ELECTROSTATICS

1. Two point charges $q_1(\sqrt{10}\ \mu C)$ and $q_2(-25\ \mu C)$ are placed on the x-axis at x = 1 m and x = 4 m respectively. The electric field (in V/m) at a point y = 3 m on y-axis is,

$\left[\text{take}\ \frac{1}{4\pi\varepsilon_0} = 9\times10^9\,\text{Nm}^2\text{C}^{-2}\right]$

(1) $(-63\hat{i}+27\hat{j})\times10^2$

(2) $(81\hat{i}-81\hat{j})\times10^2$

(3) $(63\hat{i}-27\hat{j})\times10^2$

(4) $(-81\hat{i}+81\hat{j})\times10^2$

2. Charge is distributed within a sphere of radius R with a volume charge density $\rho(r) = \frac{A}{r^2}e^{-2r/a}$, where A and a are constants. If Q is the total charge of this charge distribution, the radius R is :

(1) $\frac{a}{2}\log\left(1-\frac{Q}{2\pi aA}\right)$

(2) $a\log\left(1-\frac{Q}{2\pi aA}\right)$

(3) $a\log\left(\frac{1}{1-\frac{Q}{2\pi aA}}\right)$

(4) $\frac{a}{2}\log\left(\frac{1}{1-\frac{Q}{2\pi aA}}\right)$

3. Three charges +Q, q, + Q are placed respectively, at distance, 0, d/2 and d from the origin, on the x-axis. If the net force experienced by + Q, placed at x = 0, Ls zero, then value of q is :

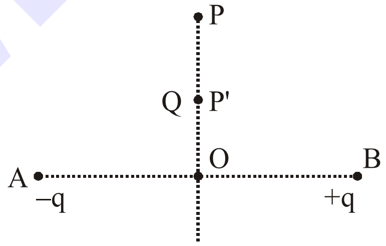
(1) +Q/2 (2) –Q/2
(3) –Q/4 (4) +Q/4

4. For a uniformly charged ring of radius R, the electric field on its axis has the largest magnitude at a distance h from its centre. Then value of h is :

(1) $\frac{R}{\sqrt{5}}$ (2) R

(3) $\frac{R}{\sqrt{2}}$ (4) $R\sqrt{2}$

5. Charges –q and +q located at A and B, respectively, constitute an electric dipole. Distance AB = 2a, O is the mid point of the dipole and OP is perpendicular to AB. A charge Q is placed at P where OP = y and y >> 2a. The charge Q experiences and electrostatic force F. If Q is now moved along the equatorial line to P' such that $OP' = \left(\frac{y}{3}\right)$, the force on Q will be close to : $\left(\frac{y}{3} >> 2a\right)$



(1) $\frac{F}{3}$ (2) 3F (3) 9F (4) 27F

6. Four equal point charges Q each are placed in the xy plane at (0, 2), (4, 2), (4, –2) and (0, –2). The work required to put a fifth charge Q at the origin of the coordinate system will be :

(1) $\frac{Q^2}{2\sqrt{2}\pi\varepsilon_0}$ (2) $\frac{Q^2}{4\pi\varepsilon_0}\left(1+\frac{1}{\sqrt{5}}\right)$

(3) $\frac{Q^2}{4\pi\varepsilon_0}\left(1+\frac{1}{\sqrt{3}}\right)$ (4) $\frac{Q^2}{4\pi\varepsilon_0}$

7. A charge Q is distributed over three concentric spherical shells of radii a, b, c $(a < b < c)$ such that their surface charge densities are equal to one another. The total potential at a point at distance r from their common centre, where $r < a$, would be :

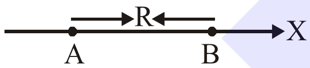
(1) $\dfrac{Q}{4\pi\varepsilon_0(a+b+c)}$

(2) $\dfrac{Q(a+b+c)}{4\pi\varepsilon_0(a^2+b^2+c^2)}$

(3) $\dfrac{Q}{12\pi\varepsilon_0}\dfrac{ab+bc+ca}{abc}$

(4) $\dfrac{Q}{4\pi\varepsilon_0}\dfrac{(a^2+b^2+c^2)}{(a^3+b^3+c^3)}$

8. Two electric dipoles, A, B with respective dipole moments $\vec{d}_A = -4qa\hat{i}$ and $\vec{d}_B = -2qa\hat{i}$ placed on the x-axis with a separation R, as shown in the figure



The distance from A at which both of them produce the same potential is :

(1) $\dfrac{\sqrt{2}R}{\sqrt{2}+1}$ (2) $\dfrac{R}{\sqrt{2}+1}$

(3) $\dfrac{\sqrt{2}\,R}{\sqrt{2}-1}$ (4) $\dfrac{R}{\sqrt{2}-1}$

9. An electric field of 1000 V/m is applied to an electric dipole at angle of 45°. The value of electric dipole moment is 10^{-29} C.m. What is the potential energy of the electric dipole ?

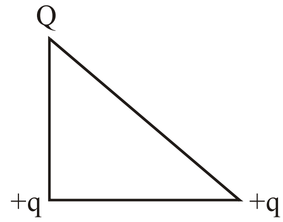
(1) -9×10^{-20} J

(2) -7×10^{-27} J

(3) -10×10^{-29} J

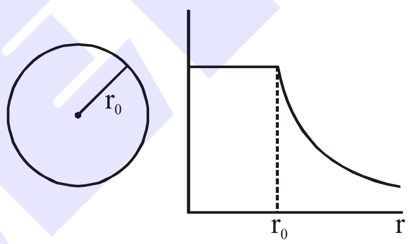
(4) -20×10^{-18} J

10. The charges Q + q and +q are placed at the vertices of a right-angle isosceles triangle as shown below. The net electrostatic energy of the configuration is zero, it the value of Q is:



(1) $\dfrac{-\sqrt{2}q}{\sqrt{2}+1}$ (2) $-2q$ (3) $\dfrac{-q}{1+\sqrt{2}}$ (4) +q

11. The given graph shows variation (with distance r from centre) of :



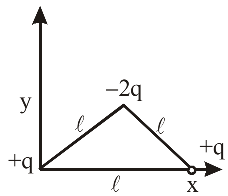
(1) Potential of a uniformly charged sphere

(2) Potential of a uniformly charged spherical shell

(3) Electric field of uniformly charged spherical shell

(4) Electric field of uniformly charged sphere

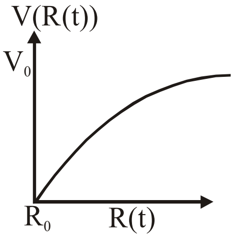
12. Determine the electric dipole moment of the system of three charges, placed on the vertices of an equilateral triangle, as shown in the figure:

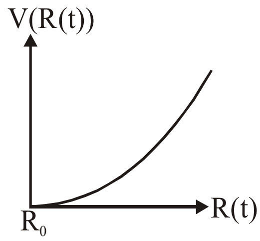


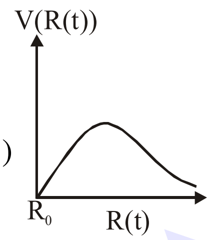
(1) $(q\ell)\dfrac{\hat{i}+\hat{j}}{\sqrt{2}}$ (2) $\sqrt{3}q\ell\dfrac{\hat{j}-\hat{i}}{\sqrt{2}}$

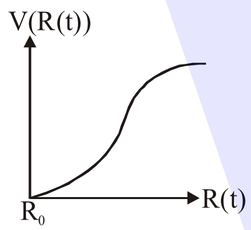
(3) $-\sqrt{3}q\ell\hat{j}$ (4) $2q\ell\hat{j}$

13. There is a uniform spherically symmetric surface charge density at a distance R_0 from the origin. The charge distribution is initially at rest and starts expanding because of mutual repulsion. The figure that represents best the speed V(R(t)) of the distribution as a function of its instantaneous radius R (t) is :

(1)


(2)


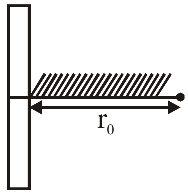
(3)


(4)


14. An electric dipole is formed by two equal and opposite charges q with separation d. The charges have same mass m. It is kept in a uniform electric field E. If it is slightly rotated from its equilibrium orientation, then its angular frequency ω is :-

(1) $\sqrt{\frac{qE}{2md}}$ (2) $2\sqrt{\frac{qE}{md}}$ (3) $\sqrt{\frac{2qE}{md}}$ (4) $\sqrt{\frac{qE}{md}}$

15. A positive point charge is released from rest at a distance r_0 from a positive line charge with uniform density. The speed (v) of the point charge, as a function of instantaneous distance r from line charge, is proportional to :-



(1) $v \propto e^{+r/r_0}$

(2) $v \propto \ell n\left(\frac{r}{r_0}\right)$

(3) $v \propto \left(\frac{r}{r_0}\right)$

(4) $v \propto \sqrt{\ell n\left(\frac{r}{r_0}\right)}$

16. The electric field in a region is given by $\vec{E} = (Ax + B)\hat{i}$, where E is in NC^{-1} and x is in metres. The values of constants are A = 20 SI unit and B = 10 SI unit. If the potential at x = 1 is V_1 and that at x = –5 is V_2, then $V_1 - V_2$ is :-

(1) –48 V

(2) –520 V

(3) 180 V

(4) 320 V

17. The bob of a simple pendulum has mass 2g and a charge of 5.0 μC. It is at rest in a uniform horizontal electric field of intensity 2000 V/m. At equilibrium, the angle that the pendulum makes with the vertical is : (take g = 10 m/s^2)

(1) $\tan^{-1}(5.0)$

(2) $\tan^{-1}(2.0)$

(3) $\tan^{-1}(0.5)$

(4) $\tan^{-1}(0.2)$

18. A solid conducting sphere, having a charge Q, is surrounded by an uncharged conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of the hollow shell be V. If the shell is now given a charge of –4 Q, the new potential difference between the same two surfaces is :

(1) V (2) 2V

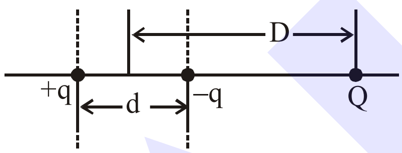
(3) –2V (4) 4V

19. Four point charges –q, +q, +q and –q are placed on y-axis at y = –2d, y = –d, y = +d and y = +2d, respectively. The magnitude of the electric field E at a point on the x-axis at x = D, with D >> d, will behave as :-

(1) $E \propto \frac{1}{D}$ (2) $E \propto \frac{1}{D^3}$

(3) $E \propto \frac{1}{D^2}$ (4) $E \propto \frac{1}{D^4}$

20. A system of three charges are placed as shown in the figure :



If D >> d, the potential energy of the system is best given by :

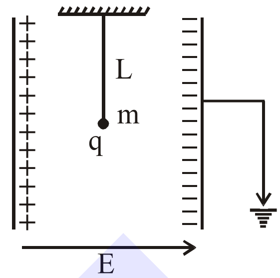
(1) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{2D^2}\right]$

(2) $\frac{1}{4\pi\varepsilon_0}\left[+\frac{q^2}{d}+\frac{qQd}{D^2}\right]$

(3) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}+\frac{2qQd}{D^2}\right]$

(4) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{D^2}\right]$

21. A simple pendulum of length L is placed between the plates of a parallel plate capacitor having electric field E, as shown in figure. Its bob has mass m and charge q. The time period of the pendulum is given by :



(1) $2\pi\sqrt{\frac{L}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$ (2) $2\pi\sqrt{\frac{L}{\left(g+\frac{qE}{m}\right)}}$

(3) $2\pi\sqrt{\frac{L}{\left(g-\frac{qE}{m}\right)}}$ (4) $2\pi\sqrt{\frac{L}{\sqrt{g^2-\frac{q^2E^2}{m^2}}}}$

22. In free space, a particle A of charge 1 μC is held fixed at a point P. Another particle B of the same charge and mass 4 μg is kept at a distance of 1 mm from P. if B is released, then its velocity at a distance of 9 mm from P is :

$\left[\text{Take } \frac{1}{4\pi\varepsilon_0}=9\times10^9\,\text{Nm}^2\,\text{C}^{-2}\right]$

(1) 2.0×10^3 m/s (2) 3.0×10^4 m/s

(3) 1.5×10^2 m/s (4) 1.0 m/s

23. A uniformly charged ring of radius 3a and total charge q is placed in xy-plane centred at origin. A point charge q is moving towards the ring along the z-axis and has speed *u* at z = 4a. The minimum value of *u* such that it crosses the origin is :

(1) $\sqrt{\frac{2}{m}}\left(\frac{1}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

(2) $\sqrt{\frac{2}{m}}\left(\frac{2}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

(3) $\sqrt{\frac{2}{m}}\left(\frac{4}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

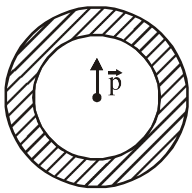
(4) $\sqrt{\frac{2}{m}}\left(\frac{1}{5}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

24. Let a total charge 2Q be distributed in a sphere of radius R, with the charge density given by $\rho(r) = kr$, where r is the distance from the centre. Two charges A and B, of –Q each, are placed on diametrically opposite points, at equal distance, a, from the centre. If A and B do not experience any force, then :

(1) $a = \frac{3R}{2^{1/4}}$ (2) $a = R/\sqrt{3}$

(3) $a = 8^{-1/4}R$ (4) $a = 2^{-1/4}R$

25. Shown in the figure is a shell made of a conductor. It has inner radius a and outer radius b, and carries charge Q. At its centre is a dipole $\vec{p}$ as shown. In this case :



(1) Electric field outside the shell is the same as that of a point charge at the centre of the shell.

(2) Surface charge density on the inner surface of the shell is zero everywhere.

(3) Surface charge density on the inner surface is uniform and equal to $\frac{(Q/2)}{4\pi a^2}$.

(4) Surface charge density on the outer surface depends on $|\vec{p}|$

26. A point dipole $\vec{p} = -p_0\hat{x}$ is kept at the origin. The potential and electric field due to this dipole on the y-axis at a distance d are, respectively: (Take V = 0 at infinity) :

(1) $\frac{|\vec{p}|}{4\pi\varepsilon_0 d^2}, \frac{-\vec{p}}{4\pi\varepsilon_0 d^3}$

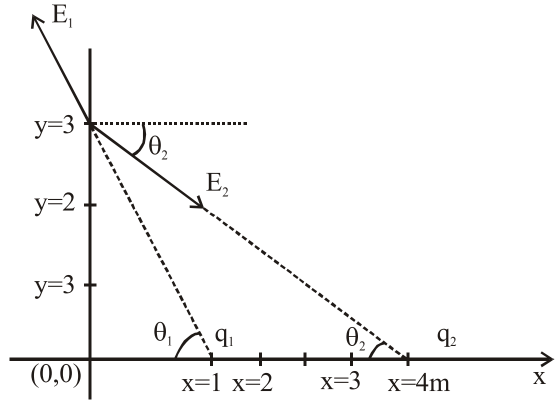
(2) $0, \frac{\vec{p}}{4\pi\varepsilon_0 d^3}$

(3) $\frac{|\vec{p}|}{4\pi\varepsilon_0 d^2}, \frac{\vec{p}}{4\pi\varepsilon_0 d^3}$

(4) $0, \frac{-\vec{p}}{4\pi\varepsilon_0 d^3}$

SOLUTION

1. Ans. (3)



Let $\vec{E}_1$ & $\vec{E}_2$ are the vaues of electric field due to q_1 & q_2 respectively magnitude of

$$E_2 = \frac{1}{4\pi \in_0} \frac{q_2}{r^2}$$

$$E_2 = \frac{9\times 10^9 \times (25)\times 10^{-6}}{(4^2+3^2)} V/m$$

$E_2 = 9 \times 10^3$ V/m

$$\therefore \vec{E}_2 = 9\times 10^3 (\cos\theta_2 \hat{i} - \sin\theta_2 \hat{j})$$

$$\because \tan\theta_2 = \frac{3}{4}$$

$$\therefore \vec{E}_2 = 9\times 10^3 \left(\frac{4}{5}\hat{i} - \frac{3}{5}\hat{j}\right) = (72\hat{i} - 54\hat{j})\times 10^2$$

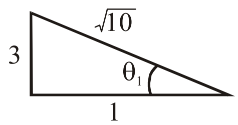
Magnitude of $E_1 = \frac{1}{4\pi \in_0} \frac{\sqrt{10}\times 10^{-6}}{(1^2+3^2)}$

$$= (9\times 10^9)\times \sqrt{10}\times 10^{-7}$$

$$= 9\sqrt{10}\times 10^2$$

$$\therefore \vec{E}_1 = 9\sqrt{10}\times 10^2 \left[\cos\theta_1 (-\hat{i}) + \sin\theta_1 \hat{j}\right]$$

$\therefore \tan\theta_1 = 3$



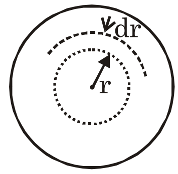
$$E_1 = 9\times \sqrt{10}\times 10^2 \left[\frac{1}{\sqrt{10}}(-\hat{i}) + \frac{3}{\sqrt{10}}\hat{j}\right]$$

$$E_1 = 9\times 10^2 \left[-\hat{i} + 3\hat{j}\right] = \left[-9\hat{i} + 27\hat{j}\right]10^2$$

$$\therefore \vec{E} = \vec{E}_1 + \vec{E}_2 = (63\hat{i} - 27\hat{j})\times 10^2 \, V/m$$

$\therefore$ correct answer is (3)

2. Ans. (4)



$$Q = \int \rho dv$$

$$= \int_0^R \frac{A}{r^2} e^{-2r/a} (4\pi r^2 dr)$$

$$= \int_0^R \frac{A}{r^2} e^{-2r/a} (4\pi r^2 dr)$$

$$= 4\pi A \int_0^R e^{-2r/a} dr$$

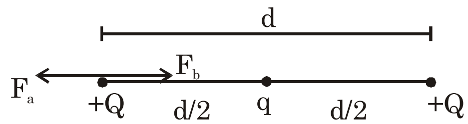
$$= 4\pi A \left(\frac{e^{-2r/a}}{-\frac{2}{a}}\right)_0^R$$

$$= 4\pi A \left(-\frac{a}{2}\right)(e^{-2R/a} - 1)$$

$Q = 2\pi a A(1 - e^{-2R/a})$

$$R = \frac{a}{2}\log\left(\frac{1}{1-\frac{Q}{2\pi a A}}\right)$$

3. Ans. (3)



For equilibrium,

$$\vec{F}_a + \vec{F}_B = 0$$

$$\vec{F}_a = -\vec{F}_B$$

$$\frac{kQQ}{d^2} = -\frac{kQq}{(d/2)^2}$$

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

4. Ans. (3)

Electric field on axis of ring

$$E = \frac{kQh}{(h^2 + R^2)^{3/2}}$$

for maximum electric field

$$\frac{dE}{dh} = 0$$

$$\Rightarrow h = \frac{R}{\sqrt{2}}$$

5. Ans. (4)

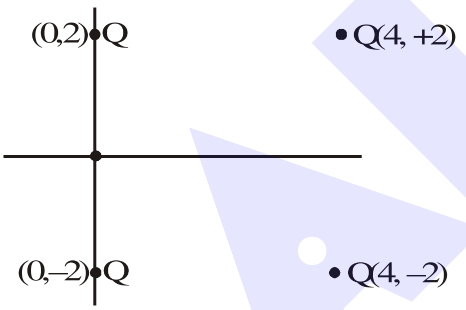
Electric field of equitorial plane of dipole

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

$\therefore$ At P, $F = -\frac{K\vec{P}}{r^3}Q.$

At P^1, $F^1 = -\frac{K\vec{P}Q}{(r/3)^3} = 27F.$

6. Ans. (2)



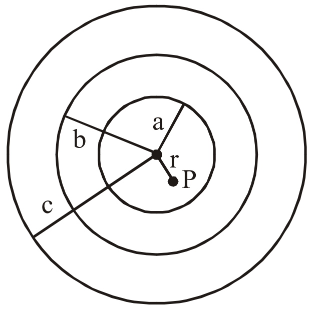
Potential at origin $= \frac{KQ}{2} + \frac{KQ}{2} + \frac{KQ}{\sqrt{20}} + \frac{KQ}{\sqrt{20}}$

(Potential at $\infty = 0$)

$$= KQ\left(1 + \frac{1}{\sqrt{5}}\right)$$

$\therefore$ Work required to put a fifth charge Q at origin is equal to $\frac{Q^2}{4\pi\varepsilon_0}\left(1 + \frac{1}{\sqrt{5}}\right)$

7. Ans. (2)



Potential at point P, $V = \frac{kQ_a}{a} + \frac{kQ_b}{b} + \frac{kQ_c}{c}$

$\because Q_a : Q_b : Q_c :: a^2 : b^2 : c^2$

{since $\sigma_a = \sigma_b = \sigma_c$}

$$\therefore Q_a = \left[\frac{a^2}{a^2 + b^2 + c^2}\right]Q$$

$$Q_b = \left[\frac{b^2}{a^2 + b^2 + c^2}\right]Q$$

$$Q_c = \left[\frac{c^2}{a^2 + b^2 + c^2}\right]Q$$

$$V = \frac{Q}{4\pi\epsilon_0}\left[\frac{(a + b + c)}{a^2 + b^2 + c^2}\right]$$

$\therefore$ correct answer is (2)

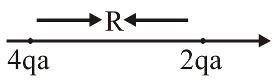
8. Correct Ans. (3)

According to JEE-Mains Ans. key (1 or 3)

$$V = \frac{4qa}{(R + x)} = \frac{2qa}{(x^2)}$$

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

$$x = \frac{R}{\sqrt{2} - 1}$$



$$\text{dist} = \frac{R}{\sqrt{2} - 1} + R = \frac{\sqrt{2}R}{\sqrt{2} - 1}$$

9. Ans. (2)

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

$= -PE\cos\theta$

$= -(10^{-29})(10^3)\cos 45°$

$= -0.707 \times 10^{-26}$ J

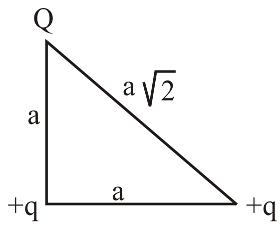
$= -7 \times 10^{-27}$ J.

10. Ans. (1)

$$U = K\left[\frac{q^2}{a}+\frac{Qq}{a}+\frac{Qq}{a\sqrt{2}}\right]=0$$

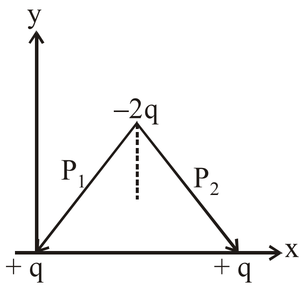
$$\Rightarrow\ q=-Q\left[1+\frac{1}{\sqrt{2}}\right]$$

$$\Rightarrow\ Q=\frac{-q\sqrt{2}}{\sqrt{2}+1}$$



11. Ans. (2)

12. Ans. (3)



$|P_1| = q(d)$
$|P_2| = qd$
$|\text{Resultant}| = 2\,P\cos 30^\circ$

$$2\,qd\left(\frac{\sqrt{3}}{2}\right) = \sqrt{3}\,qd$$

13. Ans. (1)

At any instant 't'

Total energy of charge distribution is constant

i.e. $$\frac{1}{2}mV^2+\frac{KQ^2}{2R}=0+\frac{KQ^2}{2R_0}$$

$$\therefore\ \frac{1}{2}mV^2=\frac{KQ^2}{2R_0}-\frac{KQ^2}{2R}$$

$$\therefore\ V=\sqrt{\frac{2}{m}\frac{KQ^2}{2}.\left(\frac{1}{R_0}-\frac{1}{R}\right)}$$

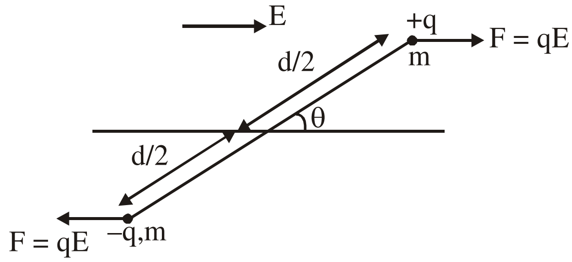
$$\therefore\ V=\sqrt{\frac{KQ^2}{m}\left(\frac{1}{R_0}-\frac{1}{R}\right)}=C\sqrt{\frac{1}{R_0}-\frac{1}{R}}$$

Also the slope of v-s curve will go on decreasing

$\therefore$ Graph is correctly shown by option(1)

14. Ans. (3)

Sol.



moment of inertia (I) = $m\left(\frac{d}{2}\right)^2\times 2=\frac{md^2}{2}$

Now by $\tau = I\alpha$

$$(qE)\,(d\sin\theta)=\frac{md^2}{2}.\alpha$$

$$\alpha=\left(\frac{2qE}{md}\right)\sin\theta$$

for small θ

$$\Rightarrow \alpha=\left(\frac{2qE}{md}\right)\theta$$

$\Rightarrow$ Angular frequency $\omega=\sqrt{\frac{2qE}{md}}$

15. Ans. (4)

Sol. $\frac{1}{2}mV^2=-q\left(V_f-V_i\right)$

$$E=\frac{\lambda}{2\pi\varepsilon_0 r}$$

$$\Delta V=\frac{\lambda}{2\pi\varepsilon_0}\ell n\left(\frac{r_0}{r}\right)$$

$$\frac{1}{2}mv^2=\frac{-q\lambda}{2\pi\varepsilon_0}\ell n\left(\frac{r_0}{r}\right)$$

$$v\propto\sqrt{\ell n\left(\frac{r}{r_0}\right)}$$

16. Ans. (3)

Sol. $\vec{E}=\left(20x+10\right)\hat{i}$

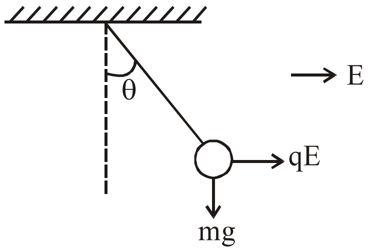
$$V_1-V_2\ -\int_{-5}^{1}\left(20x+10\right)dx$$

$$V_1-V_2=-\left(10x^2+10x\right)_{-5}^{1}$$

$V_1 - V_2 = 10(25 - 5 - 1 - 1)$
$V_1 - V_2 = 180\ V$

17. Ans. (3)

Sol.

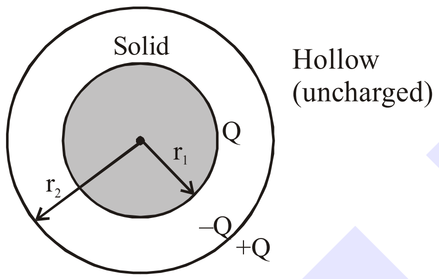


$$\tan\theta = \frac{qE}{mg} = \frac{5\times10^{-6}\times2000}{2\times10^{-3}\times10}$$

$$\tan\theta = \frac{1}{2} \Rightarrow \theta = \tan^{-1}(0.5)$$

18. Ans. (1)

Sol. As given in the first condition :

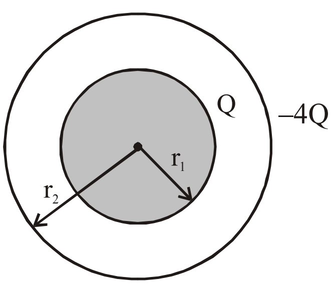


Both conducting spheres are shown.

$$V_{in} - V_{out} = \left(\frac{kQ}{r_1}\right) - \left(\frac{kQ}{r_2}\right)$$

$$= kQ\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = V$$

In the second condition :



Shell is now given charge –4Q.

$$V_{in} - V_{out} = \left(\frac{kQ}{r_1} - \frac{4kQ}{r_2}\right) - \left(\frac{kQ}{r_2} - \frac{4kQ}{r_2}\right)$$

$$= \frac{kQ}{r_1} - \frac{kQ}{r_2}$$

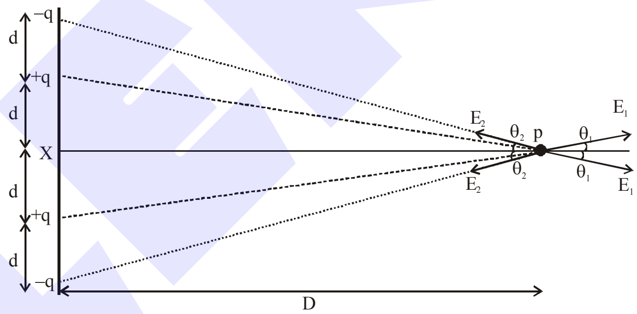
$$= kQ\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = V$$

Hence, we also obtain that potential difference does not depend on charge of outer sphere.

∴ P.d. remains same

19. Ans. (4)

Sol.



Electric field at $p = 2E_1\cos\theta_1 - 2E_1\cos\theta_2$

$$= \frac{2Kq}{(d^2+D^2)}\times\frac{D}{(d^2+D^2)^{1/2}} - \frac{2Kq}{[(2d)^2+D^2]}\times\frac{D}{[(2d)^2+D^2]^{1/2}}$$

$$= 2KqD\left[(d^2+D^2)^{-3/2} - (4d^2+D^2)^{-3/2}\right]$$

$$= \frac{2KqD}{D^3}\left[\left(1+\frac{d^2}{D^2}\right)^{-3/2} - \left(1+\frac{4d^2}{D^2}\right)^{-3/2}\right]$$

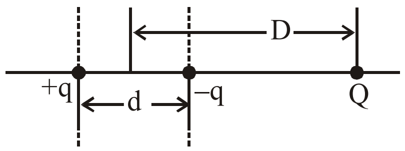
Applying binomial approximation $\because d << D$

$$= \frac{2KqD}{D^3}\left[1 - \frac{3}{2}\frac{d^2}{D^2} - \left(1 - \frac{3\times4d^2}{2D^2}\right)\right]$$

$$= \frac{2KqD}{D^3}\left[\frac{12}{2}\frac{d^2}{D^2} - \frac{3}{2}\frac{d^2}{D^2}\right]$$

$$= \frac{9kqd^2}{D^4}$$

20. Ans. (4)

Sol. 

D >> d

$U_{total} = U_{self\ of\ dipole} + U_{interaction}$

$= -\frac{kq^2}{d} - \left(\frac{kQ}{D^2}\right)qd$

$= -k\left[\frac{q^2}{d} + \frac{qQd}{D^2}\right]$

Option (4)

21. Ans. (1)

Sol. $g_{eff} = \sqrt{g^2 + \left(\frac{qE}{m}\right)^2}$

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

$= 2\pi\sqrt{\frac{\ell}{\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}}}$

22. Ans. (1)

Sol. $W_E = -[\Delta U] = U_i - U_F = \frac{1}{2}mv^2$

$U = \frac{kq_1q_2}{r}$

$\frac{(9\times10^9)\times10^{-12}}{10^{-3}} - \frac{(9\times10^9)\times10^{-12}}{9\times10^{-3}} = \frac{1}{2}\times(4\times10^{-6})v^2$

$v^2 = 4 \times 10^6$

$v = 2 \times 10^3$ m/s

23. Ans. (2)

Sol. $U_i + K_i = U_f + K_f$

$\frac{kq^2}{\sqrt{16a^2+9a^2}} + \frac{1}{2}mv^2 = \frac{kq^2}{3a}$

$\frac{1}{2}mv^2 = \frac{kq^2}{a}\left(\frac{1}{3} - \frac{1}{5}\right) = \frac{2kq^2}{15a}$

$v = \sqrt{\frac{4kq^2}{15ma}}$

24. Ans. (3)

Sol. $E\,4\pi a^2 = \frac{\int_0^a kr\,4\pi r^2\,dr}{\varepsilon_0}$

$E = \frac{k\,4\pi a^4}{4\times4\pi\varepsilon_0}$

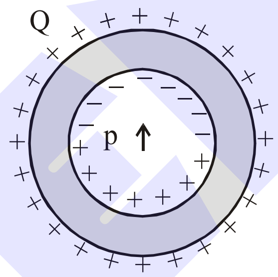
$2Q = \int_0^R kr\,4\pi r^2\,dr$

$k = \frac{2Q}{\pi R^4}$

$QE = \frac{1}{4\pi\varepsilon_0}\frac{QQ}{(2a)^2}$

$R = a8^{1/4}$

25. Ans. (1)

Sol. 

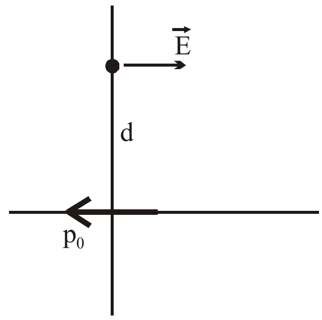
Total charge of dipole = 0, so charge induced on outside surface = 0.

But due to non uniform electric field of dipole, the charge induced on inner surface is non zero and non uniform.

So, for any observer outside the shell, the resultant electric field is due to Q uniformly distributed on outer surface only and it is equal to.

$\boxed{E = \frac{KQ}{r^2}}$

26. Ans. (4)

Sol. 

V = 0

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

$= -\frac{\vec{p}}{4\pi\varepsilon_0 d^3}$