Exercise-1

Section (A) : Properties of charge and Coulomb's Law

A-2. **Sol.** After coming is contact charge on both bodies become equal.

A-3. **Sol.** $0.144 = \frac{9 \times 10^9 9^2}{(0.05)^2}$

$9^2 = \frac{0.144}{9 \times 10^9 \times 400}$

A-4. **Sol.** Coulomb's law follows Newtons third law.

A-5. **Sol.** It will move in the direction of resultant force.

A-6. **Sol.** q = ne

$80 \times 10^{-6} = n \times 1.6 \times 10^{-19}$

A-8. **Sol.** According to principle of superposition force acting between the two charges does'nt depend on the presence of other.

A-11. **Sol.** $F = \frac{k q_1 q_2}{r^2}$ ....(1) $4F = \frac{k q_1 q_2}{16R^2}$ ...(2) $\Rightarrow$ $R = \frac{r}{8}$

Section (B) : Electric Field

B-1. **Sol.** Negative charge experiences force opposite to direction fo electric field.

B-2. **Sol.** $E = \frac{F}{Q}$

B-3. **Sol.** Electric field due to one line charge at a distance r is $E = \frac{2k\lambda}{r}$

$F = qE = \frac{(\lambda \times 1)2k\lambda}{r} = \frac{2k\lambda^2}{r}$

B-6. **Sol.** $6 = \frac{q}{4\pi r^2}$ $\Rightarrow$ $\frac{\sigma_1}{\sigma_2} = \left(\frac{r_2}{r_1}\right)^2$

B-7. **Sol.** Maximum electric field will be at the surface

$E = \frac{kq}{r^2} = \frac{9 \times 10^9 \times 1 \times 10^{-6}}{(0.1)^2}$

B-8. **Sol.** mg = qE $m = \left(P.\frac{4}{3}\pi r^3\right)$

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

B-9. **Sol.** Resultant electric field between two charged plates is E = $\frac{\sigma}{2a_0} + \frac{\sigma}{2a_0} = \frac{\sigma}{a_0}$

F = qE = $\frac{e.\sigma}{a_0}$

B-10. **Sol.** Outside the plate Net electric field is zero.

B-11. **Sol.** W = Fr cos θ ⇒ 4 = 0.2 E 2 cos 60º ⇒ E = 20 N/C.

B-12. **Sol.** T = $2\pi\sqrt{\frac{\ell}{g_{eff}}}$ where = g_{eff} = $\frac{\sqrt{m^2g^2 + q^2E^2}}{m}$ = $\sqrt{g + \left(\frac{qE}{m}\right)^2}$

B-14. **Sol.** E = $\frac{kqx}{(R^2 + x^2)^{3/2}}$, for max E, vf/kdre E ds fy, $\frac{dE}{dx}$ = 0 ⇒ x = ± $\frac{R}{\sqrt{2}}$

⇒ E_{max} = $\frac{2kq}{3\sqrt{3}R^2}$

B-15. **Sol.** F = qE ⇒ a = $\frac{qE}{m}$ ⇒ x = $\frac{1}{2}$ at² = $\frac{1}{2}\left(\frac{qE}{m}\right)t^2$

k.E = W_E = qE $\frac{1}{2}\left(\frac{qE}{m}\right)t^2 = \frac{E^2q^2t^2}{2m}$

Section (C) : Electric Potential and Potential Difference

C-1. **Sol.** E = $\frac{F}{q} = \frac{3000}{3} = \frac{v}{d}$

v = $\frac{1000 \times 1}{100} = 10$

C-3. **Sol.** E = $\frac{v}{d}$, E = $\frac{10}{2} \times 100$ = 5000 N/C

C-4. **Sol.** $V_c - V_s$ = $\frac{3}{2}\frac{KQ}{R} - \frac{KQ}{R}$

= $\frac{KQ}{2R}$ = $\frac{1}{8\pi \in_0 R}\left(\frac{4}{3}\right)\pi R^3 \rho$ = $\frac{R^2\rho}{6 \in_0}$

C-9. **Sol.** Potential at origin is v = $\frac{-kq}{a} + \frac{kq}{a} = 0$

C-10. **Sol.** Potential at the centre is

v = $\left(\frac{kq}{a/\sqrt{2}}\right) \times 4$ = $\frac{3\sqrt{3}kq}{a}$

$$\vec{E}_R = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

C-12. **Sol.** $v = \frac{kq}{r}$

C-13. **Sol.** Potential at origin is

$v = kq\left[1 - \frac{1}{2} + \frac{1}{4} - \frac{1}{8} ....\infty\right]$

$v = kq\left[\frac{1}{1+\frac{1}{2}}\right]$ $s_\infty = \left(\frac{a}{1-r}\right)$

C-15. **Sol.** For isolated sphere,

$\frac{kQ_1}{r_1} = \frac{kQ_2}{r_2} \Rightarrow \frac{Q_1}{Q_2} = \frac{r_1}{r_2}$

C-16. **Sol.** Potential of single drop $v = \frac{kq}{r}$

Radius of bigger drop R = 4r

V' (potential of bigger drop) = $\frac{k64q}{4r} = \frac{16kq}{r}$

C-18. **Sol.** V = Er $r = \frac{V}{E} = 6m.$

C-21. **Sol.** $V = \frac{9 \times 10^9 \times 1.5 \times 10^{-9}}{(.5)} = 27$ V.

C-22. **Sol.** $E = \frac{3000}{3} = 1000$ N/C.

$\Delta V = Ed = \frac{1000 \times 1}{100} = 10V.$

C-24.# **Sol.** Since B and C are at same potential

$\Delta V_{AB} = \Delta V_{AC} = Eb.$

C-26. **Sol.** KE = VQ and momentum = $\sqrt{2m(KE)} = \sqrt{2mVQ}$

C-27. **Sol.** Potential at 5cm. $= V = \frac{kq}{(10cm)}$

Pontential at 15 cm V^1 15 cm $V^1 = \frac{kq}{15cm} = \frac{2}{3}$ V.

Section (D) : Electric Potential Energy OF A PARTICLE

D-1. **Sol.** v = $\frac{kq}{R} = \frac{9 \times 10^{9} \times 50 \times 1.6 \times 10^{-19}}{10^{-12}}$

D-2.# **Sol.** Electrostatic force is a conservative force. (work done by conservative force does not depend on path.)

D-3. **Sol.** w = q($v_2 - v_1$) = $\frac{1}{2}mv^2$ = ΔK

D-4.# **Sol.** w = qV (v → Potential of diff.)
w = 0 Potential of all the points are same

D-5. **Sol.** Work done by external agent will be negative

D-6. **Sol.** PE = qV PE increases if q is +ve decreases if q is –ve.

Section (E) : Potential Energy Of a System Of Point Charge

E-1. **Sol.** ω = $\vec{F} \cdot \vec{r}$
ω = 0
Angle between force and disp. = 90° or workdone by conservative force round the trip will always be zero.

E-2. **Sol.** PE may increase may decrease dipending on sign of charges.

E-3. **Sol.** PE = $\frac{2Kq^2}{a^2} + \frac{2xkq^2}{a^2} + \frac{xkq^2}{a^2}$ = 0
where a is distance between charges.

2 + 3x = 0 x = $-\frac{2}{3}$

Section (F) : Self Energy And Energy Density

F-1. **Sol.** field near sphere = $\frac{V}{R} = \frac{800}{1 \times 10^{-2}}$ = 8 × 10^5 V/m

Energy density = $\frac{1}{2}\varepsilon_0 E^2 = \frac{4\pi\varepsilon_0}{8\pi}$ E^2 = $\frac{8 \times 8 \times 10^{10}}{8\pi \times 9 \times 10^{9}} = \frac{80}{9\pi}$ = 2.83 J/m^3.

F-2. **Sol.** Let q is charge and a is racdius of single drop. U = $\frac{3kq^2}{5a}$
charge on big drop = nq.

Let Radius of big drop is R. ⇒ $\frac{4}{3}\pi R^3 = n.\frac{4}{3}\pi a^3$ ⇒ R = $an^{1/3}$.

P.E. of big drop = $\frac{3}{5}\frac{k(qn)^2}{R} = \frac{3}{5}\frac{k.q^2n^2}{an^{1/3}} = Un^{\frac{5}{3}}$

Section (G) : Questions Based On Relation Between $\vec{E}$ And V :

G-1.# **Sol.** Electric field is always perpendicular to equipotential surface. Opposite to electric field potential increases.

G-2.# **Sol.** E = $\frac{10}{0.1\sin 30^\circ}$ = 200 V/m

G-5. **Sol.** E α r ⇒ $-\int_0^v dV \; \alpha \int_0^r r\,dr$ ⇒ V α (– $\frac{r^2}{2}$) ⇒ V α r^2

Section (H) : Dipole

H-1. **Sol.** $E \propto \frac{1}{r^3}$

H-9. **Sol.** max PE ⇒ position of unstable equilibrium ⇒ θ = π .

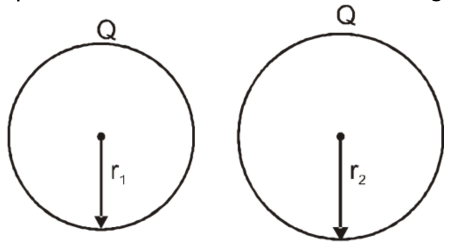
Section (J) : Conductor, It's Properties & Electric Pressure

J-2. **Sol.** $V_{inside} = V_{surface} = \frac{kq}{R} = \frac{9\times10^9 \times 3.2\times10^{-19}}{0.1}$

J-3. **Sol.** $\frac{Q_1}{Q_2} = \frac{r_1}{r_2}$, $\frac{\sigma_1}{\sigma_2} = \frac{Q_1}{4\pi r_1^2}\frac{4\pi r_1^2}{Q_2} = \frac{r_1}{r_2}\left(\frac{r_2^2}{r_1^2}\right)$

J-4. **Sol.** $q_1 = \frac{2Qr_1}{r_1+r_2}$

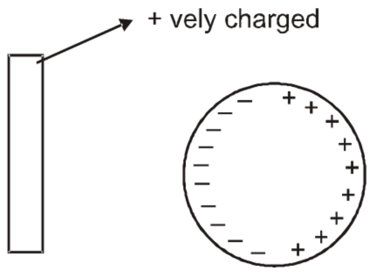
$q_2 = \frac{2Qr_2}{r_1+r_2}$ After coming in contact



$v = \frac{kq}{r}$

J-5. **Sol.** Positive charge flows from higher potential to cover lower potential.

J-11. **Sol.**

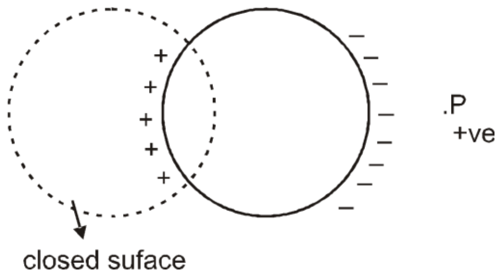


Since distance between plate and –ve charge is less than that between plate and +ve charge. electric force acts on object towards plate.

J-13.# **Sol.** Since field lines are always perpendicular to conductor surface field lines can not enter in to conductr only option C is correct.

J-15.# **Sol.** Since electric field produced by charge is conservative.

J-16.# **Sol.**



enclosed charge = +ve $\Rightarrow$ flux through closed suface = +ve.

J-17. **Sol.** final charge on both spheres = 10 μC each.

$$\frac{F_1}{F_2} = \frac{(q_1 q_2)_i}{(q_1 q_2)_f} = \frac{800}{100} = 8 : 1$$

Exercise-2

Marked Questions can be used as Revision Questions.

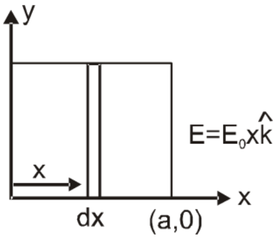
PART - I : OBJECTIVE QUESTIONS

1. **Sol.** There is no point near electric dipole having E = 0.

6. **Sol.** $V \to 2V \Rightarrow k \to 4k \Rightarrow PE_{max} \to 4PE_{max} \Rightarrow r \to \frac{r}{4}$

12. **Sol.** $eV = \frac{1}{2}mu^2 \Rightarrow u \;\alpha\; V^{\frac{1}{2}}$

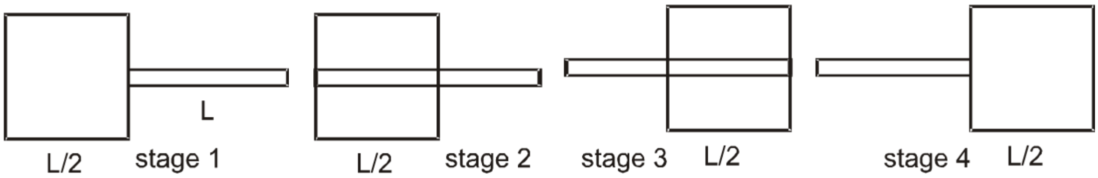
13. **Sol.**



flux through differential element $d\phi = E_0\, x\, a\, dx$. net flux

$$\phi = E_0 a \int_0^a x.\, dx = \frac{E_0 a^3}{2}$$

15.



Sol. form stage 1 to stage 2 ⇒ enclosed charge is increasing means flux is increasing
form stage 2 to stage 3 ⇒ enclosed charge is constant means flux is constant
form stage 3 to stage 4 ⇒ enclosed charge is decreasing means flux is decreasing

16. **Sol.** since same no of filed lines are passing through both spherical surfaces. flux has same value for both.

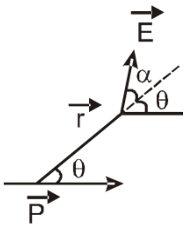
17. **Sol.** Each charge has its 1/8th part inside cube since there are 8 charges.

net enclosed charge = $\frac{q}{8} \times 8 = q$

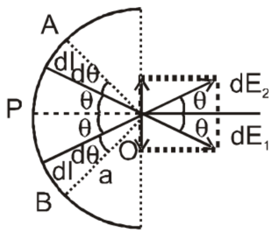
net flux = $\frac{q_{in}}{\varepsilon_0} = \frac{q}{\varepsilon_0}$.

flux through one surface = $\frac{1}{6} \times \frac{q}{\varepsilon_0} = \frac{q}{6\varepsilon_0}$

18. **Sol.**



19. **Sol.** Considering symmetric elements each of length dl at A and B, we note that electric fields perpendicular to PO are cancelled and those along PO are added. The electric field due to an element of length dl (adθ) along PO.



$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{a^2}\cos\theta$ $(\because dl = ad\theta)$

$= \frac{1}{4\pi\varepsilon_0}\frac{\lambda dl}{a^2}\cos\theta$

$= \frac{1}{4\pi\varepsilon_0}\frac{\lambda(a\,d\theta)}{a^2}\cos\theta$

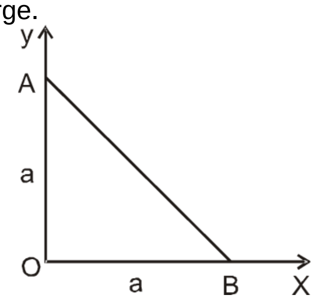
Net electric field at O

$E = \int_{-\pi/2}^{\pi/2} dE = 2\int_0^{\pi/2}\frac{1}{4\pi\varepsilon_0}\frac{\lambda a\cos\theta\, d\theta}{a^2}$

$= 2.\frac{1}{4\pi\varepsilon_0}\frac{\lambda}{a}[\sin\theta]_0^{\pi/2}$

$= 2.\frac{1}{4\pi\varepsilon_0}.\frac{\lambda}{a}.1 = \frac{\lambda}{2\pi\varepsilon_0 a}$

20. **Sol.** **Key Idea :** The work done in carrying a test charge consists in product of difference of potential at points A and B and value of test charge.



potential at

$V_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{a}$

potential at B

$V_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{a}$

Thus, work done in carrying a test charge – Q from A to B

$w = (V_A - V_B)(-Q) = 0$

21. **Sol.** **Key Idea :** The cjhange in potential energy of the system is $U_D - U_C$ as discussed undr.

When charge q_3 is at C, then its potential energy is

$U_C = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_3}{0.4}+\frac{q_2q_3}{0.1}\right)$

When charge q_3 is at D, then

$U_D = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_3}{0.4}+\frac{q_2q_3}{0.1}\right)$

Hence, change in potential energy

$\Delta U = U_D - U_C$

$= \frac{1}{4\pi\varepsilon_0}\left(\frac{q_2q_3}{0.1}+\frac{q_2q_3}{0.5}\right)$

but $\Delta U = \frac{q_3}{4\pi\varepsilon_0}\ k =$

$\frac{1}{4\pi\varepsilon_0}\left(\frac{q_2 q_3}{0.1}+\frac{q_2 q_3}{0.5}\right)$

$\therefore \frac{q_3}{4\pi\varepsilon_0} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_2 q_3}{0.1}+\frac{q_2 q_3}{0.5}\right)$

$\Rightarrow$ $k = q_2 (10 - 2) = 8q_2$

24. **Sol.** $dU = \frac{1}{2}\varepsilon_0 E^2 4\pi r^2 dr$

$dU = \frac{q^2}{8\pi\varepsilon_0}\frac{dr}{r^2}$ $\Rightarrow$ $U = \int_R^\infty dU = \frac{q^2}{8\pi\varepsilon_0 R}$

$\frac{1}{2}U = \frac{q^2}{8\pi\varepsilon_0}\int_R^{R_0}\frac{dr}{R^2}$

$\frac{1}{2R} = \frac{1}{R}-\frac{1}{R_0}$

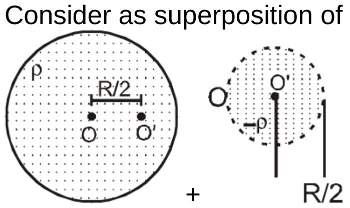
$R_0 = 2R$.

36_ **Sol.** Nearby the plate, field is uniform. Equal and opposite forces are experienced by upper half and lower half

38_ **Sol.** Case (i) : (with cavity) :

Let charge density be ρ.

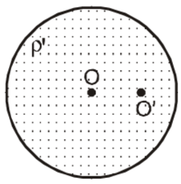
Consider as superposition of the bodies shown below :



At O′ $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{4}{3}\pi\left(\frac{R}{2}\right)^3 \rho + 0$

Case (ii)

At O′ $E' = \frac{1}{4\pi\varepsilon_0}\cdot\frac{4}{3}\pi\left(\frac{R}{2}\right)^3 \rho'$



$\therefore \frac{E'}{E}=\frac{\rho'}{\rho} = \frac{q/V'}{q/V} = \frac{V}{V'} = \frac{7}{8}$

$\left(V = \frac{4}{3}\pi R^3 - \frac{4}{3}\pi\left(\frac{R}{2}\right)^3 \text{ and } V' = \frac{4}{3}\pi R^3\right)$

39_ **Sol.** $-4(1) + 6(1) = \frac{q}{\varepsilon_o}$ $\Rightarrow$ $q = 2\varepsilon_o$ **Ans.**

40. **Sol.** $\phi = \int \vec{E}.d\vec{s}$

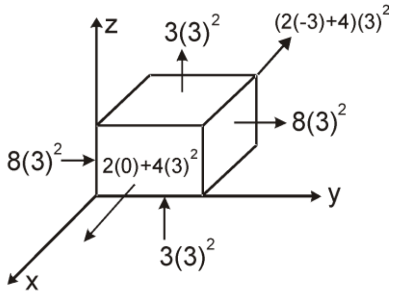
Direction of field at x = – 3m is along negative x axis. Area vector is also along same direction.

$\phi = 6 \times 9 = \frac{Q}{\varepsilon_0}$

$Q = 54 \in_0$

Components of electric field which are constant,
do not contribute in net flux in or out.

$\frac{q_{in}}{\in_0} = 54 \quad \Rightarrow q_{in} = 54 \in_0$



41._ **Sol.** The distribution of charge on the outer surface, depends only on the charges outside, and it distributes itself such that the net, electric field inside the outer surface due to the charge on outer surface and all the outer charges is zero. Similarly the distribution of charge on the inner surface, depends only on the charges inside the inner surface, and it distributes itself such that the net, electric field outside the inner surface due to the charge on inner surface and all the inner charges is zero.
Also the force on charge inside the cavity is due to the charge on the inner surface. Hence answer is option **(A)**.

42._ **Sol.** $E_i = \frac{KQ^2}{2a} + \frac{KQ^2}{4a} + \frac{KQ}{2a}.Q = \frac{KQ^2}{a} + \frac{KQ^2}{4a} = \frac{5KQ^2}{4a}$

$E_f = \frac{K(2Q)^2}{4a} = \frac{KQ^2}{a}$

$E_i - E_f = H = \frac{KQ^2}{4a}$

43._ **Sol.** From given conditions,
$V_A = V_C$ and $V_B = 0$

$\Rightarrow V_B = \frac{K(Q-q_1)}{3a} + \frac{Kq_2}{2a} + \frac{3q_1}{2a} = 0$

$\Rightarrow 2Q + q_1 + 3q_2 = 0$ .... (1)

Using $V_A = V_C$

$V_A = V_C$

$\frac{K(Q-q_2)}{3a} + \frac{Kq_2}{3a} + \frac{Kq_1}{3a} = \frac{Kq_1}{a} + \frac{K(Q-q_1)}{3a} + \frac{Kq_2}{2a}$

$\Rightarrow q_1 = -\frac{q_2}{4}$ .... (2)

Using it in (1), $q_2 = -\frac{8}{11}Q$

PART - II : MISCELLANEOUS QUESTIONS

Section (A) : Assertion/Reasoning

A-1. Sol. The electric field inside the cavity depends only on point charge q. Hence $V_A - V_B$ remains constant even if point charge Q is shifted. Here statement 2 is correct explanation of statement 1.

A-2. Sol. From the frame of cylinder, the pseudo force acting on free electrons shifts them towards left. As a result, left end of cylinder becomes negatively charged and right end becomes positively charged. The electric field thus produced balances the pseudo force when a stage of equilibrium is reached.
Here statement 2 is correct explanation of statement 1.

A-3. Sol. The potential at each point within an isolated thin conducting charged shell is same. Hence if charge is changed on this shell, potential at all points within the shell change by same amount. Hence statement-2 is true.
The potential 'V' at any point on or inside the outer shell in statement-1 is sum of potential due to outer shell (V_1) and potential due to inner shell (V_2).

$$\therefore V = V_1 + V_2$$

From statement-2 'V_1' (potential due to outer shell) at all points on or inside the outer shell is same. Further as the charge on outer shell is changed, potential at all points on and inside outer shell change by same amount. Hence potential difference between both the shells remains same. Hence statement 1 is true and statement-2 is correct explanation.

Section (B) : Match The Column

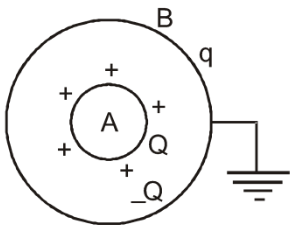
B-1. Ans. (a) → (R), (b) → (S), (c) → (Q), (d) → (P)

B-2. Ans. (a) → S; (b) → R; (c) → Q; (d) → P

Sol. Electric field is uniform in all four cases. Equipotential lines in x-y plane shall be normal to corresponding electric lines of forces. Also direction of electric field is from region of higher potential to lower potential.
Hence (a) → S; (b) → R; (c) → Q; (d) → P

Section (C) : One or More Than One Options Correct

C-1.
Sol.



(i) Due to earthing
Let total charge on B is q.

$V_B = 0 \quad \therefore \quad \frac{kq}{b} + \frac{kQ}{b} = 0 \quad$ or $\quad q = -Q.$

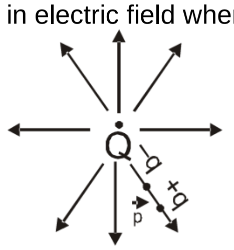
(ii) ∴ All charge q = – Q
appears on inner surface of B due to induction
⇒ Charge on outer surface of B = 0

⇒ Field between A and B due to B = 0
Field between A and B due to A ≠ 0
Net field between A and B ≠ 0.

C-2. **Sol.** (i) At any point P inside the sphere, electric field ⇒ $E_P = \frac{kQr}{R^3}$.
∴ E_P increases as r increases .

(ii) At any point M outside the sphere, $E_M = \frac{kQ}{r^2}$
∴ E_M decreases as r increases.

C-3.* **Sol.** The electric force on dipole can never be zero in the given electric field. But torque may be zero in electric field when placed in shown orientation.



C-4.* **Sol.** If charge is at A or D, its all field lines cut the given surface twice which means that net flux due to this charge remains zero and flux through given surface remains unchanged.

C-5. **Sol.** $\frac{kQ}{(r+5\text{cm})} = 100\text{V}$ & $\frac{kQ}{(r+10\text{cm})} = 75\text{ V}$
∴ $Q = \frac{5}{3}\times10^{-9}\text{C}$, r = 10 cm
∴ $V_{\text{surface lrg}} = \frac{kQ}{r} = 150\text{V}$ $E_{\text{surface lrg}} = \frac{kQ}{r^2} = 1500\text{ V/m}$
$V_{\text{centre}} = \frac{3}{2}V_{\text{surface}} = \frac{3}{2}\times150 = 225\text{ V}$

Exercise-3

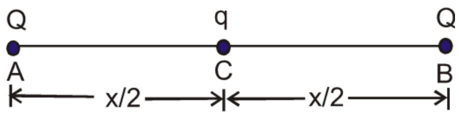
Marked Questions can be used as Revision Questions.

PART - I : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1.
Sol. Potential difference between two points in a electric field is,
$V_A - V_B = \frac{W}{q_0}$
where, W is work done by moving charge q_0 from point A to B.
So $V_A - V_B = \frac{2}{20}$
(Here : W = 2 J, q_0 = 20C)
= 0.1 V

2. **Sol.** Let charge q is placed at mid point of line AB as shown below.
Also, AB = x (say)

$\therefore$ AC = $\frac{x}{2}$, BC = $\frac{x}{2}$



For the system to be in equilibrium

$F_{Qq} + F_{QQ} = 0$

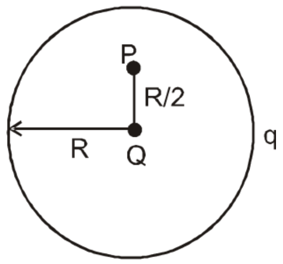
So, $\frac{1}{4\pi\varepsilon_0}\frac{Qq}{(x/2)^2} + \frac{1}{4\pi\varepsilon_0}\frac{QQ}{x^2} = 0$

$\Rightarrow$ $q = -\frac{Q}{4}$

3. **Sol.** At P, potential due to shell :

$V_1 = \frac{q}{4\pi\varepsilon_o R}$

At P , potential due to Q :



$V_2 = \frac{Q}{4\pi\varepsilon_o \frac{R}{2}}$

$\therefore$ Net potential at P

$V = V_1 + V_2$

$= \frac{q}{4\pi\varepsilon_o R} + \frac{2Q}{4\pi\varepsilon_o R}$

4. **Sol.** $\vec{F}_{12(x)} = \frac{q_1q_2}{4\pi_0 b^2}(-\hat{i})$

$\vec{F}_{13\,(x)} = \frac{q_1q_3}{4\pi\varepsilon_0 a^2}(-\sin\theta\hat{i})$

$\therefore$ Net $\vec{F}_x = \frac{Kq_1q_2}{b^2}(-\hat{i}) + \frac{kq_1q_3}{a^2}\sin\theta(-\hat{i})$

or $F_x = -Kq_1\left[\frac{q_2}{b^2} + \frac{q_3}{a^2}\sin\theta\right]$

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

5. **Sol.** $\Delta\phi = \frac{q}{\varepsilon_0}$ $\Rightarrow$ $\phi_2 - \phi_1 = \frac{q}{\varepsilon_0}$

So, the electric charge inside the surface will be

$\Rightarrow$ $q = (\phi_2 - \phi_1)\varepsilon_0$

6. **Sol.** Initially : $\frac{kQ^2}{r^2} = F$

Finally : Charge on B = Q/2

and Charge on C = $\frac{3Q}{4}$ (By conduction)

$\therefore F' = \dfrac{k(Q/2)(3Q/4)}{r^2} = \dfrac{3kQ^2}{8r^2} = \dfrac{3F}{8}$

7. **Sol.** By energy conservation

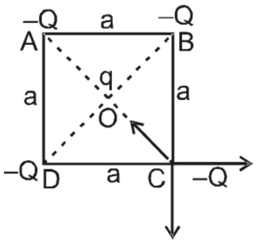
Initially : $0 + \dfrac{1}{2}mv^2 = \dfrac{kQq}{r}$

Finally : $\dfrac{1}{2}m(2v)^2 = \dfrac{kQq}{r'}$

So, $\dfrac{4kQq}{r} = \dfrac{kQq}{r'}$

or $r' = \dfrac{r}{4}$

8. **Sol.**



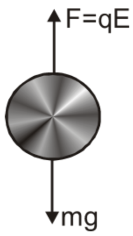
Charge q at O is in equilibrium.
For –Q to be in equilibrium, we see charge at C.

$\therefore$ F_{net} on – Q (at C) = 0

or $\dfrac{kQ^2}{(\sqrt{2}a)^2} + \dfrac{\sqrt{2}kQ^2}{a^2} - \dfrac{kQq}{(a/\sqrt{2})^2} = 0$

$\therefore$ $q = \dfrac{Q}{4}(1+2\sqrt{2})$

9. **Sol.** In steady state,
electric force on drop = weight of drop



$\therefore$ $qE = mg$

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

$= \dfrac{9.9 \times 10^{-15} \times 10}{3 \times 10^4} = 3.3 \times 10^{-18}$ C

10. **Sol.** The dipole will have some distance along the electric field, so, option (1) is correct.

11. **Sol.** By work energy theorem:
$W_{\text{all forces}} = \Delta KE$
So $q(\Delta V) = KE_{\text{final}} - KE_{\text{Initial}}$

or $1.6 \times 10^{-19} \times (20) = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$

$\therefore v = 2.65 \times 10^6$ m/s

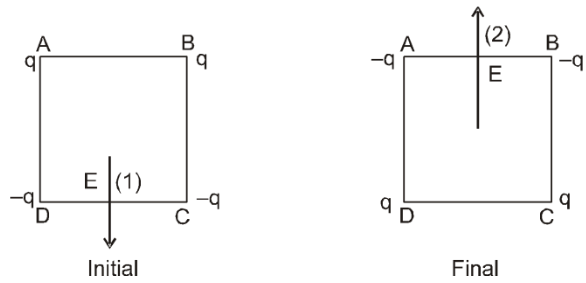
12. **Sol.** After connecting with conducting wire, let the charges on both spheres are q_1 & q_2.

$\therefore \frac{q_1}{q_2} = \frac{r_1}{r_2} = \frac{1}{2}$

$\therefore \frac{E_1}{E_2} = \frac{q_1}{r_1^2} \cdot \frac{r_2^2}{q_2} = 2 : 1$

13. **Sol.** Since, $V_A = 9 \times 10^9 \frac{10^{-9}}{\{2+2\}^{\frac{1}{2}}} = 4.5$ volt, $V_B = 9 \times 10^9 \frac{10^{-9}}{\{2+2\}^{\frac{1}{2}}}$ volt, $V_A - V_B = 0$

14. **Sol.** In initial case, E is along (1) whereas in final case E is along (2). Potential at centre remains same.



15. **Sol.** $v(x) = \frac{20}{x^2 - 4}$, $E = -\frac{dv}{dx} = -\frac{d}{dx}\left(\frac{20}{x^2-4}\right) = \frac{20}{(x^2-4)^2}(2x)$

E at x = 4 μm, $\frac{(20)(2 \times 4)}{144} = \frac{10}{9}$ volt/μm

Also as x increases, V decreases. So, E is along +ve x -axis.

16. **Sol.** Since, the electric field inside the shell is zero and outside, the electric field is given as $\frac{kQ}{r^2}$, where r = distance from centre.

So, graph is as shown in option (4).

17. **Sol.** **Ans. (3)**

$W_{P \to Q}|_{ext} = q\,(V_Q - V_P)$

$= -1.6 \times 10^{-19} \times 100\,(-4 - 10)$

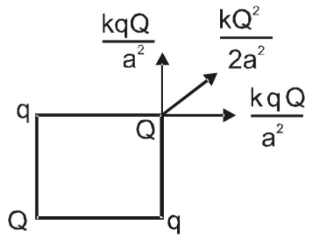
$= 2.24 \times 10^{-16}$ J

18. **Sol.** Ans. (4)

Since, F_{net} on Q is zero, so :

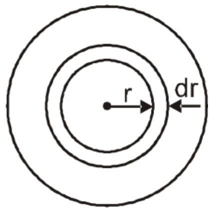
$$\frac{kqQ}{a^2}[\sqrt{2}] + \frac{kQ^2}{2a^2} = 0$$

$$\frac{Q}{q} = -2\sqrt{2}$$



19. **Sol.** **Ans. (1)**
Statement–1 : Correct as the field is conservative
statement –2 : Correct Explanation

20. **Sol.** Ans. (2)
Consider a spherical shell having radius r and thickness dr



dq = $\frac{Q}{\pi R^4}$ r × 4πr²dr

or q = $\frac{4Q}{R^4}\int_0^{r_1} r^3 dr$

so , q = $\frac{Q.r_1^4}{R^4}$

Electric field at a distance r_1 from the center (inside)

E = $\frac{1}{4\pi\varepsilon_0}.\frac{q}{r_1^2}$

E = $\frac{1}{4\pi\varepsilon_0} \times \frac{Q.\, r_1^2}{R^4}$

21. Ans. (3)

Sol. $\vec{E} = \left(\frac{2k\lambda}{r}\right)(-\hat{j}) \Rightarrow \vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}(-\hat{j})$

$\lambda = \frac{q}{\pi r} \Rightarrow \vec{E} = \frac{q}{2\pi^2\varepsilon_0 r^2}(-\hat{j})$

22. Ans. **(2)**
Sol. Consider a spherical shell of radius x and thickness dx.
Charge on it dq

dq = ρ $\left(\frac{5}{4} - \frac{x}{R}\right)$ × 4πx² . dx

dq = ρ_0 x 4πx² dx

q = $4\pi\rho_0 \int_0^r \left(\frac{5x^2}{4} - \frac{x^3}{R}\right) dx$

$$q = 4\rho_0\left(\frac{5r^3}{3\times4}-\frac{r^4}{4R}\right)$$

$$E = \frac{kq}{r^2} = \frac{1}{4\pi r^2}\times 4\pi\rho_0\left(\frac{5r^3}{3\times4}-\frac{r^4}{4R}\right)$$

$$E = \frac{\rho_0 r}{4\rho_0}\left(\frac{5}{3}-\frac{r}{R}\right)$$

23. Ans. **(3)**

Sol. At equilibrium

$$\tan\theta/2 = \frac{F_e}{mg} = \frac{1}{4\pi\epsilon_0}\frac{q^2}{[\ell\sin(\theta/2)]^2}\cdot\frac{1}{mg}$$

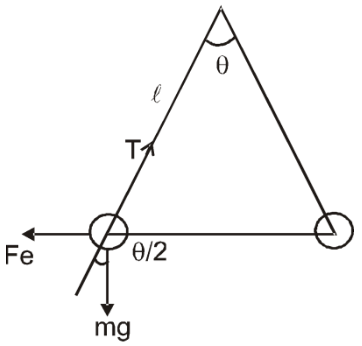
When suspended in liquid

$$\tan\frac{\theta}{2} = \frac{1}{4\pi\epsilon_0 K}\frac{q^2}{[\ell\sin(\theta/2)]^2}\frac{1}{(mg-F_B)}$$

$$= \frac{1}{4\pi\epsilon_0 K}\frac{q^2}{[\ell\sin(\theta/2)]^2}\cdot\frac{1}{(mg-\frac{m}{1.6}\times0.8g)}$$

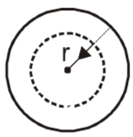
on comparing the two equation we get

$$K\left(1-\frac{0.8}{1.6}\right) = 1 \qquad \Rightarrow \qquad K = 2$$



24. **Ans.** **(4)**

Sol.



$\phi = ar^2 + b$

$$E = -\frac{d\phi}{dt} = -2ar \qquad\qquad \oint \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$$

$$-2ar\,.\,4\pi r^2 = \frac{q}{\varepsilon_0}$$

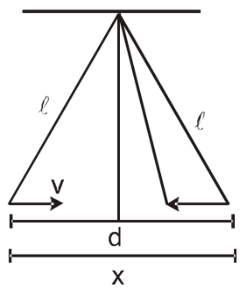
$q = -8\,\varepsilon_0 a\pi r^3$

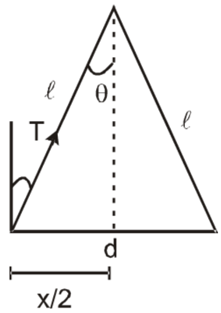
$$\rho = \frac{q}{\frac{4}{3}\pi r^3}$$

$\rho = -6a\varepsilon_0$ **Ans.**

25. **Ans.** **(1)**

Sol.





$\sin\theta = \frac{kq^2}{d^2}$

$\cos\theta = mg$

$\tan\theta = \frac{k}{mg}\cdot\frac{q^2}{x^2}$

$\frac{x}{2\ell}\cdot = \frac{k}{mg}\cdot\frac{q^2}{x^2}$

$x^3 = \frac{2k\ell}{mg}q^2$

$q^2 \propto x^3$

$q \propto x^{3/2}$

$\frac{dq}{dt} \propto \frac{3}{2}x^{1/2}\frac{dx}{dt}$ (dq/dt)

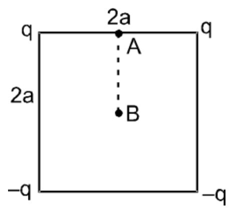
$c \propto x^{1/2}\,v$

$v \propto x^{-1/2}$.

26. **Ans.** **(4)**

Sol. Potential at point A,

$V_A = \frac{2Kq}{a} - \frac{2Kq}{a\sqrt{5}}$



Potential at point B,

$V_B = 0$

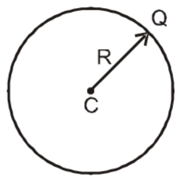
∴ Using work energy theroem,

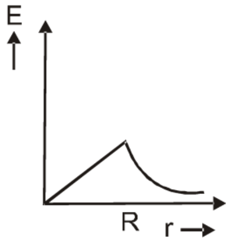
$W_{AB})_{electric} = Q(V_A - V_B)$

$= \frac{2KqQ}{a}\left[1-\frac{1}{\sqrt{5}}\right] = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{2Qq}{a}\left[1-\frac{1}{\sqrt{5}}\right]$

27. **Ans.** (3)

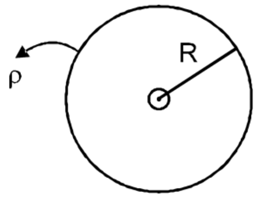
Sol.





28. **Ans.** (3)

Sol.



$U_c = \frac{3}{2}\frac{KQ}{R}q$

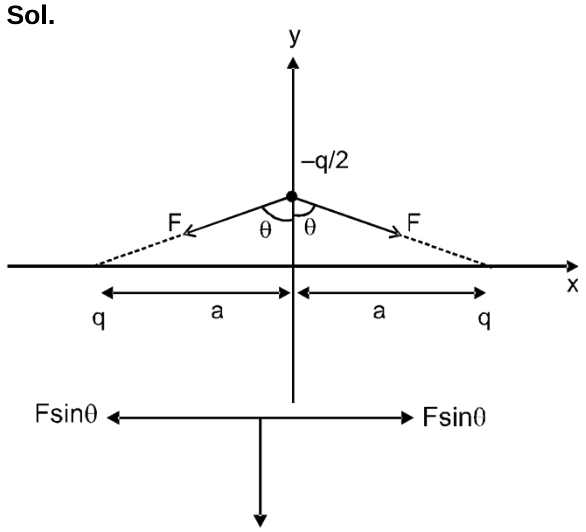
$U_S = \frac{KQ}{R}q$

$\therefore \quad \Delta U = \frac{KQ}{2R}q$

$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{1}{2R}\rho\frac{4\pi R^3}{3}q$

$= \frac{\rho R^2 q}{6\varepsilon_0}$

29. **Sol.**

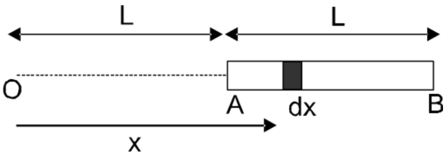


$\Rightarrow$ $2F\cos\theta$ $\Rightarrow$ $F_{net} = 2F\cos\theta$

$F_{net} = \frac{2kq\left(\frac{q}{2}\right)}{\left(\sqrt{y^2+a^2}\right)^2}\cdot\frac{y}{\sqrt{y^2+a^2}}$

$F_{net} = \frac{2kq\left(\frac{q}{2}\right)y}{(y^2+a^2)^{3/2}} \Rightarrow \frac{kq^2y}{a^3} \propto y$ **Ans. (1)**

30. **Sol.**



$V = \int_{L}^{2L} \frac{kdq}{x}$

$= \int_{L}^{2L} \frac{1}{4\pi\varepsilon_0} \frac{\left(\frac{q}{L}\right)dx}{x} = \frac{q}{4\pi\varepsilon_0 L}\ell n(2)$ **Ans. (4)**

31. **Ans.** **(3)**

Sol. $V_A - V_0 = -\int_O^A E_x dx$

$V_A - V_0 = \int_0^2 30x^2 dx$

$= -30 \frac{2^3}{3} = -80V$

32. **Ans.** **(1)**

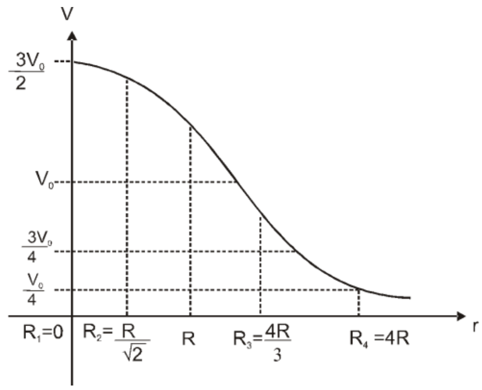
Sol. (2) and (3) is not possible since field lines should originate from positive and terminate to negative charge.

(4) is not possible since field lines must be smooth.

(1) satisfies all required condition.

33.* **Ans.** **(3, 4)**

Sol. $V_0 = \frac{KQ}{R}$



$V_{(r > R)} = \frac{KQ}{r}$

$V_{(r < R)} = \frac{KQ}{2R^3}(3R^2 - r^2)$

$V_{\text{centredsUæ}} = \frac{3}{2}\frac{KQ}{R} = \frac{3V_0}{2}$

V at R_2 (R_2 ij V) = $\frac{5V_0}{4} = \frac{kQ}{2R^3}(3R^2 - R_2^2)$

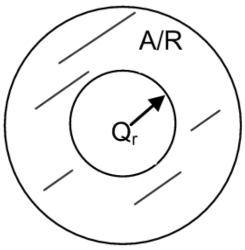
$\Rightarrow \frac{5}{2} = 3 - \frac{R_2^2}{R^2}$ $\Rightarrow$ $R_2 = \frac{R}{\sqrt{2}}$

V at R_3 (R_3 ij V) = $\frac{3V_0}{4} = \frac{kQ}{R_3}$ $\Rightarrow R_3 = \frac{4}{3}R$

V at R_4 (R_4 ij V) = $\frac{V_0}{4} = \frac{kQ}{R_4}$ $\Rightarrow$ $R_4 = 4R$

$\therefore$ $R_4 - R_3 = 4R - \frac{4}{3}R = \frac{8R}{3} > R_2$

34. Ans. (4)



$$(E)(4\pi r^2) = \frac{Q + \int_a^r \frac{A}{r} 4\pi r^2 dr}{\varepsilon_0}$$

$$\Rightarrow (E)\, 4\pi r^2 = \frac{Q + \frac{4\pi A}{2}(r^2 - a^2)}{\varepsilon_0}$$

$$\Rightarrow E = \frac{Q}{4\pi\varepsilon_0 r^2} + \frac{A}{\varepsilon_0 2r^2}(r^2 - a^2)$$

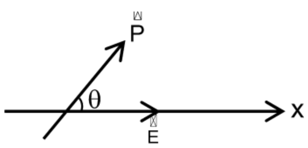
$$= \frac{Q}{4\pi\varepsilon_0 r^2} + \frac{A}{2\varepsilon_0} - \frac{Aa^2}{2\varepsilon_0 r^2}$$

$$\frac{Q}{4\pi\varepsilon_0} = \frac{Aa^2}{2\varepsilon_0}$$

$$A = \frac{Q}{2\pi a^2}$$

35. Ans. (4)

Sol.



$PE\sin\theta = P(\sqrt{3}E)\sin(90° - \theta)$

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

$\theta = 60°$

PART - II : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1.* **Ans.** (ABCD)

Sol. This is the variation of potential of a hollow sphere with the distance from the centre and the total charge within the sphere will be q.
As no electric field is doveloped within it, so electrostatic energy for $r \le R_0$ is zero.

and the total charge resides over its surface and also at r = R_0 electric field is discontinuous, since it changes abruptly.

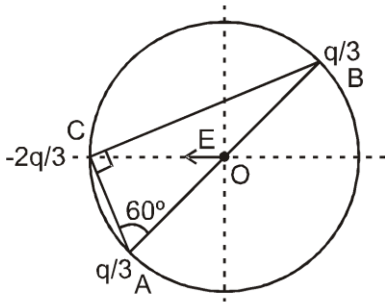
2. **Sol.** When inner cylinder is charged (outer cylinder may or maynot be charged) an electric field will be present in the gap between the cylinders which will produce a potential difference.

3. Ans. (D)
Sol. Sphere is electrically neutral therefore net charge will be zero. (by conservation of charge)

4. Ans. (C)
Sol. Both the points are at equitorial position. So,Potential is zero at both the points.
5. **Ans. (C)**

Sol. Net electric field due to both charges q/3, will get cancelled. Electric field due to $\left(\frac{-2q}{3}\right)$ will be directed in –ve axis

$$E = \frac{k\left(\frac{2q}{3}\right)}{R^2} \Rightarrow E = \frac{q}{6\pi\varepsilon_0 R^2}$$



P.E. of system = $\frac{K\left(\frac{q}{3}\right)^2}{2R} + \frac{K\frac{q}{3}\left(-\frac{2q}{3}\right)}{2R\sin 60^\circ} + \frac{K\frac{q}{3}\left(-\frac{2q}{3}\right)}{2R\cos 60^\circ}$
P.E. of system ≠ 0
Force between B and C

$$F = \frac{K\left(\frac{2q}{3}\right)\left(\frac{q}{3}\right)}{(2R\sin 60^\circ)^2} = \frac{4\times 2Kq^2}{9\times 4\times 3R^2} = \frac{2q^2}{9\times 3\times 4\pi\varepsilon_0 R^2} \text{ (attractive)} = \frac{1}{54}\frac{q^2}{\pi\epsilon_0 R^2}$$

Potential at O $V = \frac{K\left(\frac{q}{3}+\frac{q}{3}-\frac{2q}{3}\right)}{R} = 0$

6. **Sol.** Statement-1 is true by information
Statement-2 is true by formula. But statement-2 is not the explanation of 1.
Ans. (B) B (Ans. of JEE was A)

7. **Sol.** From Gauss's law

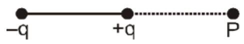
$$\frac{\Sigma Q_{in}}{\varepsilon_0} = \frac{(8C/4)-7C+(6C/2)}{\varepsilon_0} = -\frac{2C}{\varepsilon_0}$$

8. **Sol.** (A)
Torque about Q of charge –q is zero, so angular momentum charge –q is constant, but distance between charges is changing, so force is changing, so speed and velocity are changing.

9. **Sol.** The frequency will be same $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

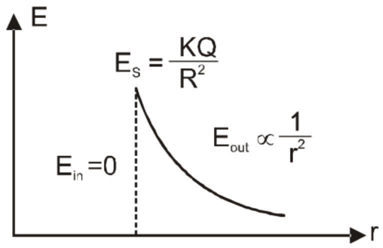
but due to the constant qE force, the equilibrium position gets shifted by $\frac{qE}{K}$ in forward direction. So Ans. will be (A)

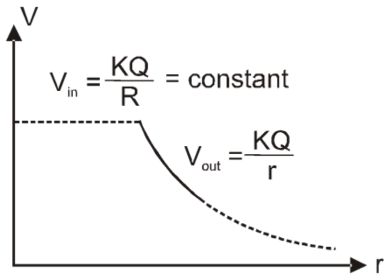
10. **Sol.** $\phi = \int E ds = \frac{Kq}{r^2}4\pi r^2 = \frac{q}{\varepsilon_0}$



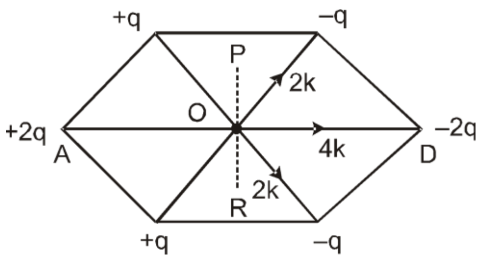
$W_{ext} = q(V_B - V_A)$
Comment : (D) is not crrect answer because it is not given that charge is moving slowly.

11. **Ans.** **(D)**
Sol.



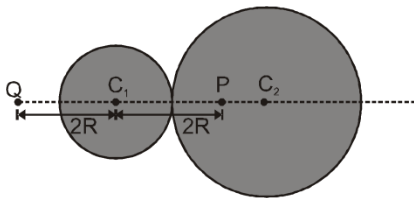


12.* **Ans.** **(A,B,C)**
Sol.



E_0 = 6 K (along OD)
$V_0 = 0$
Potential on line PR is zero
Ans. (A), (B), (C)

13.* **Ans.** **(B,D)**
Sol.



At point P
If resultant electric field is zero
then

$$\frac{KQ_1}{4R^2} = \frac{KQ_2}{8R^3}R$$

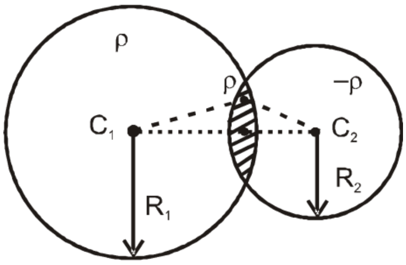
$$\frac{\rho_1}{\rho_2} = 4$$

At point Q
If resultant electric field is zero
then

$$\frac{KQ_1}{4R^2} + \frac{KQ_2}{25R^2} = 0$$

$$\frac{\rho_1}{\rho_2} = -\frac{32}{25}$$ (ρ_1 must be negative)

14.* **Ans.** (CD)
Sol.



For electrostatic field,

$$\vec{E}_P = \vec{E}_1 + \vec{E}_2$$

$$= \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1P} + \frac{(-\rho)}{3\varepsilon_0}\overrightarrow{C_2P}$$

$$= \frac{\rho}{3\varepsilon_0}(\overrightarrow{C_1P} + \overrightarrow{PC_2})$$

$$\vec{E}_P = \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1C_2}$$

For electrostatic potential, Since electric field is non zero so it is not equipotential.

15. **Ans.** **(C)**

Sol. $E_1 = \frac{KQ}{R^2}$

$E_2 = \frac{k(2Q)}{R^2} \Rightarrow E_2 = \frac{2kQ}{R^2}$

$E_3 = \frac{k(4Q)R}{(2R)^3} \Rightarrow E_3 = \frac{kQ}{2R^2}$

$E_3 < E_1 < E_2$

16. **Ans.** **(C)**

Sol. $$\frac{Q}{4\pi \in_0 r_0^2} = \frac{\lambda}{2\pi \in_0 r_0} = \frac{\sigma}{2 \in_0}$$

$Q = 2\pi\sigma r_0^2$ A incorrect

$r_0 = \frac{\lambda}{\pi\sigma}$ B incorrect

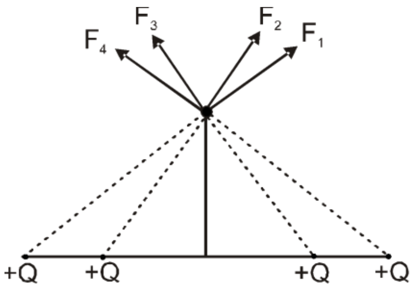
$E_1\left(\frac{r_0}{2}\right) = \frac{4E_1(r_0)}{1}$

$E_2\left(\frac{r_0}{2}\right) = 2E_2(r_0) \Rightarrow$ C correct

$E_3\left(\frac{r_0}{2}\right) = E_3(r_0) = E_2(r_0)$ D incorrect

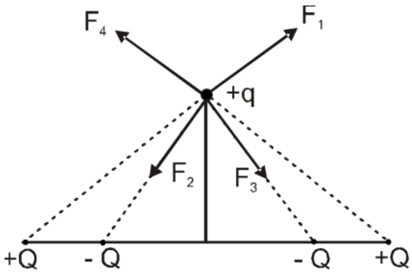
17. Ans. (A)

Sol. (P)

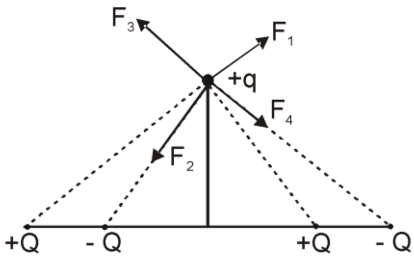


Component of forces along x-axis will vanish. Net force along +ve y-axis

Component of forces along y-axis will vanish. Net force along +ve x-axis



Component of forces along x-axis will vanish. Net force along -ve y-axis.



Component of forces along y-axis will vanish. Net force along -ve x-axis.

Ans. **(A)** P—3, Q—1, R—4, S—2

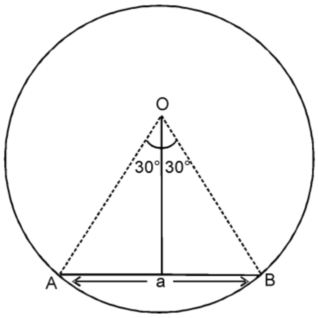
18. Ans 6

Sol. Flux from total cylindrical surface (angle = 2π)

$$= \frac{Q_{in}}{\varepsilon_0}$$

Flux from cylindrical surface AB = flux from the given surface

$$= \frac{Q_{in}}{6\varepsilon_0} = \frac{\lambda\ell}{6\varepsilon_0} = n = 6$$



19. **Ans** **(C)**

As +q is displaced towards right, the repulsion of right side wire will dominate and the net force on +q will be towards left, and vice versa

$F_{\text{restoring izR;ku cy}} = q\left(\frac{2k\lambda}{d-x} - \frac{2k\lambda}{d+x}\right) \Rightarrow \quad F_{\text{restoring izR;ku cy}} = \frac{2k\lambda(2x)q}{d^2 - x^2} \approx \left(\frac{4k\lambda q}{d^2}\right)x$

Hence SHM

For –q, as it is displaced towards right the attraction of right side wire will dominate, which forces the –q charge to move in the same direction of displacement similarity for other side

Hence it is not SHM.

20. **Ans.** **(D)**

Electric field in cavity

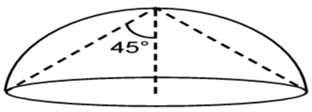
$\vec{E} = \frac{\rho \vec{OP}}{3 \in_0}$

OP = R_1 –- R_2

$= \frac{\rho \vec{a}}{3 \in_0}$

21. **Ans.** **(CD)**

Sol.



(A)

ϕ total due to charge Q is = $\frac{Q}{\varepsilon_0}$

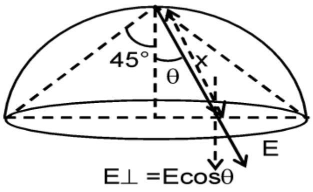
so ϕ through the curved and flat surface will be less than $\frac{Q}{\varepsilon_0}$

(B)

The component of the electric field perpendicular to the flat surface will decrease so we move away from the centre as the distance increases (magnitude of electric field decreases) as well as the angle between the normal and electric field will increase.

Hence the component of the electric field normal to the flat surface is not constant.

Aliter :



x = $\frac{R}{\cos\theta}$

E = $\frac{KQ}{x^2} = \frac{KQ\cos^2\theta}{R^2}$

E⊥ = $\frac{KQ\cos^3\theta}{R^2}$

As we move away from centre θ↑ cosθ↓ so E⊥↓

(C)

Since the circumference is equidistant from 'Q' it will be equipotential V = $\frac{KQ}{\sqrt{2}R}$

(D)

Ω = 2π(1 – cosθ); θ = 45°

ϕ = $-\frac{\Omega}{4\pi}\times\frac{Q}{\varepsilon_0} = -\frac{2\pi(1-\cos\theta)}{4\pi}\frac{Q}{\varepsilon_0}$

$= -\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$

Additional Problems For Self Practice (APSP)

PART-I : PRACTICE TEST PAPER

1. **Sol.** By M.E. conservation between initial & final point :
$U_i + K_i = U_f + K_f$
$\therefore$ Answer is (4)

2. **Sol.** $\because$ $E = \frac{F}{q}$ $\therefore$ $E = \frac{2000}{5} = 400$ N/C

Potential difference, $V = E.\,d = 400 \times \frac{2}{100} = 8V$

3. **Sol.** Property of equipotential surface

4. **Sol.** $\because$ $V = \frac{kq}{r} - \frac{kq}{3r}$ $V = \frac{2kq}{3r}$

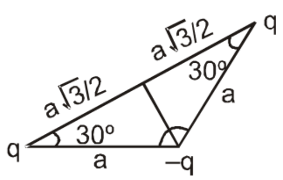
$\therefore$ Field intensity at distance 3r from centre = $\frac{kq}{9r^2} = \frac{V}{6r}$

5. **Sol.** The whole volume of a uniformly charged spherical shell is equipotential.

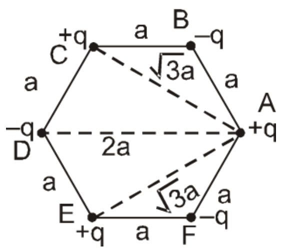
6. **Sol.** By conservation of machenical energy
$\frac{1}{2}mv^2 = \frac{kq_1q_2}{r_1} - \frac{kq_1q_2}{r_2}$ $\frac{1}{2}(2 \times 10^{-3})\,v^2 = 9 \times 10^9 \times 10^{-6} \times 10^{-3}\left(\frac{1}{1} - \frac{1}{10}\right)$

or $v^2 = 9 \times 10^3 \times \frac{9}{10}$ or $v = 90$ m/sec

7.# **Sol.**



$\Rightarrow$



(i) E.P.E. of charge +q at point A can be given as :

$E_A = \frac{-2kq^2}{a} + \frac{-2kq^2}{\sqrt{3}\,a} - \frac{kq^2}{2a}$ & E.P.E. of system

$\Rightarrow$ $E_S = \frac{E_A + E_B + E_C + E_D + E_E + E_F}{2}$

tgk¡ where $E_A = E_B = E_C = E_D = E_E = E_F$

$\therefore$ $E_S = 3\,E_A$

$\therefore$ $E_S = 6\left(-\frac{kq^2}{a}\right) + 6\left(\frac{kq^2}{a\sqrt{3}}\right) + 3\left(-\frac{kq^2}{2a}\right) = \frac{q^2}{\pi \in_0 a}\left[\frac{\sqrt{3}}{a} - \frac{15}{8}\right]$

8. **Sol.** $U = \frac{Kq^2}{a}\left(-1+2-\frac{2}{\sqrt{2}}\right)$

$= \frac{Kq^2}{a}(1-\sqrt{2})$ $\Rightarrow U = -\frac{Kq^2}{a}(\sqrt{2}-1)$

9. **Sol.** E = Field near sphere = $\frac{V}{R} = \frac{8000}{1\times10^{-2}}$ = 8×10^5 V/m

$\therefore$ Energy density = $\frac{1}{2}\varepsilon_0 E^2 = \frac{4\pi\varepsilon_0}{8\pi}$ $E^2 = \frac{8\times8\times10^{10}}{8\pi\times9\times10^9} = \frac{80}{9\pi}$ = 2.83 J/m^3.

11. **Sol.** $E = -\frac{dV}{dx}$ = –10 × –10

$\therefore$ $E_{(x=1m)}$ – 10 (1) – 10 = – 20 V/m

12. **Sol.** A = (O, O), B = (x_o, O)

$\int_A^B \bar{E}.d\bar{n}$ = $V_A - V_B$ = O – V_B

$E_o X_o = -V_B$

$V_B = -E_o x_o$

13.# **Sol.** Since P & Q are axial & equatorial points, so electric fields are parallel to axis at both points.

14. **Sol.** Work done in moving a dipole by angle θ in a given electric field E

W = pE (1 – cosθ)

= PE(1 – cos 60º) = $\frac{PE}{2}$

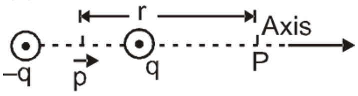
For θ = 180º

W' = PE (1 – cos 180º) = 2pE = 4W

15. **Sol.** $\tau_{max} = PE$ = $4 \times 10^{-8} \times 2 \times 10^{-4} \times 4 \times 10^8$ = 32×10^{-4} N-m.

Work done = $(P.E.)_f - (P.E.)_i$ = PE – (–PE) = 2PE = 64×10^{-4} N-m

16. **Sol.**



At a point 'P' on axis of dipole electric field E = $\frac{2kp}{r^3}$ and electric potential V = $\frac{kp}{r^2}$

both nonzero and electric field along dipole on the axis.

17. **Sol.** Force on one dipole due to another

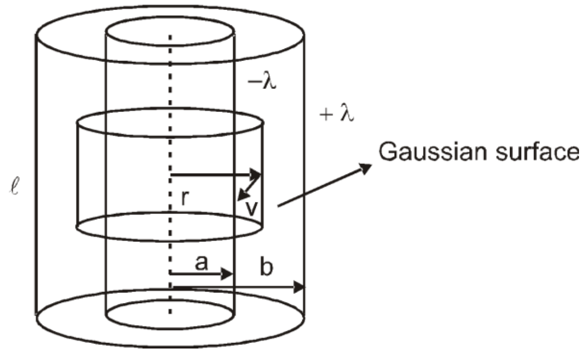
$= P\left(\frac{dE}{dr}\right)$ where E is field due to second dipole at first dipole.

$E \;\alpha\; \frac{1}{r^3}$ $\therefore$ $\frac{dE}{dr}\,\alpha\,\frac{1}{r^4}$ $\therefore$ Force $\alpha\,\frac{1}{r^4}$

18.# **Sol.** Density of electric field lines at a point i.e. no. of lines per unit area shows magnitude of electric field at that point.

19. **Sol.** Since, dipole has net charge zero, so flux through sphere is zero with non-zero electric field at each point of sphere.

20.# **Sol.**



Using Gauss's law for Gaussian surface shown in figure.

$\oint \vec{E}.\vec{dA} = \frac{q_{in}}{\varepsilon_0}$; E. $2\pi r\ell = \frac{\lambda\ell}{\varepsilon_0}$ $\therefore$ $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

For circular motion.

$qE = \frac{mV^2}{r} = \frac{q\lambda}{2\pi\varepsilon_0 r}$ $\therefore$ $V = \sqrt{\frac{q\lambda}{2\pi\varepsilon_0 m}}$

21.# **Sol.** For the closed surface made by disc and hemisphere

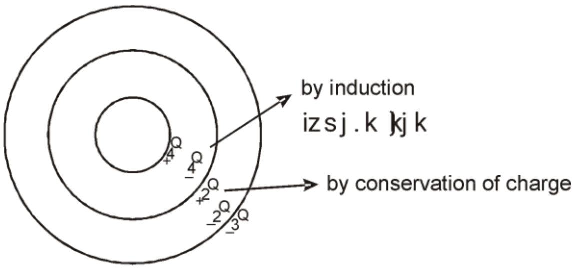
$q_{in} = 0$ $\therefore$ $\phi_{net} = 0$

$\phi_{disc} + \phi_{H.S} = 0$

$\therefore$ $\phi_{HS} = -\phi_{disc} = -\phi$

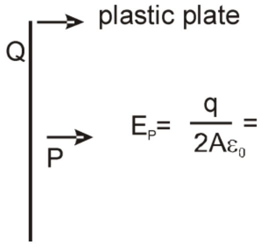
22. **Sol.** Induction takes place on outer surface of sphere producing non-uniform charge distribution & since external electric field can not enter the sphere, so interior remains charge free.

23. **Sol.**



Given diagram shows the charge distribution on shells due to induction & conservation of charge.

24. **Sol.**



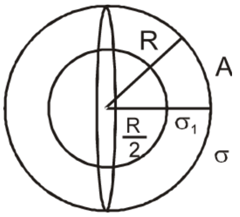
$E_P = \frac{q}{2A\varepsilon_0} = 50$ V/m

$E_P = \frac{q/2}{2A\varepsilon_0} + \frac{q/2}{2A\varepsilon_0} = \frac{q}{2A\varepsilon_0} = 50\,V/m$

25.# **Sol.** Since A, B and C are at same potantial electric field inside C must be zero. for this final charge on A and B must be zero. and final charge on C = Q + q_1 + q_2. (By conservation of charge)

$\because$ All charge comes out to the surface of C.

26._ **Sol.**



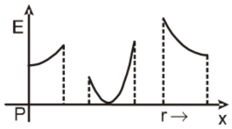
Let surface charge density on inner shell is σ_1

Due to inner sphere, field at A = $\frac{1}{4} \times \frac{\sigma_1}{\varepsilon_0} = \frac{\sigma_1}{4\varepsilon_0}$,

and electrostatic pressure at point A. = $\frac{\sigma^2}{2\varepsilon_0} + \frac{\sigma_1\sigma}{4\varepsilon_0}$

$\Rightarrow \sigma^2 + \frac{\sigma_1\sigma}{2} = 0$, or $\sigma_1 = -2\sigma$

27. **Sol.** Electric field being a vector quatnity gets added or substracted accordingly. So somewhere the field can be zero (where the field due to both the charges are equal and opposite).Also the electric field is inversely proportional to the distance (x). Hence the E–x graph is represented by



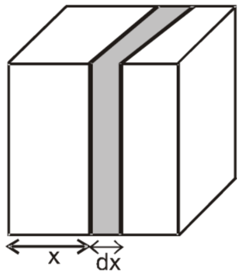
28. **Sol.** $\therefore \frac{1}{2}mV_A^2 = qV$, $\frac{1}{2}mV_B^2 = 4\,qV$ $\therefore \frac{V_A^2}{V_B^2} = \frac{1}{4}$ $\Rightarrow \frac{V_A}{V_B} = \frac{1}{2}$

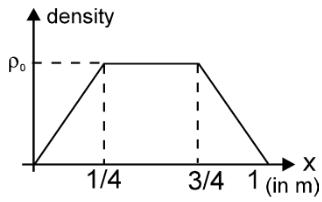
29.# **Sol.** Net flux through the cube, $\phi_{net} = \frac{q_{in}}{\varepsilon_0}$

To find q_{in}, let's divide the cube into small elements, and consider a small element of width dx as shown.

Charge on the small element = (ρ) (A.dx)

Total charge = $\int \rho A\, dx$





$= A\int \rho\, dx$

= (A) (Area of ρ–x graph)

$= (1)^2 \left(\frac{1}{2}\left(1+\frac{1}{2}\right)(\rho_0)\right)$

$= \frac{3}{4}\rho_0.$

$\Rightarrow$ Net flux $\phi_{net} = \frac{q_{in}}{\varepsilon_0} = \frac{\frac{3}{4}\rho_0}{\varepsilon_0} = \frac{3}{4}$ (as $\rho_0 = 8.85 \times 10^{-12}$)

30.# **Sol.** Force on Q due to E is QE. and not zero. Force on Q is zero due to E & electric field of induced outer charges on sphere.
Charge density on inner surface is not uniform therefore net force on charge Q is not zero.
Due to E, net force on shell is zero because net charge on shell is zero.

Practice Test (JEE-Main Pattern)

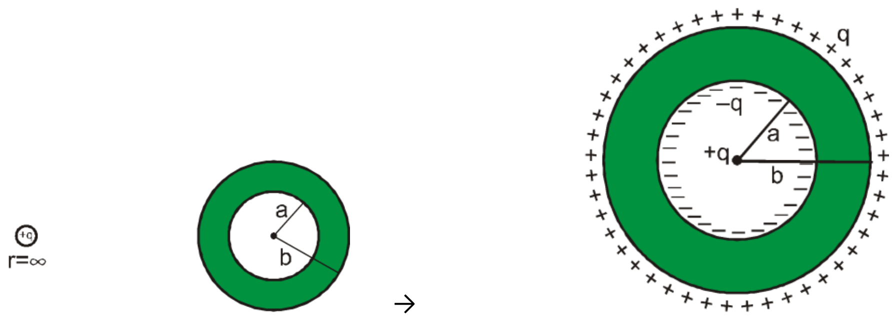
OBJECTIVE RESPONSE SHEET (ORS)

Que.	1	2	3	4	5	6	7	8	9	10
Ans.										
Que.	11	12	13	14	15	16	17	18	19	20
Ans.										
Que.	21	22	23	24	25	26	27	28	29	30
Ans.										

PART - II : PRACTICE QUESTIONS

Practice Questions: 20-50 depending on chapter length.

1.# **Sol.**



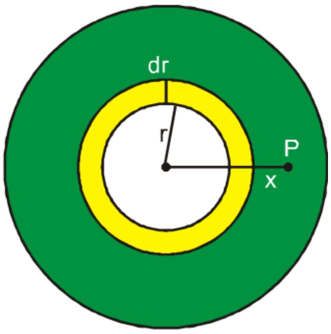
Work done by external agent :

$W_{ext} = U_F - U_i$

$$\therefore \quad W_{ext} = \left(\frac{Kq^2}{2a} + \frac{Kq^2}{2b} + \frac{K(+q)(-q)}{(a)} + \frac{K(-q)(+q)}{b} + \frac{K(+q)(+q)}{b}\right) - 0 = \frac{Kq^2}{2b} - \frac{Kq^2}{2a}$$

2. **Sol.** Lets take a small spherical element of thickness dr.

Electric field at point P due to this element :



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

$\therefore$ Total electric field :

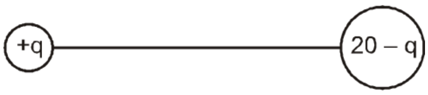
$$E = \int \frac{K\,dq}{x^2}$$

$$E = \int \frac{K(\text{density})(\text{volume of the element})}{x^2}$$

$$E = \int_{r=\infty}^{r=x} \frac{K(\rho_0 r^2)(4\pi r^2 dr)}{x^2}$$

$$E = \frac{K\rho_0}{x^2}\left(\frac{x^5}{5}\right) = \frac{x\rho_0}{5}\,(x^3) \qquad \therefore\ (E \propto x^3)$$

3. **Sol.**



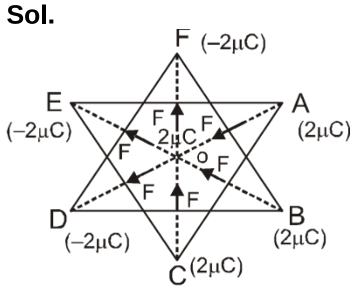
Let the two charges are q & (20 – q) μC

$$\therefore F_e = \frac{K(q)(20-q)}{r^2}$$

F_e will be max, when $\dfrac{dF_e}{dq} = 0$

or $\frac{dFe}{dq} = \frac{K}{r^2}(20 - 2q) = 0$
$\Rightarrow$ $\therefore$ q = 10 μC.

4.# **Sol.**



The given figure shows force diagram for charge at O due to all other charges with r = $\frac{10}{\sqrt{3}}$ cm

$\therefore$ $F_{net} = 2F + 4F \cos 60^o = 4F$

$$= \frac{4k(2\mu c)(2\mu c)}{\left(\frac{10}{\sqrt{3}100}\right)^2} = \frac{4 \times 9 \times 10^9 \times 2 \times 2 \times 10^{-12}}{\left(\frac{1}{300}\right)} = 36 \times 4 \times 300 \times 10^{-3} \text{ N} = 43.2 \text{ N. (Towards E)}$$

5. **Sol.** Since, no external electric field can enter into a conductor so force experienced by Q = 0

6.# **Sol.** Potential energy= $-\vec{P}_1 \cdot \vec{E}$; where, $\vec{E}$ = Electric field due to dipole P_2.

$\therefore$ $U_{12} = -(P_1)(E_2)$

$U_{12} = -(P_1)\left(\frac{2KP_2 \cos\theta}{r^3}\right)$

7.# **Sol.** T = $2\pi\sqrt{\frac{\ell}{g_{eff}}}$; where, $g_{eff} = \frac{mg - qE}{m}$

$= g - \frac{qE}{m}$ $\therefore$ Time period increases.

8. **Sol.** Electric field at given location is only due to inner solid metalic sphere.

9. **Sol.** P.D, = $\int \vec{E}.\vec{dr}$ and E between spheres does not depend on charge on outer sphere.

10.# **Sol.** B & C are equipotential and field is conservative, therefore :

$\therefore$ $W_{CA} = W_{BA}$. $= -\int_{2a}^{a} \frac{\lambda}{2\pi\varepsilon_0 r} q\,dr.$ $= \frac{q\lambda}{2\pi\varepsilon_0} \ln 2$

11.# **Sol.** (B) In a conductor, potential is same everywhere

$\therefore$ Potential at A = potential at centre = $V_{\text{due to p}} + V_{\text{due to induced charges}}$

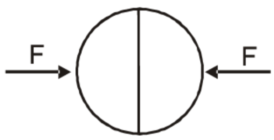
$= \frac{kp}{(r\sec\phi)^2} + 0 = \frac{kp\cos^2\phi}{r^2}$

12.# Sol. **(C)** Total flux through closed cubical vessel = $\frac{q}{\varepsilon_0}$.

& Flux through one face = $\frac{1}{6}\left(\frac{q}{\varepsilon_0}\right)$

So, total flux passing through given cubical vessel is = $5\left(\frac{q}{6\varepsilon_0}\right)$; (as vessel has 5 faces)

13.# Ans. (1)
Sol.



Electrostatics repulsive force ; $F_{ele} = \left(\frac{\sigma^2}{2\varepsilon_0}\right)\pi R^2$; $F = F_{ele} = \frac{\sigma^2 \pi R^2}{2\varepsilon_0}$

14. Ans. (4)
Sol. In equilibrium,

$mg = qE$

In absence of electric field,

$mg = 6\pi\eta rv$

$\Rightarrow \quad qE = 6\pi q rv$

$m = \frac{4}{3}\pi R r^3 d. = \frac{qE}{g}$

$\frac{4}{3}\pi\left(\frac{qE}{6\pi\eta v}\right)^3 d = \frac{qE}{g}$

After substituting value we get,

$q = 8 \times 10^{-19}$ C **Ans.**

15.# Sol. According to option (A) the electric field due to P and S and due to Q and T add to zero. While due to U and R will be added up. Hence the correct option is (A).

16. Sol. (3) The electric field at the surface will be due to all charges. However, net flux coming out of the surface will be = $\phi_{net} = \frac{q_{in}}{\varepsilon_0} = \frac{q_1 - q_1}{\varepsilon_0} = 0$.