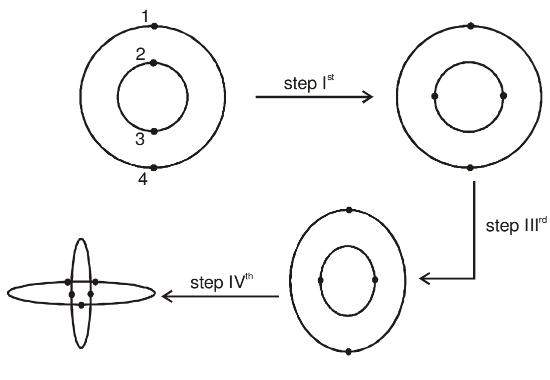


$\Rightarrow \quad h = h_1 + h_2 - \dfrac{g\ell^2}{v^2}$

5 Distance between charges 1 & 4 & 2 & 3 don't change

$w_{1^{st}} = \Delta U = 2\left(\dfrac{kq^2}{r} + \dfrac{kq^2}{(3r)}\right) - \dfrac{4kq^2}{\sqrt{5}\,r} = \dfrac{kq^2}{r}\left(\dfrac{8}{3} - \dfrac{4}{\sqrt{5}}\right)$

$W_{II^{nd}} = u_2 - u_3 = \dfrac{4}{\sqrt{5}}\dfrac{kq^2}{r} - \dfrac{4}{\sqrt{5}}\dfrac{kq^2}{r} = 0$



$W_{final} = u_i - u_f$

$= 2\left(\frac{kq^2}{r} + \frac{kq^2}{3r}\right) - 2\left(\frac{kq^2}{r} + \frac{kq^2}{3r}\right) = 0$

6 $(\Delta P_x)_1 = q_1 E_x t = \frac{3}{4} mv$

$(\Delta P_x)_2 = q_2 E_x t = mv$

$\Rightarrow \frac{q_1}{q_2} = \frac{3}{4}$

$(\Delta p_y)_1 = \frac{\sqrt{3}}{4} mv$ and $(\Delta p_y)_2 = mv'$

$\Rightarrow \frac{\frac{\sqrt{3}}{4} mv}{mv'} = \frac{q_1}{q_2} \Rightarrow v' = \frac{v}{\sqrt{3}}$

$\begin{bmatrix} (\Delta p_y)_1 = q_1 E_y t \\ (\Delta p_x)_2 = q_2 E_y t \end{bmatrix}$

7 $k = k_2 - k_1$

$= p_1 - p_2$

$= \frac{1}{4\pi\varepsilon_0} \frac{q^2}{a}$ {Interaction energy between Ist and IInd charge}

$= q = [k(4\pi\varepsilon_0)a]^{1/2}$

8 $\vec{E} = \frac{E_0 x}{\ell} \hat{i}$

Incoming flux = $\frac{E_0}{\ell}(0) \times a^2 = 0$

Outgoing flux = $\frac{E_0}{\ell}(a) \times a^2$

$\Rightarrow \frac{q}{\varepsilon_0} = \frac{E_0}{\ell} \times a^3$

$\Rightarrow q = \frac{\varepsilon_0 \times E_0 \times a^3}{\ell}$

$= \frac{8.85 \times 10^{-12} \times 5 \times 10^3}{2 \times 10^{-2}} [10^{-2}]^3 \Rightarrow$

$q = 2.2 \times 10^{-12}$ C

9 $U = \frac{k}{R} \int q\,dq$

$U = \frac{kq^2}{2R_1} + \frac{k(Q-q)^2}{2R_2} + \frac{kq(Q-q)}{d}$

$= \frac{kq^2}{2R_1} + \frac{k(Q-q)^2}{2R_2} + \frac{kq(Q-q)}{d}$

$\because$ $d >> R_1$

$d >> R_2$

Where Q = total charge

For $U_{min} = \frac{dU}{dq} = 0$

$0 = \frac{2q}{R_1} + \frac{2(Q-q)(-1)}{R_2} + K[(Q-q) - q]$

Say $q = q_1$ and $Q - q_1 = q_2$

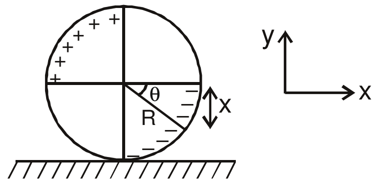
$0 = \frac{2q_1}{R_1} - \frac{2q_2}{R_2} + \frac{q_2 - q_1}{d}$ $\because$

d is very large

$\Rightarrow \frac{q_1}{R_1} = \frac{q_2}{R_2} \Rightarrow \frac{q_1}{q_2} = \frac{R_1}{R_2}$

10 $x = R \sin\theta$

and $dF = dq\,E$



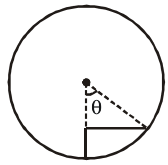
$= E(R\,d\theta) \times \lambda$

$d\tau = dF x$

$d\tau = E_0 \times R^2 \lambda \sin\theta\, d\theta$

$\tau = 2E_0 R^2 \lambda \int_0^{\pi/2} \sin\theta\, d\theta$

$= [-\cos\theta]_0^{\pi/2} \times 2E_0 R^2 \lambda = 2E_0 R^2 \lambda$



$\Rightarrow I_{CM}\,\alpha = 2E_0 R^2 \lambda - fR$

$\alpha = \frac{2E_0 R^2 \lambda - fR}{I_{CM}}$ ...(1)

Where $x = R(1 - \cos\theta)$

$df = E_0 \lambda R\, d\theta$

$d\tau = df\ x$

$$\tau = \left|\int_{\pi}^{3\pi/2} E\lambda R^2(1-\cos\theta)d\theta\right| - \left|\int_{0}^{\pi/2} E\lambda R^2(1-\cos\theta)d\theta\right|$$

$$= E_0 \lambda R^2\left[\left|\frac{3\pi}{2} - \pi - \sin\frac{3\pi}{2} - \sin\pi\right| - \left|\frac{\pi}{2} - 0 - \sin\frac{\pi}{2} - 0\right|\right]$$

$$= E_0 \lambda R^2\left\{\left[\frac{\pi}{2}+1\right] - \left[\frac{\pi}{2}-1\right]\right\} = 2E_0 \lambda R^2$$

$$I_p\,\alpha = 2E_0 \lambda R^2$$

$$\alpha = \frac{2E_0 \lambda R^2}{I_p} \quad ....(2)$$

By (1) & (2)

$$\frac{2E_0 R^2 \lambda - fR}{(I_{cm} = MR^2)} = \frac{2E_0 R^2 \lambda}{2MR^2}$$

$$fR = E_0 R^2 \lambda$$

$$f = E_0 R \lambda\,\hat{i}$$

11 $\tan\theta = \dfrac{fe}{mg}$ ....(1)

Now $\tan\theta = \dfrac{f_e/\varepsilon_r}{m^1 g}$ ....(2)

By (1) & (2)

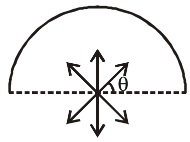
$$m'\varepsilon_r = m$$

$$v(\rho_S - \rho_0)\varepsilon_r = \rho_s v \Rightarrow \rho_S = \frac{\rho_0 \varepsilon_r}{-1+\varepsilon_r}$$

12 $dE = 2dE\cos\theta(-\hat{i})$

$$E = \left|\frac{k}{R^2}\int_0^{\pi/2}\cos\theta\lambda R\, d\theta\right| = \left|\frac{k\lambda}{R}\int_0^{\pi/2}\cos\theta\, d\theta\right|$$

$$= \frac{k\lambda}{R}\left[\sin\theta\right]_0^{\pi/2} = \frac{k\lambda}{R}$$



$$\vec{E} = \frac{-k\lambda}{R}\hat{i} \quad \& \quad \lambda = \frac{q}{\frac{\pi}{4}R}$$

$$\vec{E} = -\frac{4kq}{\pi R^2}\hat{i}$$

EXERCISE – V

JEE QUESTIONS

ELECTROSTATICS - I

1. **D**

Electric lines enters and exit perpendicular to the surface.

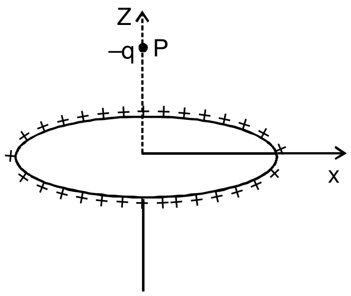
2. **A**

$$\int_{\ell=\infty}^{\ell=0} -E.d\ell = v_0 - v_\infty = \frac{KQ}{R} \Rightarrow$$

$$= \frac{9\times10^9 \times 1.11\times10^{-10}}{0.5} \approx +2$$

3. **(i) A,C**

$$E = \frac{KQZ}{(R^2+Z^2)^{3/2}} \Rightarrow F = \frac{-KqQZ}{(R^2+Z^2)^{3/2}}$$

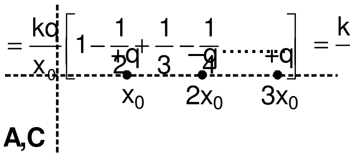


$$F = \frac{-KqQZ}{R^3}\{z << R\}$$

(ii) **D**

$$= \frac{kq}{x_0} - \frac{kq}{2x_0} + \frac{kq}{3x_0} ....$$

$$= \frac{kq}{x_0}\left[1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} ....\right] = \frac{kq\ell n2}{x_0}$$



(iii) **A,C**

$E \propto r \{ 0 < r < R \Rightarrow E \propto \frac{1}{r^2} \; \{R < r < \infty$

4. **E**

[IIT-2000(Scr)]

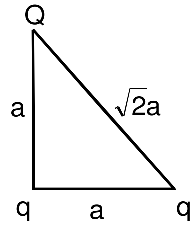
$$U = \frac{1}{2}\varepsilon_0 E^2 = \frac{c^2}{Nm^2} \times \frac{N^2}{C^2} = \frac{N}{m^2} \Rightarrow \text{Dimensionally}$$

$$U = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$$

(b) **B**

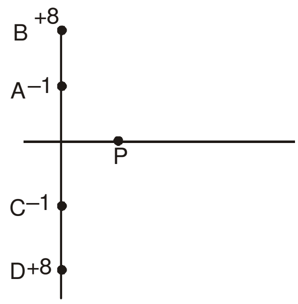
$$\frac{Kq^2}{a} + \frac{KqQ}{a} + \frac{KqQ}{\sqrt{2}a} = 0 \Rightarrow q + Q + \frac{Q}{\sqrt{2}} = 0 \Rightarrow$$

$$Q\left[\frac{\sqrt{2}+1}{\sqrt{2}}\right] = -q \Rightarrow Q = \frac{-q\sqrt{2}}{(\sqrt{2}+1)}$$



(c) Check where force is zero

$$AP = CP = \sqrt{\frac{3}{2} + x^2} \Rightarrow BP = DP = \sqrt{\frac{27}{2} + x^2}$$



$$\therefore \text{ Potential } \quad V_p = \frac{2k\times8}{\sqrt{\frac{27}{2}+x^2}} - \frac{2k\times1}{\sqrt{\frac{3}{2}+x^2}}$$

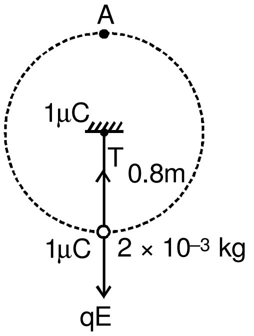
5. (C)

El. field lines never form a closed loop

6. $T + mg - qE = \frac{mv^2}{R}$

at A $\quad T = 0$

$mv^2 = (mg - qE)\,R \qquad ...(1)$



E.C.

$(W.D.)_T + (W.D.)_E = k_f + U_f - k_i - U_i$

$(W.D)_T = 0$

$(W.D)_E = 0$

$0 = \frac{1}{2}mv^2 + 2mg - \frac{1}{2}mv^2$

using (1)

$\frac{1}{2}(mgR - qER) + 2mgR = \frac{1}{2}mv^2$

$\Rightarrow 5\times10\times0.8 - \frac{(10^{-6})^2\times9\times10^9}{0.8\times2\times10^{-3}} = u^2$

$\Rightarrow$ u = 5.86 m/s.

7. Perform S.H.M.

$\therefore$ $F \propto x$

$\therefore$ $U \propto x^2$

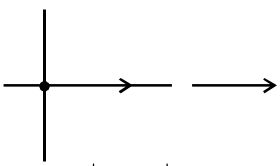
8. Four charges (+ve) are same & four charges (–ve) are same

$\therefore = \frac{[u_1 + u_2 + ...+ u_8]}{8} = \frac{4(u_+ + u_-)}{2}$

$= 2\left[-3\frac{kq^2}{a} + \frac{3kq^2}{\sqrt{2}a} - \frac{kq^2}{\sqrt{3}a} - \frac{3kq^2}{a} + \frac{3kq^2}{\sqrt{2}a} - \frac{kq^2}{\sqrt{3}a}\right]$

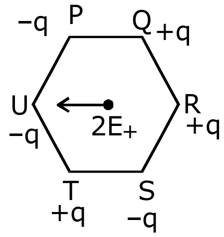
9. From E.C.

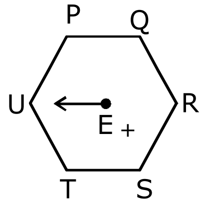
$\frac{KPQ}{r^2} = \frac{1}{2}mv^2 = K.E.$



force $= \left|P\frac{dE}{dr}\right|$

10.





11. $\sigma_1 > \sigma_2$

e.f. in between the sheet

$= \frac{\sigma_1}{2\varepsilon_0} - \frac{\sigma_2}{2\varepsilon_0}$

$\varepsilon = \frac{(\sigma_1 - \sigma_2)}{2\varepsilon_0} \Rightarrow$ W.D. = $(Q\varepsilon)\,\frac{a}{\sqrt{2}} = \frac{Q(\sigma_1 - \sigma_2)a}{2\sqrt{2}\varepsilon_0}$

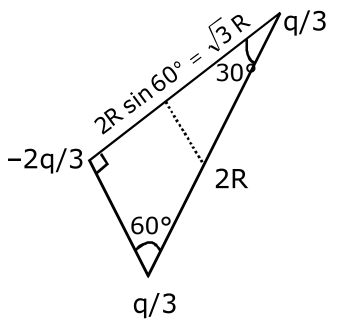
12. $\phi = \vec{E}.\vec{A}$, ϕ & $\vec{E}$ can not have same dimension.

13. Both points are on perpendicular bisector.

$\Delta v = 0 \Rightarrow w = 0$

14. E.f. $= \frac{k(2q/3)}{R^2} = \frac{2kq}{3R^2}(-\hat{i})$

$\Rightarrow U = \frac{kq^2}{q(2R)} - \frac{k2q^2}{2\sqrt{3}R} - \frac{2kq^2}{qR} \neq 0$



$\Rightarrow F_{CB} = \frac{kq_1q_2}{r^2} = \frac{k(q/3)(-2q/3)}{3R^2}$

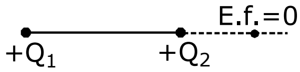
$\Rightarrow F = \frac{2kq^2}{27R^2} = \frac{q^2}{54\pi\varepsilon_0R^2}$

15. $\therefore$ Lines emerging from $Q_1 \Rightarrow$ +ve

Lines terminate at $Q_2 \Rightarrow$ – ve

no. of lines originate or terminate depends on magnitude of charge

$\Rightarrow \left|\frac{Q_1}{Q_2}\right| = \frac{13}{9} \Rightarrow |Q_1| > |Q_2|$

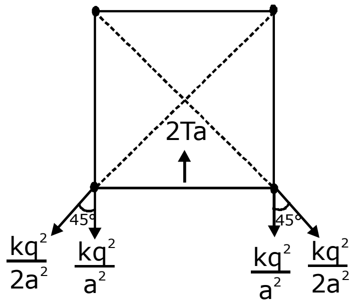
Now situation is 

16. A

17. $m = 4/3\, \mu r^3 \rho$

$q\varepsilon = mg \Rightarrow 6\pi\eta rv = mg$

18. $2Ta = \dfrac{2kq^2}{a^2} + 2\left(\dfrac{kq^2}{2a^2}\cos 45^\circ\right)$



$$Ta = \frac{kq^2}{a^2}\left(1 + \frac{1}{2\sqrt{2}}\right)$$

$$\Rightarrow a = \left(\frac{q^2}{T}\right)^{1/3}\left[\left(1 + \frac{1}{2\sqrt{2}}\right)k\right]^{\frac{1}{3}}$$

So N = 3

19. $EQ = kx_0$

Mean Position shift but frequency remains the same.