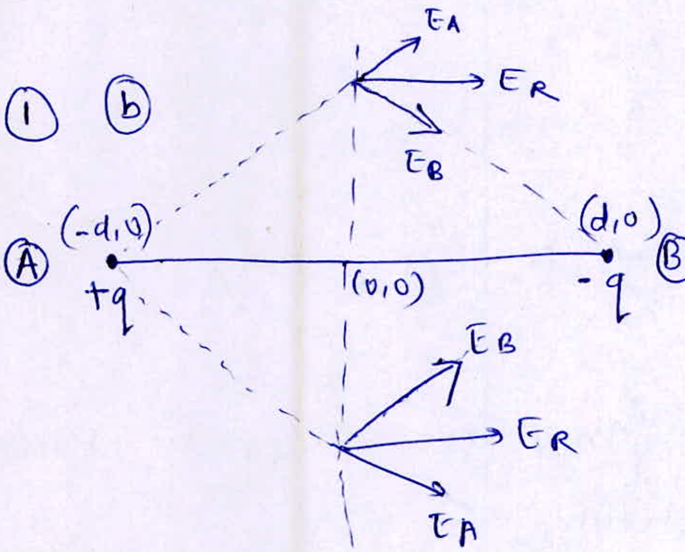
Electric Charge And Field

Level - 1

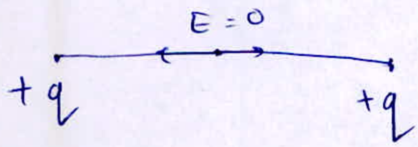
① ⓑ



The resultant electric field (E_R) on all the points on Y axis is along X axis.

② ⓓ

If both the charges are alike, then E will be zero at the midpoint



~~If charges are opposite, E will be zero at two points on the axis.~~

~~E/P at points P and Q~~

3. ⓐ

$Q_1 \quad d \quad Q_2 \quad d \quad Q_3$

$\qquad\qquad q \qquad -q$

Force on $Q_3 = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1(-q)}{(2d)^2} + \frac{q(-q)}{d^2}\right] = 0$

$\therefore \frac{Q_1}{4d^2} = \frac{q}{d^2}$

$\therefore \boxed{Q_1 = 4q}$

4] (b)

E at end-on position is given by,

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

$$F = qE \Rightarrow F = \frac{qp}{4\pi\varepsilon_0 r^3}$$

$\therefore F \propto \frac{1}{r^3}$, so if r is doubled F will be $F/8$

5] (c)

(2,4) show attraction. This means they are of oppsite charges (1,2) and (4,1) also show attraction.

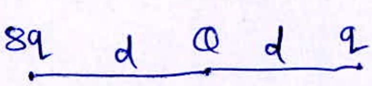
1 shows attraction with both 2 and 4 which are oppositely charged.

$\therefore$ 1 should be neutral.

6] (c)

Force between any two charges is independent of any external charges

7] (b)



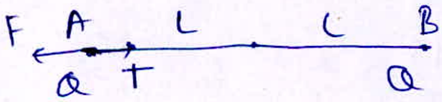
$$\frac{1}{4\pi\varepsilon_0}\left[\frac{8q \times q}{(2d)^2} + \frac{Qd}{d^2}\right] = 0$$

$$\therefore \boxed{Q = -2q}$$

8] (c)

As the electric force does not need to balance gravitationa force

9] (d)



For charge A,

$$T = \text{Electric force} = \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{(2L)^2}$$

10] (d)

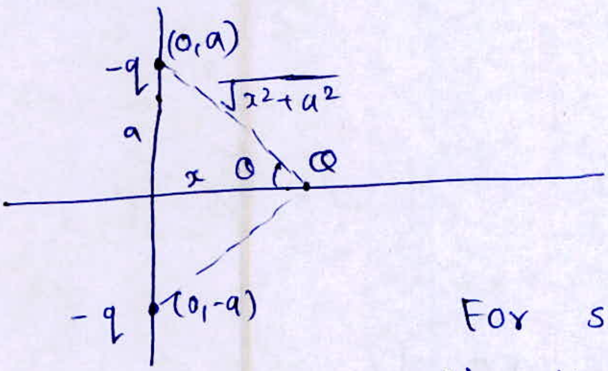
$W = F \cdot dx = qE \cdot dx = 0.2 \times E \times 2\cos 60^\circ$

$\therefore \quad 4 = 0.2E$

$\therefore \quad \boxed{E = 20 \text{ N/C}}$

11) (d)

12) (d)



Net force on Q

$$F_{net} = 2 \times \frac{1}{4\pi\varepsilon_0} \frac{(-q) \times Q}{(\sqrt{x^2+a^2})^2} \cos\theta$$

$$F_{net} = -\frac{1}{2\pi\varepsilon_0} \frac{Qq \cdot x}{(x^2+a^2)^{3/2}}$$

For simple harmonic motion, F is directly proportion to x.

i.e $F = -kx$

This is not the case here. So the motion won't be simple harmonic

13] (c)

14] (c)

Area vector $= 100\hat{k}$

$\vec{E} = \hat{i} + \sqrt{2}\hat{j} + \sqrt{3}\hat{k}$

Flux $= \vec{E} \cdot \vec{ds}$

$= (\hat{i} + \sqrt{2}\hat{j} + \sqrt{3}\hat{k}) \cdot (100\hat{k})$

$= 100\sqrt{3}$

$\boxed{\therefore \text{Flux} = 173.2 \text{ V-m}}$

15] (c)

Work done $= -\Delta U$

$$= -\left[\left(\frac{1}{4\pi\varepsilon_0}\frac{2q^2}{q} + \frac{1}{4\pi\varepsilon_0}\frac{(-2q^2)}{a^2}\right) - 0\right]$$

U_{final} at infinity

$$= 0$$

16] (a)

17] (a)

18] (d)

Here, $\theta = 90°$, $\therefore E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$

$F = qE \quad \therefore F \propto \frac{1}{r^3}$

So if r is doubled, F will become $F/8$.

19] (a)

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$\text{Current} = \frac{\text{charge}}{\text{time}} = q/t$$

$\therefore \quad q =$ current $\times$ time

$$\therefore \quad MLT^{-2} = \frac{q_1 q_2}{[\varepsilon_0][L^2]}$$

$[q] = [AT]$

$$\therefore [\varepsilon_0] = \frac{A^2T^2}{(MLT^{-2})[L^2]}$$

$$\therefore [\varepsilon_0] = M^{-1}L^{-3}T^4A^2$$

20] (d)

23] (b) $F_{medium} = \dfrac{F_{vacuum/air}}{K}$ $(K = \text{relative permitivity})$

$$\therefore \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{(50)^2} = \frac{1}{4\pi\varepsilon_{med}}\frac{q_1q_2}{(d)^2}$$

$$\therefore d^2 = \frac{(50)^2}{\varepsilon_{med}/\varepsilon_0}$$

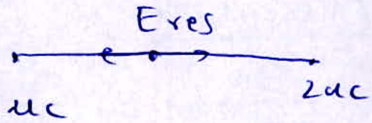
$$\therefore d^2 = \frac{(50)^2}{5} \quad \left(\because \frac{\varepsilon_{med}}{\varepsilon_0} = K = 5\right)$$

$$\therefore \boxed{d = \frac{50}{\sqrt{5}} = 22.3 \text{ cm}}$$

24] (c)

25) (b)

$$E_{res} = E_1 + E_2$$



$$= k\left[\frac{10^{-6}}{(1/2)^2} - \frac{2\times10^{-6}}{(1/2)^2}\right]$$

$$= 9\times10^9\left[10^{-6}(4-8)\right]$$

$$= 9 \times -4 \times 10^3$$

$$\boxed{E_{res} = -3.6\times10^4}$$

$$\therefore \boxed{|E_{res}| = 3.6\times10^4}$$

26) (d)

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

$$\therefore \frac{9e}{x^2} = \frac{16e}{(70-x)^2} \Rightarrow \frac{(70-x)^2}{x^2} = \frac{16}{9}$$

$$\therefore \frac{70-x}{x} = \frac{4}{3} \Rightarrow 210 - 3x = 4x$$

$$7x = 210$$

$$\boxed{x = 30}$$

27] (a)

$$\text{Flux} = \frac{Q_{in}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$$

28] (b)

$$\phi = \frac{20\mu c}{\varepsilon_0} \quad ; \quad \phi' = \frac{100\mu c}{\varepsilon_0}$$

$$\therefore \boxed{\phi' = 5\phi}$$

30] (a)

$$F_1 = \frac{K(7)(-5)}{r^2}$$

After adding $-2\mu c$ charge on both balls,

$$F_2 = \frac{K(5)(-7)}{r^2}$$

$$\therefore \boxed{F_1 = F_2}$$

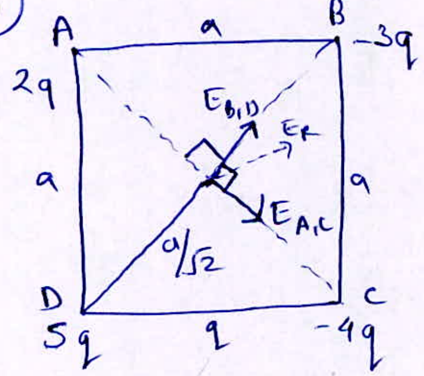
31] (a)

Electric field in a metal is zero.

$$E = \frac{1}{4\pi\varepsilon_{med}} \frac{Q}{r^2}$$

$$E = 0 \Rightarrow \boxed{\varepsilon_{med} = \infty}$$

32] (b)



$$E_{res\,(A,C)} = K\left[\frac{2q}{(a/\sqrt{2})^2} + \frac{4q}{(a/\sqrt{2})^2}\right] = \frac{12Kq}{a^2}$$

$$E_{res\,(B,D)} = K\left[\frac{3q}{(a/\sqrt{2})^2} + \frac{5q}{(a/\sqrt{2})^2}\right] = \frac{16Kq}{a^2}$$

$$\therefore E_R = \frac{kq}{a^2}\sqrt{(12)^2+(16)^2}$$

$$\therefore \boxed{E_R = \frac{20kq}{a^2}}$$

33) (a)

$$\vec{E} = \frac{k\,q}{r^2} = \frac{K}{x^2}$$

$$\therefore \frac{1}{4\pi\varepsilon_0}\,q = K$$

Dimension of $\frac{1}{\varepsilon_0}$

$\therefore$ Dimension of $K = [ML^3T^{-4}A^{-2}]\,[AT]$ (ε_0 dimensions derived in Q.19)

$$= [ML^3T^{-3}A^{-1}]$$

34) (c)

Electric field due to linear charge density $= \frac{2k\lambda}{r}$

$F = qE$

$$\therefore F = 5\times10^{-6} \times \frac{2\times9\times10^{9}\times5\times10^{-6}}{0.1}$$

$$\therefore F = 18\times25\times10^{-2}$$

$$\therefore \boxed{F = 4.5\ N/m}$$

35) (a)

$F \propto q_1q_2$ (when r is constant)

$$\therefore \frac{F_1}{F_2} = \frac{q_1q_2}{q_1'q_2'} \Rightarrow \frac{12}{F_2} = \frac{2\times6}{(-2)\cancel{(4)}(2)} \Rightarrow \boxed{F_2 = -4N}$$

This force will be attractive as the charges are opposite

36) (c)

$\text{Flux} = \vec{E}\cdot\vec{ds}$

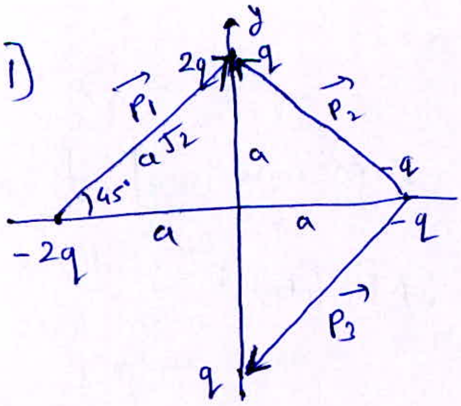
$= (5\hat{i} + 2\hat{j})\cdot(2\hat{i} + 2\hat{j})$

$= 14$

$\therefore \boxed{\text{Flux} = 14}$

Level - 2

1)



Dipole moment $= \vec{P_1} + \vec{P_2} + \vec{P_3}$

$= 2qa\sqrt{2}(\cos 45°\hat{i} + \sin 45\hat{j}) + qa\sqrt{2}(-\cos 45°\hat{i} + \sin 45°\hat{j}) + qa\sqrt{2}(-\cos 45°\hat{i} - \sin 45°\hat{j})$

$= 2qa\hat{i} + 2qa\hat{j} - qa\hat{i} + qa\hat{j} - qa\hat{i} - qa\hat{j}$

$= 2qa\hat{j}$

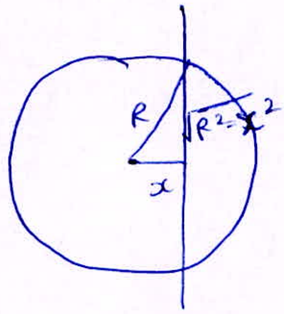
2) (c)

$\phi = \frac{q_{in}}{\varepsilon_0}$

q_{in} = charge density × area enclosed in spherical surface

$= \sigma \times \pi(\sqrt{R^2 - x^2})^2$

$= \sigma\pi(R^2 - x^2)$



$\therefore \boxed{\phi = \frac{\pi(R^2 - x^2)\sigma}{\varepsilon_0}}$

3) (d)

$\vec{r_1} = (2\hat{i} + 3\hat{j})$; $\vec{r_2} = (8\hat{i} - 5\hat{j})$

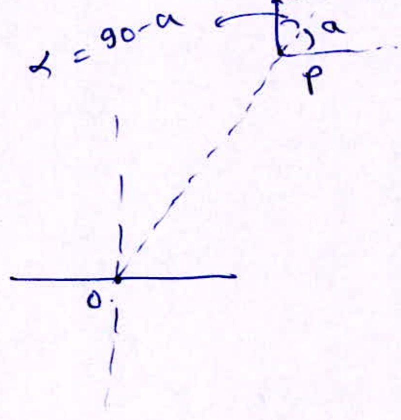
$|\vec{r_2} - \vec{r_1}| = \sqrt{(8-2)^2 + (-5-3)^2}$

$= \sqrt{36 + 64}$

$= 10$

$\therefore E = \frac{KQ}{r^2} = \frac{9 \times 10^9 \times 50 \times 10^{-6}}{(10)^2} = 4500$ V/m

4)



$\tan\alpha = \frac{1}{2}\tan a$

$\alpha = 90 - a$

$\therefore \tan(90 - a) = \frac{1}{2}\tan a$

$\therefore \cot a = \frac{1}{2}\tan a$

$\therefore \tan^2 a = 2$

$\therefore \boxed{\tan a = \sqrt{2}}$

5) (b)

Electric field in a spherical shell due to charge on it surface is zero. So, electric field at their common centre would be zero

6) (b)

$\vec{E} = 8\hat{i} + 4\hat{j} + 3\hat{k}$; $\vec{A} = 100\hat{k}$

$\therefore \phi = E \cdot dA = (8\hat{i} + 4\hat{j} + 3\hat{k})(100\hat{k})$

$\therefore \boxed{\phi = 300}$

7] (b)

$\Delta U = q\Delta V$

Potential energy will convert into kinetic energy

$\therefore \Delta U = K.E = q\Delta V$

$= qEy \qquad (\because \Delta V = Ey)$

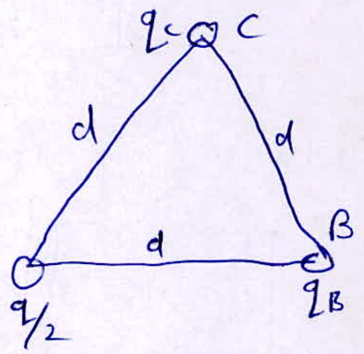
8]

The charge on sphere A after contact to 4th sphere will be $\frac{q}{2}$ ($\because$ spheres are identical)

When B is earthed, potential of sphere B should be zero.

$$\therefore \frac{K(q/2)}{d} + \frac{K q_B}{a} = 0$$

Potential due to sphere A



$$\therefore \frac{q_B}{a} = -\frac{q}{2d} \Rightarrow \boxed{q_B = \frac{-aq}{2d}}$$

Now sphere C is earthed, so potential of sphere C = 0

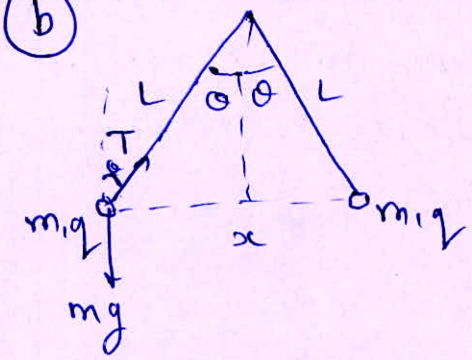
$$\therefore \frac{K(q/2)}{d} + \frac{K\left(\frac{-qa}{2d}\right)}{d} + \frac{Kq_c}{a} = 0$$

$$\therefore \frac{q_c}{a} = \frac{qa - qd}{2d^2}$$

$$\therefore q_c = \frac{qa}{2d}\left(\frac{a-d}{a}\right)$$

$$\therefore \boxed{q_c = -\frac{qa}{2d}\left(\frac{d-a}{d}\right)}$$

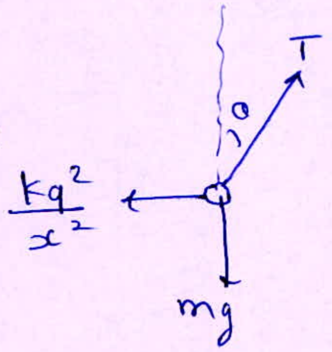
9) (b)



$T\cos\theta = mg \quad \text{.... (1)}$

$T\sin\theta = \dfrac{kq^2}{x^2} \quad \text{.... (2)}$

F.B.D of particle



Divide (2) by (1),

$$\tan\theta = \frac{kq^2}{x^2 mg}$$

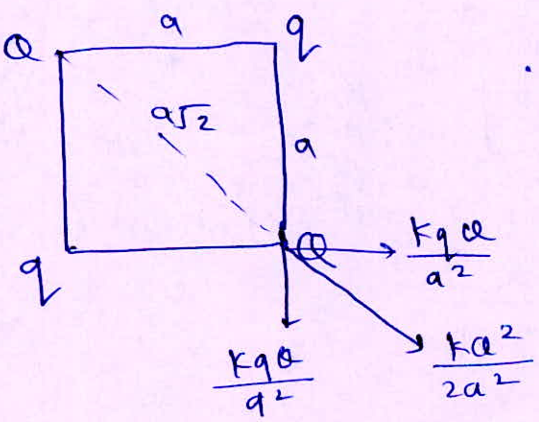
$$\tan\theta = \frac{x/2}{L} \quad \text{... (from diagram)}$$

$$\therefore \quad \frac{x}{2L} = \frac{kq^2}{x^2 mg}$$

$$x^3 = \frac{1}{4\pi\varepsilon_0} \times \frac{2q^2L}{mg}$$

$$\therefore \boxed{x = \left(\frac{q^2L}{2\pi\varepsilon_0 mg}\right)^{1/3}}$$

10) (a)

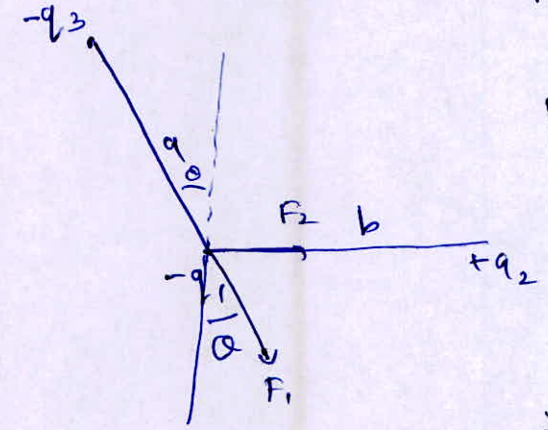


$$\therefore \sqrt{\left(\frac{kqQ}{a^2}\right)^2 + \left(\frac{kqQ}{a^2}\right)^2} = -\frac{kQ^2}{2a^2}$$

$$\therefore \frac{\sqrt{2}\,kqQ}{a^2} = \frac{-kQ^2}{2a^2}$$

$$\therefore \boxed{Q = -2\sqrt{2}\,q}$$

11] (a)



$$F_1 = \frac{k(q_1)(q_3)}{a^2}$$

$$F_2 = \frac{k(q_2)(q_1)}{b^2}$$

So. x component of the force will be

$$F_x = F_1 \sin\theta + F_2$$

$$\therefore F_x = \frac{kq_1q_3}{a^2}\sin\theta + \frac{kq_2q_1}{b^2}$$

$$\therefore F_x = kq_1\left(\frac{q_2}{b^2} + \frac{q_3\sin\theta}{a^2}\right)$$

$$\therefore F_x \propto \left(\frac{q_2}{b^2} + \frac{q_3\sin\theta}{a^2}\right)$$

12) (a)

$$E = E_0 - ax$$

$$F = qE \Rightarrow F = q(E_0 - ax)$$

$$F = ma = m\frac{dv}{dt}$$

$$\therefore m\frac{dv}{dt} = q(E_0 - ax)$$

$$\therefore m\frac{dv}{dx}\cdot\frac{dx}{dt} = q(E_0 - ax)$$

$$\frac{dx}{dt} = v \quad \therefore m\frac{v\,dv}{dx} = q(E_0 - ax)$$

$$\therefore v\,dv = \frac{q}{m}(E_0 - ax)\,dx$$

Integrating both sides,

$$\left.\frac{v^2}{2}\right|_{v_1}^{v_2} = \frac{q}{m}\left(E_0x - \frac{ax^2}{2}\right)\Big|_{x_1}^{x_2}$$

Here, both v_1 and $v_2 = 0$, x_1 also is 0

$\therefore \quad 0 = \frac{q}{m}\left(E_0 x_2 - \frac{a x_2^2}{2}\right)$

$\therefore \quad \boxed{x_2 = \frac{2E_0}{a}}$

13) (d)

14) (a)

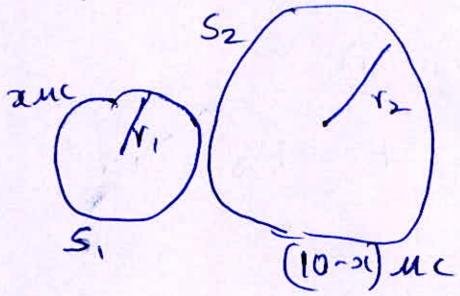
$F = qE = Q(E_1\hat{i} + E_2\hat{j})$

$W = F\cdot ds = Q(E_1\hat{i} + E_2\hat{j})\cdot(a\hat{i} + b\hat{j})$

$\therefore \quad \boxed{W = Q(E_1 a + E_2 b)}$

15) (c)

Charge will flow till potential of both spheres become equal.



$\therefore \quad \frac{Kx}{r_1} = \frac{K(10-x)}{r_2}$

$\therefore \quad \frac{x_1}{r_1} = \frac{(10-x)}{r_2}$

Now, ratio of surface charge densities of S_1 and S_2

$= \frac{x/4\pi r_1^2}{(10-x)/4\pi r_2^2}$

$= \frac{x\, r_2^2}{r_1^2 . (10-x)}$

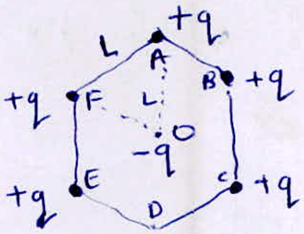
$= \frac{x}{r_1} \times \frac{r_2}{(10-x)} \times \frac{r_2}{r_1}$

$= \frac{r_2}{r_1}$

$\therefore$ surface density of charges ratio of S_2 to S_1

$= \frac{r_1}{r_2} = 1:2$

16) (d)



The force on $-q$ by B would be ~~equal~~ balanced by that by E.

Force by C would be balanced by F.

Force by q at A is unbalanced

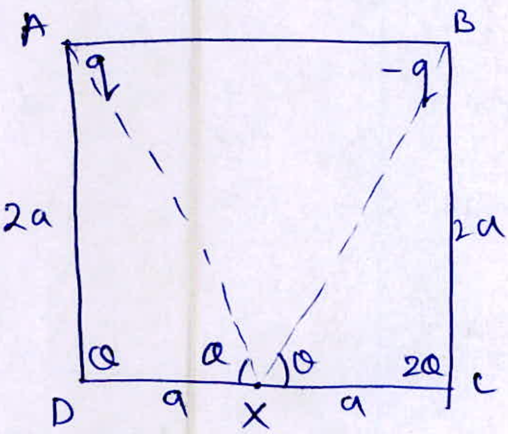
As ΔAOF is an equilateral triangle

$$AO = AF = L$$

$$\therefore |F_{net}| = \left| \frac{1}{4\pi\varepsilon_0} \frac{(q)(-q)}{L^2} \right|$$

$$\therefore |F_{net}| = \frac{1}{4\pi\varepsilon_0} \frac{q^2}{L^2}$$

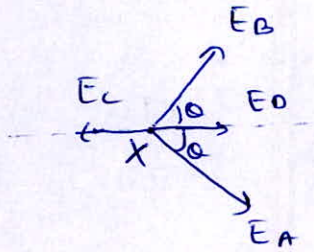
17) (a)



$$\tan\theta = \frac{2a}{a} = 2$$

$$\therefore \sin\theta = \frac{2}{\sqrt{5}}$$

$$\cos\theta = \frac{1}{\sqrt{5}}$$



$$E_X = 0$$

$$\therefore E_B\cos\theta + E_A\cos\theta + E_D - E_C = 0$$

$$\therefore E_C = E_D + E_A\cos\theta + E_B\cos\theta$$

$$\therefore \frac{k\,2Q}{a^2} = \frac{kQ}{a^2} + \frac{kq}{5a^2}\cos\theta + \frac{kq}{5a^2}\cos\theta$$

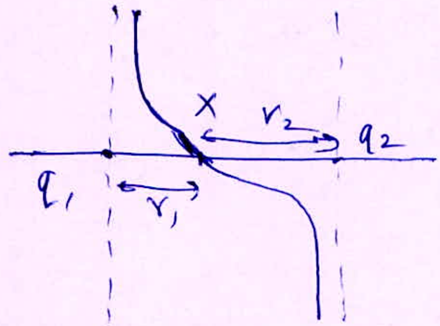
$$\therefore \frac{Q}{a^2} = \frac{2q}{5\sqrt{5}a^2}$$

$$\therefore \boxed{\frac{q}{Q} = \frac{5\sqrt{5}}{2}}$$

18) (b)

As the plates are large, the electric field will be same all over between the plates

19) (a)



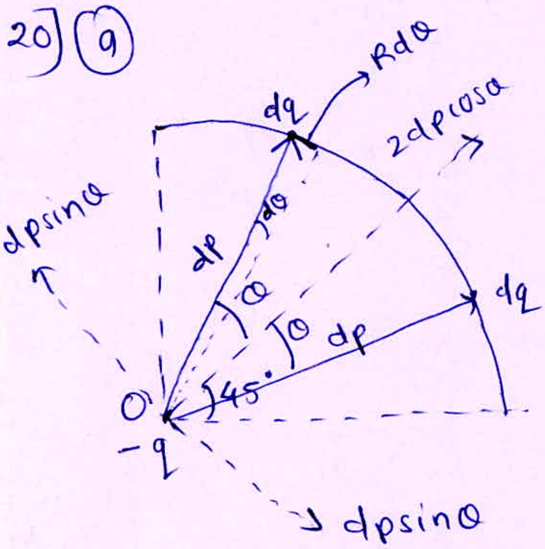
$\vec{E}$ at $x = 0$

$$\therefore \frac{kq_1}{r_1^2} = \frac{kq_2}{r_2^2} \Rightarrow \frac{q_1}{q_2} = \frac{r_1^2}{r_2^2}$$

Now, $r_2 > r_1$

$\therefore q_2 > q_1$

20) (a)



Take two small charges dq at equal angles from the angle bisector of the arc.

$$\text{charge density} = \frac{q}{\frac{\pi R}{2}} = \frac{2q}{\pi R}$$

$$\therefore dq = Rd\theta \times \frac{2q}{\pi R}$$

$$\therefore dq = \frac{2q\,d\theta}{\pi} \Rightarrow \boxed{dp = Rdq}$$

The $\sin\theta$ components of dp cancel each other.

$$\therefore \text{Net electric dipole} = \int 2dp\cos\theta$$

$$\therefore p = \int_0^{\pi/4} 2 \times R \times \left(\frac{2q\,d\theta}{\pi}\right)\cos\theta$$

$$\therefore p = \frac{4qR}{\pi}\int_0^{\pi/4} \cos\theta\, d\theta$$

$$\therefore p = \frac{4qR}{\pi} \sin\theta \Big|_0^{\pi/4}$$

$$\therefore p = \frac{4qR}{\pi} \times \frac{1}{\sqrt{2}}$$

$$\therefore \boxed{p = \frac{2\sqrt{2}\,qR}{\pi}}$$

Assertion AND Reason

1) (c)

The number of positive and negative ions keeps varying and is not constant

2) (a)

$W = F \cdot ds = F ds \cos\theta$

Here $\theta = 90^\circ$, so $W = 0$

3) (c)

The least possible charge is the charge of one electron i.e 1.6×10^{-19} C

4) (a)

Tangent to electric lines gives the direction of electric field.

5) (d)

Quark particle has charge less than that of electron.

6) (b)

Both assertion and reason are true.

7) (a)

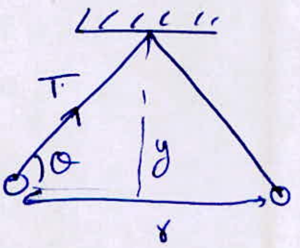
8) (d)

Charge will divide so that the potential of both surfaces are equal.

PREVIOUS YEARS QUESTIONS

Questions Asked in 2013, 2014

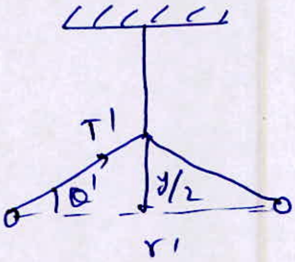
1) (c)



$$T\cos\theta = \frac{kq^2}{r^2} \quad ; \quad T\sin\theta = mg$$

$$\tan\theta = \frac{y}{r/2} = \frac{2y}{r}$$

$$\therefore \tan\theta = \frac{mg}{kq^2/r^2} = \frac{2y}{r} \Rightarrow \boxed{\frac{mgr^2}{kq^2} = \frac{2y}{r}} \quad (1)$$



$$\tan\theta' = \frac{y/2}{r'/2} = \frac{y}{r'}$$

$$T'\sin\theta' = mg = T\sin\theta$$

$$T'\cos\theta' = \frac{kq^2}{r'^2}$$

$$\therefore \tan\theta' = \frac{mgr'^2}{kq^2} = \frac{y}{r'}$$

$$\therefore \boxed{r'^3 = \frac{kq^2 y}{mg}}$$

From (1), $\boxed{r^3 = \frac{2ykq^2}{mg}}$

$$\therefore \frac{r'^3}{r^3} = \frac{1}{2}$$

$$\therefore \boxed{r' = \left(\frac{r}{2}\right)^{1/3}}$$

2] (b)

$$V(x,y,z) = 6x - 8xy - 8y + 6yz$$

$$\therefore \quad E_x = -\frac{\partial V}{\partial x} = -(6-8y)$$

$$E_y = \frac{-\partial V}{\partial y} = -(-8x - 8 + 6z)$$

$$E_z = \frac{-\partial V}{\partial z} = -6y$$

$$\therefore \quad \vec{E} = (8y-6)\hat{i} + (-6z + 8 + 8x)\hat{j} - 6y\,\hat{k}$$

$\therefore$ At $(1,1,1)$

$$\vec{E} = 2\hat{i} + 10\hat{j} - 6\hat{k}$$

$$F = qE$$

$$\therefore F = 4\hat{i} + 20\hat{j} - 12\hat{k}$$

$$\therefore F = \sqrt{16 + 400 + 144}$$

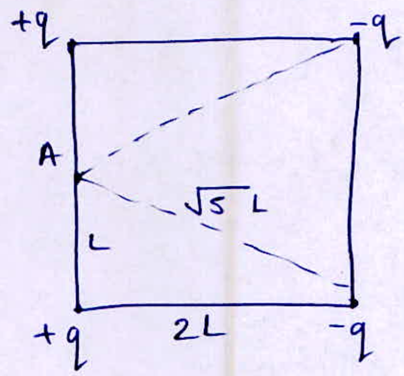
$$= \sqrt{560}$$

$$= \sqrt{16 \times 35}$$

$$\therefore \boxed{F = 4\sqrt{35}}$$

3] (a)

1) (b)



$$V_A = \frac{kq}{L} + \frac{kq}{L} - \frac{kq}{\sqrt{5}L} - \frac{kq}{\sqrt{5}L}$$

$$V_A = \frac{2kq}{L} - \frac{2kq}{\sqrt{5}L}$$

$$\therefore \boxed{V_A = \frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1-\frac{1}{\sqrt{5}}\right)}$$

2] (b)

$W_{ext} = \Delta U = Vq$

3] (c)

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

$\therefore$ V varies as $1/r^2$

4] (a)

5] (c)

Let the number of electrons missing from each ion be n

$\therefore$ charge on both ions = ne

$$\therefore F = \frac{1}{4\pi\varepsilon_0}\frac{(ne)(ne)}{d^2}$$

$$\therefore F = \frac{1}{4\pi\varepsilon_0}\frac{n^2e^2}{d^2}$$

$$\therefore \boxed{n = \sqrt{\frac{4\pi\varepsilon_0 F d^2}{e^2}}}$$

6 c

Number of atoms on each ball $= \frac{10}{63.5} \times 6.023 \times 10^{23}$

1 electron from each 10^6 atoms is transferred, so

electrons transferred $= \frac{10}{63.5} \frac{\times 6.023 \times 10^{23}}{10^6}$

$\therefore$ charge on each ball $= \frac{10}{63.5} \times 6.023 \times 10^{17} \times 1.6 \times 10^{-19}$

$= 1.51 \times 10^{-2}$ C

$\therefore F = \frac{9 \times 10^9 \times (1.51 \times 10^{-2})^2}{(10^{-2})^2} = 2 \times 10^8$ N

7) d

Charge acquired each second $= 1.6 \times 10^{-19} \times 10^{10}$

$= 1.6 \times 10^{-9}$

$\therefore$ Time required to get charge of 1 C

$\Rightarrow t = \frac{1}{1.6 \times 10^{-9}}$

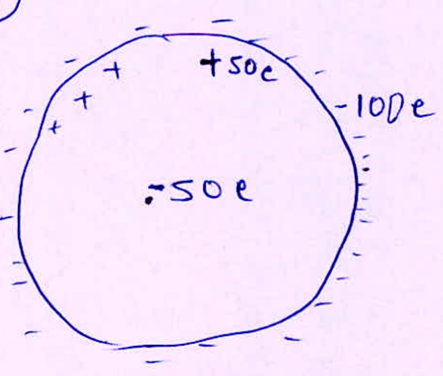
$\therefore \boxed{t = 6.25 \times 10^8}$ sec

$\therefore$ ~~t = 20 yrs~~

$\therefore t = \frac{6.25 \times 10^8}{60 \times 60 \times 24 \times 365}$ years.

$\therefore \boxed{t \approx 20 \text{ yrs}}$

8) d



The charge on inner surface will be +50e as total charge should be zero.
So, for net charge to be −50e, the charge on outer shell will be −100e.

9] (b)

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

$$F_{final} = \frac{K \left(\frac{q_1+q_2}{2}\right)^2}{r^2}$$

($\because$ both spheres/balls are identical, they will have equal charges).

Now, Arithmetic mean $\geq$ Geometric mean

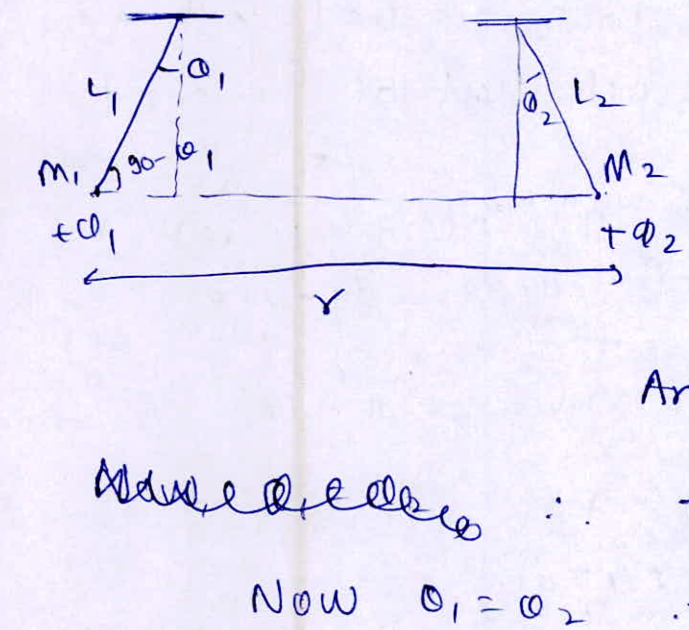
$$Am \geq Gm$$

$$\therefore \frac{q_1+q_2}{2} \geq \sqrt{q_1 q_2}$$

$$\therefore \left(\frac{q_1+q_2}{2}\right)^2 \geq q_1 q_2$$

$$\therefore F_{final} \geq F_{initial}$$

10] (b)



Let the tension in thread L_1 be T_1 and in L_2 be T_2

$$\therefore T_1 \cos(90-\theta_1) = \frac{K Q_1 Q_2}{r^2}$$

$$\therefore T_1 \sin\theta_1 = \frac{K Q_1 Q_2}{r^2}$$

And $$T_2 \sin\theta_2 = \frac{K Q_1 Q_2}{r^2}$$

$$\therefore T_1 \sin\theta_1 = T_2 \sin\theta_2$$

Now $\theta_1 = \theta_2$ $\therefore$ $T_1 = T_2$

Now, $$T_1 \cos\theta_1 = m_1 g$$

$$T_2 \cos\theta_2 = m_2 g$$

Since, $T_1 = T_2$ and $\theta_1 = \theta_2$

$$T_1 \cos\theta_1 = T_2 \cos\theta_2 = m_1 g = m_2 g$$

$$\therefore \boxed{m_1 = m_2}$$

11] (b)

$mg = qE \Rightarrow (0.003 \times 10^{-3})g = q \times 6 \times 10^{4}$

$\therefore q = \dfrac{3 \times 10^{-5}}{6 \times 10^{4}}$

$\therefore q = 0.5 \times 10^{-9}$

$\therefore \boxed{q = 5 \times 10^{-10}\,C}$

12] (b)

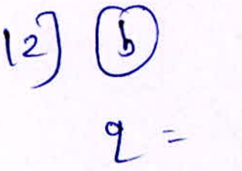
$q = 1.6 \times 10^{-19} \times 10^{19}$

$\therefore \boxed{q = +1.6\,C}$

13] (a) Total charge $= 10^{-6} + 10^{-5} = 10^{-6} + 10 \times 10^{-6} = 11 \times 10^{-6}$

The potential of both disks should be same. We assume the disks to be conducting. So the potential will be same everywhere. So, we find potential at the centre of the discs.

$\boxed{\sigma = \dfrac{Q}{\pi R^2}}$ — (1)



Potential at centre by this element will be

$dV = \dfrac{k\,\sigma\,2\pi r\,dr}{r}$ ($\sigma\,2\pi r\,dr = dq \rightarrow$ charge on the element)

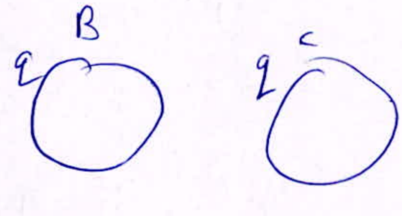
$\therefore V = \int_0^R \sigma\,2\pi r\,dr \Rightarrow V = \sigma 2\pi \int_0^R dR \Rightarrow \boxed{V = \sigma 2\pi R}$

So, for both discs, $\sigma_1 2\pi R_1 = \sigma_2 2\pi R_2 \Rightarrow \boxed{\dfrac{q_1}{R_1} = \dfrac{q_2}{R_2}}$ from (1)

$\therefore \dfrac{x}{10} = \dfrac{(11-x)}{30} \Rightarrow \boxed{x = 2.75\,\mu C}$

14] (a)

15] (d)

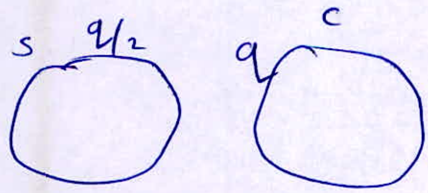


$F \propto q_1 q_2$

$\therefore F_{initial} \propto q^2$

When the third sphere with same radius is in contact of B, charge on both will be $q/2$

Then when the sphere is borought in contact of sphere C, again charges on both spheres will divide equally



Total charge $= q/2 + q = 3/2\, q$

$\therefore$ Charge on each sphere $= \frac{3/2}{2} q = 3/4\, q$

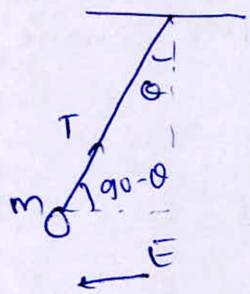
$\therefore$ Final charges on spheres B and C will be $q/2$ and $\frac{3q}{4}$ respectively

$\therefore F_{final} \propto \left(q/2\right)\left(\frac{3q}{4}\right)$

$\therefore F_{final} \propto \frac{3q^2}{8}$

$\therefore \boxed{F_{final} = \frac{3 F_{initial}}{8}}$

16] (b)



$F = qE$

$\therefore F = aE$

$T\cos(90-\theta) = aE$

$\therefore T\sin\theta = qE$

$\therefore \boxed{T = \frac{aE}{\sin\theta}}$

Also $T\sin(90-\theta) = mg$

$\therefore T\cos\theta = mg$

$\therefore \boxed{T = \frac{mg}{\cos\theta}}$

18] (c)

Force at $x = 0$

$\therefore \frac{K(5\times10^{-11})}{(0.2+d)^2} = \frac{K(2.7\times10^{-11})}{d^2}$

$\therefore \frac{(0.2+d)^2}{d^2} = \frac{5}{2.7}$

solving this we get $\boxed{d = 0.556}$

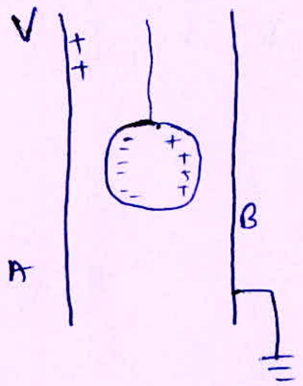
22] (d)

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

$$\therefore F_1 = \frac{k \cdot q_1 q_2}{r^2} \quad ; \quad F_2 = \frac{k\,(2q_1)(2q_2)}{(r/2)^2}$$

$$\therefore \boxed{F_2 = 16 F_1}$$

24] (c)



Due to induction of charge, it will first get attracted towards plate A.
After touching A, it will get some charge from A and the now repel A.
It will move towards B and after toching B, it will lose its charge as plate B is grounden. The motion will then be repeated.

26] (c)

$$F_1 = \frac{k(12)(8)}{d^2} = \frac{96k}{d^2}$$

when brought in contact, the charge on the spheres will redistribute so that each sphere has the same charge (as the spheres are identical).

$$\therefore \text{charge on each sphere} = \frac{12 + (-8)}{2} = \frac{4}{2} = 2$$

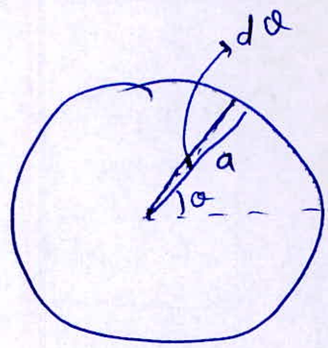
$$\therefore F_2 = \frac{k(2)(2)}{d^2} = \frac{4k}{d^2}$$

$$\therefore \boxed{\frac{F_1}{F_2} = \frac{96}{4} = \frac{24}{1}}$$

27] (d)

charge desities are greater at curved and pointed regions

28) (c)



$\lambda = \lambda_0 \cos^2\theta$

$dq = a\,d\theta \times \lambda_0 \cos^2\theta$

$\therefore q = \int_0^{2\pi} \lambda_0 a \cos^2\theta \, d\theta$

$\therefore q = \lambda_0 a \int \frac{1}{2}(\cos 2\theta + 1)\, d\theta \qquad (\because \cos 2\theta = 2\cos^2\theta - 1)$

$\therefore q = \lambda_0 a \frac{1}{2}\left(\frac{\sin 2\theta}{2} + \theta\right)\Big|_0^{2\pi}$

$\therefore q = \lambda_0 a \frac{1}{2}[0 + 2\pi]$

$\therefore \boxed{q = \lambda_0 a \pi}$

29) (a)

$F_1 = 200N = \frac{kq_1q_2}{r^2}$

$F_2 = \frac{k(1.1q_1)(0.9q_2)}{r^2} = 0.99 \times \frac{kq_1q_2}{r^2}$

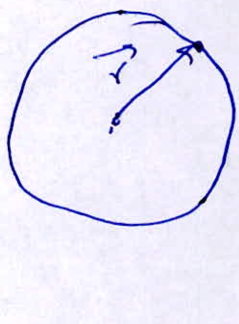
$\therefore F_2 = 0.99 \times F_1$

$\therefore F_2 = 0.99 \times 200$

$\therefore \boxed{F_2 = 198\,N}$

32) (b)

There is one proton in the nucleus



$\therefore \vec{F} = \frac{ke^2}{r^2}(-\hat{r})$

$\therefore \vec{F} = -\frac{ke^2}{r^2}\hat{r}$

$\hat{e} = \frac{\vec{r}}{|r|} = \frac{\vec{r}}{r} \Rightarrow \boxed{F = -\frac{ke^2}{r^3}\vec{r}}$

33] (d)

$F = 10\, mg\, wt = 10 \times 10^{-3} \times g$

$= 100 \times 10^{-3}$ $(\because g = 10)$

$= 0.1$

$\therefore \boxed{F = 10^{-1} N}$

$\therefore F = 10^{-1} = \frac{kq^2}{r^2} = \frac{9 \times 10^9 \times q^2}{0.6 \times 0.6}$

$\therefore q^2 = \frac{36 \times 10^{-3}}{9 \times 10^9}$

$\therefore q^2 = 4 \times 10^{-12}$

$\therefore q = 2 \times 10^{-6}$

$\therefore \boxed{q = 2\, \mu C}$

34] (b)

Charge on each sphere after contact $= \frac{-9+5}{2}$

$= -2\, \mu C$

$\therefore$ Number of electrons excess on each sphere,

$n = \frac{2 \times 10^{-6}}{1.6 \times 10^{-19}}$

$\therefore \boxed{n = 1.25 \times 10^{13}}$

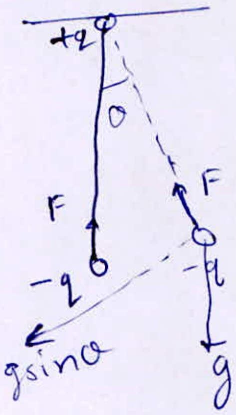
35] (a)

Power $= \frac{\text{Work}}{\text{time}} = \frac{q \Delta V}{t} = \frac{4 \times 4 \times 10^6}{100 \times 10^{-3}} = 16 \times 10^7\, W$

$\therefore \boxed{\text{Power} = 160\, MW}$

36] (d)

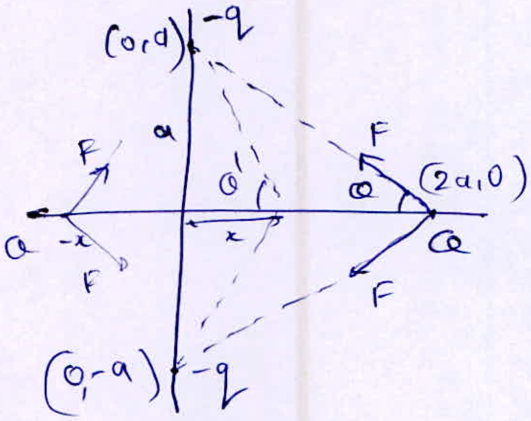
37] (c)



The electric force does not apply any restoring force for the ball as the force is always along the thread joining the balls.

So, as the restoring force is still the gravity, time period will not change

38] (d)



For SHM, force should be proportional to the displacement of the particle from the mean position.

i.e $F = -kx$

In this case, net ~~force~~ force on charg Q will be

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

$$F = \frac{kqQ}{(\sqrt{a^2+x^2})^2} = \frac{kqQ}{a^2+x^2}$$

$$\therefore F_{net} = 2F\cos\theta$$

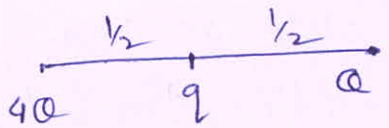
$$= 2 \times \frac{kqQ}{a^2+x^2} \times \frac{x}{\sqrt{a^2+x^2}}$$

$$\therefore F_{net} = \frac{2kqQx}{(x^2+a^2)^{3/2}}$$

∴ since $F_{net} \neq -kx$, the motion will not be a simple harmonic motion.

But the ~~ba~~ motion will be oscillatory as the force is ~~dire~~ always directed ~~d~~ towards the mean position i.e origion (0,0).

39) (d)



Force on Q $= \frac{K 4Q^2}{1} + \frac{KqQ}{(1/2)^2}$

$F = 0$

$\therefore \; K4Q^2 = -4KqQ$

$\therefore \; \boxed{q = -Q}$

40] (a)

1] (d)

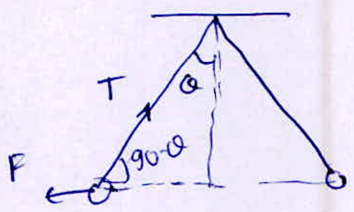
Area vector for the square in xy plane is along $\hat{k}$.

$\therefore \phi = E \cdot ds = (1\hat{j}) \cdot (1\hat{k})$

$\therefore \boxed{\phi = 1 \cos 90^{\circ} = 0}$

2] (a)

Let the volume of each sphere be V



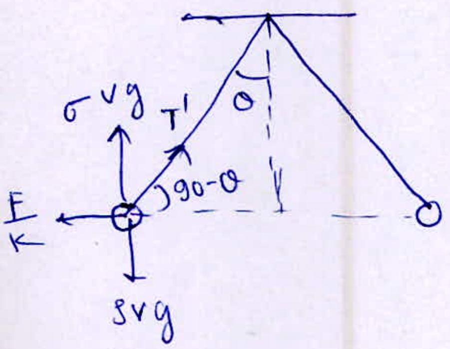
$T\cos(90-\theta) = F$ (F is the electric force between the spheres)

$\therefore \boxed{T\sin\theta = F}$ — (1)

$T\sin(90-\theta) = \rho vg$

$\therefore \boxed{T\cos\theta = \rho vg}$ — (2)

When suspended in a liquid of density σ and dielectric constant k



Electric force between the spheres will now be F/K

$\therefore T'\cos(90-\theta) = \frac{F}{K}$

$\therefore \boxed{T'\sin\theta = \frac{F}{K}}$ — (3)

Dividing (1) by (3) we get

$$\boxed{\frac{T}{T'} = k} \longrightarrow (a)$$

Now $T'\sin(90-\theta) + \sigma vg$ (Buoyant force) $= \rho vg$

$\therefore \boxed{T'\cos\theta = (\rho - \sigma) vg}$ — (4)

Dividing (2) by (4) we get

$$\boxed{\frac{T}{T'} = \frac{\rho}{(\rho - \sigma)}} \longrightarrow (b)$$

From (a) and (b) $\boxed{K = \frac{\rho}{\rho - \sigma}}$

3) (c)

$F = qE = 1.6 \times 10^{-19} \times 10^{3}$

$= 1.6 \times 10^{-16}$ N

$\therefore$ deacceleration $(a) = \frac{qE}{m} = \frac{1.6 \times 10^{-16}}{9 \times 10^{-31}}$

$v^2 = u^2 - 2as$

$v = 0$

$\therefore \quad u^2 = 2as \Rightarrow (5 \times 10^{6})^2 = \frac{3.2 \times 10^{-16}}{9 \times 10^{-31}} s$

$\therefore \quad s = \frac{25 \times 10^{12} \times 9 \times 10^{-31}}{3.2 \times 10^{-16}}$

$\therefore \quad s = 70.31 \times 10^{-3}$ m

$\therefore \quad \boxed{s \doteq 7\text{cm}}$

4) (b)

$\frac{\sigma}{2\varepsilon_0}\left(1 - \frac{z}{\sqrt{z^2+R^2}}\right) = \frac{1}{2} \times \frac{\sigma}{2\varepsilon_0}$

$\therefore \quad 1 - \frac{z}{\sqrt{z^2+R^2}} = 1$

$\therefore \quad \frac{z^2}{z^2+R^2} = \frac{1}{4}$

$\therefore \quad 4z^2 = z^2 + R^2 \Rightarrow 3z^2 = R^2 \Rightarrow \boxed{z = R/\sqrt{3}}$

5) (c)

$\frac{K \cancel{q} \times 6}{r^2} = \frac{K \times 15}{(2-r)^2}$

$\therefore \quad \frac{(2-r)^2}{r^2} = \frac{15}{6} \Rightarrow \frac{2-r}{r} = \frac{\sqrt{5}}{\sqrt{2}}$

$\therefore \quad 2\sqrt{2} = r(\sqrt{2} + \sqrt{5})$

$r = \frac{2\sqrt{2}}{\sqrt{2}+\sqrt{5}}$

$\therefore \quad \boxed{r = 0.77}$

6] (c)

$$a = \frac{qE}{m} = \frac{4\times10^{-3}\times5}{2\times10^{-3}} = 10$$

$$\therefore\ v = u + at$$

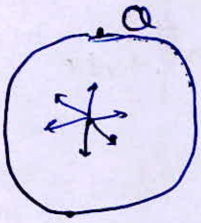
$$\therefore\ v = 0 + 10\times10 \Rightarrow v = 100\,m/s.$$

$$\therefore\ K.E = \frac{1}{2}mv^2 = \frac{1}{2}\times2\times10^{-3}\times10^4$$

$$\therefore\ \boxed{K.E = 10J}$$

(7) (c)

(8) (a)



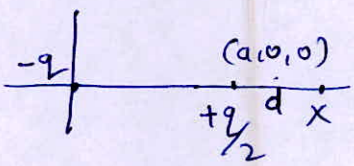
The resultant E will be zero

9] (a)

$$a = \frac{qE}{m}\ ;\ v^2 = u^2 + 2as$$

$$\therefore\ v^2 = 0 + \frac{2qE}{m}s \Rightarrow \boxed{v = \sqrt{\frac{2qEL}{m}}}$$

10] (c)



E = 0 at x

$$\therefore\ \frac{kq}{(a+d)^2} = \frac{kq/2}{d^2}$$

$$\therefore\ \frac{(a+d)^2}{d^2} = 2$$

$$\therefore\ a+d = \sqrt{2}\,d \Rightarrow d = \frac{a}{\sqrt{2}-1}$$

$$\therefore\ x = a+d = a + \frac{a}{\sqrt{2}-1} = \frac{a\sqrt{2}}{\sqrt{2}-1}$$

12] (d)

$e \times 10.39 = e \times 1.5 \times 10^{6} \times d$

$\therefore \boxed{d = \frac{10.39}{1.5 \times 10^{6}}\ m}$

13) (a)

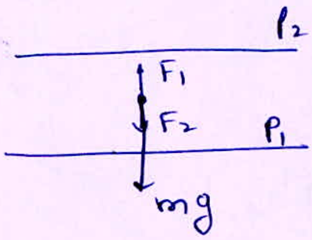
$qE = mg$

$\therefore q \times 3 \times 10^{4} = 9.9 \times 10^{-15} \times 10$

$\therefore q = \frac{9.9 \times 10^{-14}}{3 \times 10^{4}}$

$\therefore \boxed{q = 3.3 \times 10^{-18}\ C}$

16] (c)

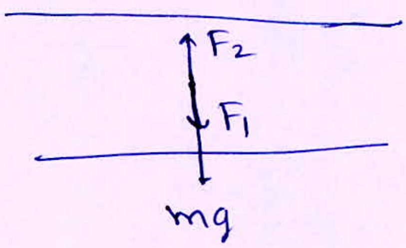


F_1 and F_2 are the forces by plates P_1 and P_2 respectively

$\therefore F_1 = F_2 + mg$

$\therefore \boxed{F_1 - F_2 = mg}$ — (1)

Now, when polarity of plates is reversed, the forces on the drop will also reverse



Here, $F_1 + mg - F_2 = ma$

From (1), $F_1 - F_2 = mg$

$\therefore 2mg = ma$

$\therefore a = 2g$

$\therefore \boxed{a = 20 m/s^2}$

17] (d)

$\vec{E}_x = -\frac{\partial V}{\partial x} = -\frac{\partial(3x^2)}{\partial x} = -6x$

$\vec{E}_y = \frac{-\partial V}{\partial y} = 0$; $\vec{E}_z = \frac{-\partial V}{\partial z} = 0$

$\therefore \vec{E}$ at $(2,0,1) = -6x = -6 \times 2 = -12 V/m$

20] (a)

$$\frac{KQ}{r} = Q \times 10^{11} \Rightarrow \frac{1}{4\pi\varepsilon_0 r} = 10^{11} \Rightarrow r = \frac{10^{-11}}{4\pi\varepsilon_0}$$

$$\therefore E = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r^2}$$

$$\therefore E = \frac{1}{4\pi\varepsilon_0} \frac{Q(4\pi\varepsilon_0)^2}{10^{-22}} \Rightarrow \boxed{E = 4\pi\varepsilon_0 Q \times 10^{22}} \text{ V/m}$$

27] (b)

Electric field due to parts AC and BD will get cancelled

28] (c)

Their potential will be equal.

$$\therefore \frac{Kq_1}{r_1} = \frac{Kq_2}{r_2} \Rightarrow \frac{q_1}{q_2} = \frac{r_1}{r_2}$$

$$\therefore \frac{E_1}{E_2} = \frac{Kq_1/r_1^2}{Kq_2/r_2^2} = \frac{q_1}{q_2}\frac{r_2^2}{r_1^2}$$

$$\therefore \frac{E_1}{E_2} = \frac{r_1}{r_2} \times \frac{r_2^2}{r_1^2}$$

$$\therefore \boxed{\frac{E_1}{E_2} = \frac{r_2}{r_1}}$$

30] (b)

Field due to the shell will be zero.

$\therefore$ E due to sphere $= \frac{1}{4\pi\varepsilon_0}\frac{3Q}{R^2}$

32] (a)

Field line start at +ve charge and end at -ve charge. So, A is +ve and B is -ve.

Number of field lines around A is more than B

$\therefore |A| > |B|$

33) (a)

$$\frac{KQ}{R} = 500 \Rightarrow \frac{9\times10^9 \times 3\times10^{-6}}{r} = 500$$

$$\therefore \boxed{r = 50\,m}$$

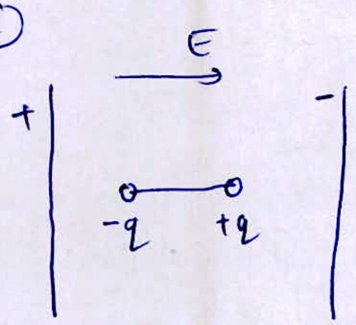
$$\therefore E = \frac{KQ}{r^2} = \frac{9\times10^9 \times 3\times10^{-6}}{2500} = \frac{150}{25} < 10$$

38) (c)

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

Electric Dipole

① ⓒ



For stable equilibrium the angle between $\vec{p}$ and $\vec{E}$ would be zero

3) ⓒ

$E_a = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$; $E_q = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$

$\therefore \boxed{E_a = 2E_q}$

5) ⓓ

$W = \tau\, d\theta$

$\therefore dW = (\vec{p}\times\vec{E})\, d\theta$

$\therefore dW = pE\sin\theta\, d\theta$

$\therefore W = \int_0^{\pi/2} pE\sin\theta\, d\theta$

$\therefore W = -pE\cos\theta \Big|_0^{\pi/2}$

$\therefore \boxed{W = pE}$

8) ⓓ

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

$= pE\sin\theta$

$\therefore \tau_{max} = pE = qdE$

$= 5\times10^{-8}\times 30\times10^{-3}\times10^{6}$

$= 150\times10^{-5}$

$\therefore \boxed{\tau_{max} = 1.5\times10^{-3}}$

10) ⓐ

$\phi = \frac{q_{in}}{\varepsilon_0} = 0$

11] (d)

As the fied is non uniform, it will experience both torque and force

12] (c)

The point lying initially on the axis of dipole will now be on its perpendicular bisector

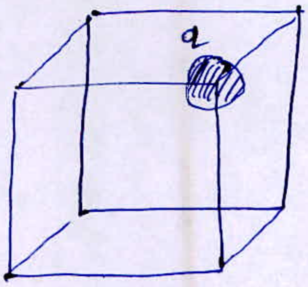
and $E_{\perp \text{ bisector}} = \frac{1}{2} E_{axis}$.

Electric flux and Gauss theorem

1) (b)

Since q_{in} is same, flux will remain the same

4) (c)



Part of the charge inside the cube is $q/8$

$$\therefore \phi_{cube} = \frac{q_{in}}{\varepsilon_0} = \frac{Q}{8\varepsilon_0}$$

7) (e)

See Q.4.

8) (b)

$$\phi = \vec{E}\cdot\vec{ds} = (4\hat{i} + 4\hat{j} + 4\hat{k}).(5\hat{i})$$
$$= 20$$

9) (d)

$$\phi_{total} = \frac{q_{in}}{\varepsilon_0}$$

$\therefore$ ϕ through on face $= \dfrac{\phi_{total}}{6}$

$$\therefore \phi_{face} = \frac{1}{6}\frac{q_{in}}{\varepsilon_0} = \frac{q}{6\varepsilon_0}.$$

10) (d)

$$\phi_2 - \phi_1 = \frac{q_{in}}{\varepsilon_0}$$

$$\therefore q_{in} = \varepsilon_0(\phi_2 - \phi_1)$$

11) (c)

~~E1.1d~~ 1-10

Since $E\cdot ds = 0$, flux will be zero.