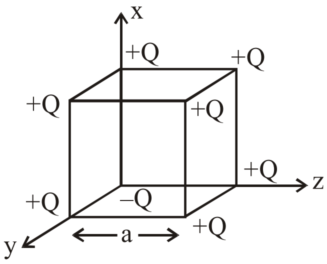
ELECTROSTATICS

1. A cube of side 'a' has point charges +Q located at each of its vertices except at the origin where the charge is –Q. The electric field at the centre of cube is :



(1) $\frac{-Q}{3\sqrt{3}\,\pi\varepsilon_0 a^2}\left(\hat{x}+\hat{y}+\hat{z}\right)$

(2) $\frac{-2Q}{3\sqrt{3}\,\pi\varepsilon_0 a^2}\left(\hat{x}+\hat{y}+\hat{z}\right)$

(3) $\frac{2Q}{3\sqrt{3}\,\pi\varepsilon_0 a^2}\left(\hat{x}+\hat{y}+\hat{z}\right)$

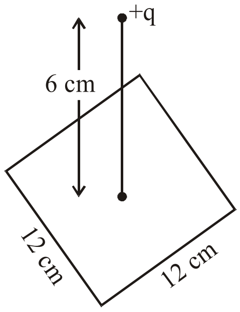
(4) $\frac{Q}{3\sqrt{3}\,\pi\varepsilon_0 a^2}\left(\hat{x}+\hat{y}+\hat{z}\right)$

2. Two electrons each are fixed at a distance '2d'. A third charge proton placed at the midpoint is displaced slightly by a distance x (x << d) perpendicular to the line joining the two fixed charges. Proton will execute simple harmonic motion having angular frequency : (m = mass of charged particle)

(1) $\left(\frac{2q^2}{\pi\varepsilon_0 md^3}\right)^{\frac{1}{2}}$ (2) $\left(\frac{\pi\varepsilon_0 md^3}{2q^2}\right)^{\frac{1}{2}}$

(3) $\left(\frac{q^2}{2\pi\varepsilon_0 md^3}\right)^{\frac{1}{2}}$ (4) $\left(\frac{2\pi\varepsilon_0 md^3}{q^2}\right)^{\frac{1}{2}}$

3. A point charge of +12 μC is at a distance 6 cm vertically above the centre of a square of side 12 cm as shown in figure. The magnitude of the electric flux through the square will be ______ × 10^3 Nm^2/C.

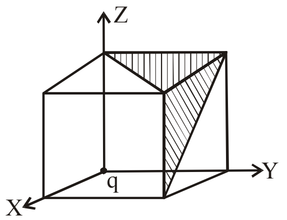


4. The electric field in a region is given $\vec{E}=\left(\frac{3}{5}E_0\hat{i}+\frac{4}{5}E_0\hat{j}\right)\frac{N}{C}$. The ratio of flux of reported field through the rectangular surface of area 0.2 m^2 (parallel to y – z plane) to that of the surface of area 0.3 m^2 (parallel to x – z plane) is a : b, where a = _____.

[Here $\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along x, y and z-axes respectively]

5. 512 identical drops of mercury are charged to a potential of 2V each. The drops are joined to form a single drop. The potential of this drop is ____ V.

6. A charge 'q' is placed at one corner of a cube as shown in figure. The flux of electrostatic field $\vec{E}$ through the shaded area is :



(1) $\frac{q}{4\varepsilon_0}$ (2) $\frac{q}{24\varepsilon_0}$

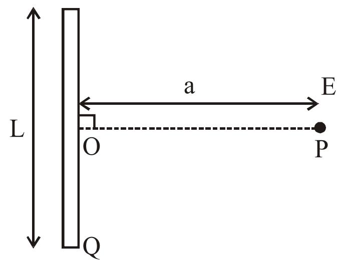
(3) $\frac{q}{48\varepsilon_0}$ (4) $\frac{q}{8\varepsilon_0}$

7. Two small spheres each of mass 10 mg are suspended from a point by threads 0.5 m long. They are equally charged and repel each other to a distance of 0.20 m. The charge on each of the sphere is $\frac{a}{21} \times 10^{-8}$ C. The value of 'a' will be ______. [Given g = 10 ms^{-2}]

8. Two identical conducting spheres with negligible volume have 2.1 nC and –0.1 nC charges, respectively. They are brought into contact and then separated by a distance of 0.5 m. The electrostatic force acting between the spheres is__________$\times 10^{-9}$ N.

[Given : $4\pi\varepsilon_0 = \frac{1}{9 \times 10^9}$ SI unit]

9. Find the electric field at point P (as shown in figure) on the perpendicular bisector of a uniformly charged thin wire of length L carrying a charge Q. The distance of the point P from the centre of the rod is $a = \frac{\sqrt{3}}{2}L$.



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

(3) $\frac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$ (4) $\frac{Q}{4\pi\varepsilon_0 L^2}$

10. 27 similar drops of mercury are maintained at 10 V each. All these spherical drops combine into a single big drop. The potential energy of the bigger drop is .... times that of a smaller drop.

11. Given below are two statements :

Statement I : An electric dipole is placed at the centre of a hollow sphere. The flux of electric field through the sphere is zero but the electric field is not zero anywhere in the sphere.

Statement II : If R is the radius of a solid metallic sphere and Q be the total charge on it. The electric field at any point on the spherical surface of radius r (< R) is zero but the electric flux passing through this closed spherical surface of radius r is not zero.

In the light of the above statements, choose the correct answer from the options given below :

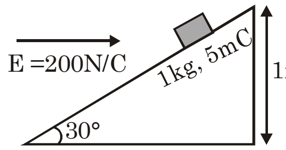
(1) Both Statement I and Statement II are true

(2) Statement I is true but Statement II is false

(3) Both Statement I and Statement II are false

(4) Statement I is false but Statement II is true.

12. An inclined plane making an angle of 30° with the horizontal is placed in a uniform horizontal electric field 200 $\frac{N}{C}$ as shown in the figure. A body of mass 1kg and charge 5 mC is allowed to slide down from rest at a height of 1m. If the coefficient of friction is 0.2, find the time taken by the body to reach the bottom.[g = 9.8 m/s^2, $\sin 30° = \frac{1}{2}$; $\cos 30° = \frac{\sqrt{3}}{2}$]



(1) 0.92 s (2) 0.46 s

(3) 2.3 s (4) 1.3 s

13. Find out the surface charge density at the intersection of point x = 3 m plane and x-axis, in the region of uniform line charge of 8 nC/m lying along the z-axis in free space.

(1) 0.424 nC m^{-2} (2) 47.88 C/m

(3) 0.07 nC m^{-2} (4) 4.0 nC m^{-2}

14. The electric field in a region is given by $\vec{E} = \frac{2}{5}E_0\hat{i} + \frac{3}{5}E_0\hat{j}$ with $E_0 = 4.0 \times 10^3 \frac{N}{C}$.The flux of this field through a rectangular surface area 0.4 m^2 parallel to the Y – Z plane is _________Nm^{2}C^{-1}.

15. An oil drop of radius 2 mm with a density 3g cm^{-3} is held stationary under a constant electric field 3.55×10^5 V m^{-1} in the Millikan's oil drop experiment. What is the number of excess electrons that the oil drop will possess ? (consider g = 9.81 m/s^2)

(1) 48.8×10^{11} (2) 1.73×10^{10}

(3) 17.3×10^{10} (4) 1.73×10^{12}

16. An infinite number of point charges, each carrying 1 μC charge, are placed along the y-axis at y = 1 m, 2 m, 4 m, 8 m................. The total force on a 1 C point charge, placed at the origin, is x × 10^3 N. The value of x, to the nearest integer, is________.

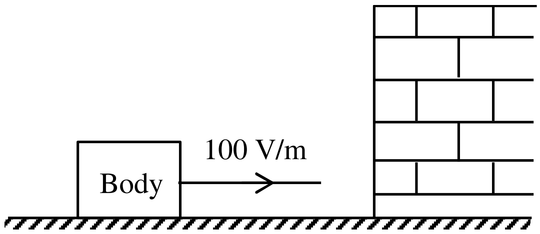
[Take $\frac{1}{4\pi \in_0} = 9 \times 10^9$ Nm^2/C^2]

17. A certain charge Q is divided into two parts q and (Q–q). How should the charges Q and q be divided so that q and (Q–q) placed at a certain distance apart experience maximum electrostatic repulsion ?

(1) $Q = \frac{q}{2}$ (2) Q = 2q

(3) Q = 4q (4) Q = 3q

18. A body having specific charge 8 μC/g is resting on a frictionless plane at a distance 10 cm from the wall (as shown in the figure). It starts moving towards the wall when a uniform electric field of 100 V/m is applied horizontally towards the wall. If the collision of the body with the wall is perfectly elastic, then the time period of the motion will be ______ s.



19. An electric dipole is placed on x-axis in proximity to a line charge of linear charge density 3.0×10^{-6} C/m. Line charge is placed on z-axis and positive and negative charge of dipole is at a distance of 10 mm and 12 mm from the origin respectively. If total force of 4 N is exerted on the dipole, find out the amount of positive or negative charge of the dipole.

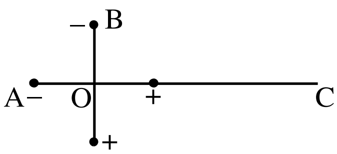
(1) 815.1 nC (2) 8.8 μC

(3) 0.485 mC (4) 4.44 μC

20. The total charge enclosed in an incremental volume of 2×10^{-9} m^3 located at the origin is ______ nC, if electric flux density of its field is found as $D = e^{-x} \sin y\ \hat{i} - e^{-x} \cos y\ \hat{j} + 2z\hat{k}$ C/m^2.

21. A particle of mass 1 mg and charge q is lying at the mid-point of two stationary particles kept at a distance '2 m' when each is carrying same charge 'q'. If the free charged particle is displaced from its equilibrium position through distance 'x' (x << 1 m). The particle executes SHM. Its angular frequency of oscillation will be _____ $\times 10^5$ rad/s if $q^2 = 10\ C^2$.

22. Two ideal electric dipoles A and B, having their dipole moment p_1 and p_2 respectively are placed on a plane with their centres at O as shown in the figure. At point C on the axis of dipole A, the resultant electric field is making an angle of 37° with the axis. The ratio of the dipole moment of A and B, $\frac{p_1}{p_2}$ is : (take $\sin 37° = \frac{3}{5}$)



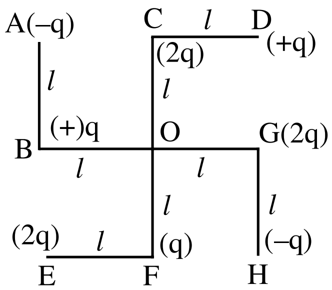
(1) $\frac{3}{8}$ (2) $\frac{3}{2}$ (3) $\frac{2}{3}$ (4) $\frac{4}{3}$

23. Two identical tennis balls each having mass 'm' and charge 'q' are suspended from a fixed point by threads of length 'l'. What is the equilibrium separation when each thread makes a small angle 'θ' with the vertical ?

(1) $x = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{2}}$ (2) $x = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$

(3) $x = \left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g}\right)^{\frac{1}{3}}$ (4) $x = \left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g^2}\right)^{\frac{1}{3}}$

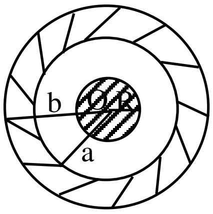
24. What will be the magnitude of electric field at point O as shown in figure? Each side of the figure is l and perpendicular to each other?

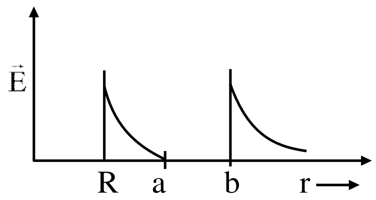


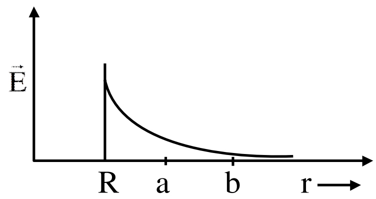
(1) $\frac{1}{4\pi\varepsilon_0}\frac{q}{l^2}$ (2) $\frac{1}{4\pi\varepsilon_0}\frac{q}{(2l^2)}\left(2\sqrt{2}-1\right)$

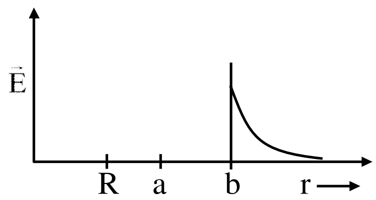
(3) $\frac{q}{4\pi\varepsilon_0(2l)^2}$ (4) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{2l^2}\left(\sqrt{2}\right)$

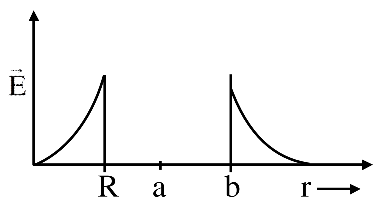
25. A solid metal sphere of radius R having charge q is enclosed inside the concentric spherical shell of inner radius a and outer radius b as shown in figure. The approximate variation electric field $\vec{E}$ as a function of distance r from centre O is given by :



(1)


(2)


(3)


(4)


26. The two thin coaxial rings, each of radius 'a' and having charges +Q and –Q respectively are separated by a distance of 's'. The potential difference between the centres of the two rings is :

(1) $\frac{Q}{2\pi\varepsilon_0}\left[\frac{1}{a}+\frac{1}{\sqrt{s^2+a^2}}\right]$

(2) $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{a}+\frac{1}{\sqrt{s^2+a^2}}\right]$

(3) $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{a}-\frac{1}{\sqrt{s^2+a^2}}\right]$

(4) $\frac{Q}{2\pi\varepsilon_0}\left[\frac{1}{a}-\frac{1}{\sqrt{s^2+a^2}}\right]$

27. A uniformly charged disc of radius R having surface charge density σ is placed in the xy plane with its center at the origin. Find the electric field intensity along the z-axis at a distance Z from origin :-

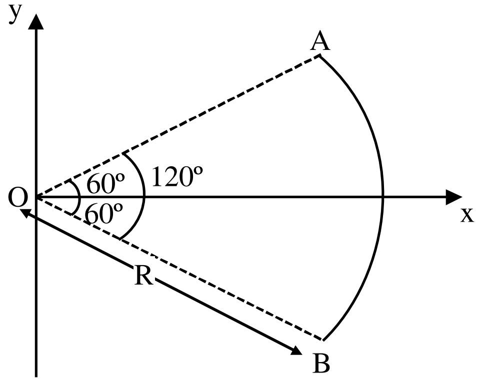
(1) $E=\frac{\sigma}{2\varepsilon_0}\left(1-\frac{Z}{(Z^2+R^2)^{1/2}}\right)$

(2) $E=\frac{\sigma}{2\varepsilon_0}\left(1+\frac{Z}{(Z^2+R^2)^{1/2}}\right)$

(3) $E=\frac{2\varepsilon_0}{\sigma}\left(\frac{1}{(Z^2+R^2)^{1/2}}+Z\right)$

(4) $E=\frac{\sigma}{2\varepsilon_0}\left(\frac{1}{(Z^2+R^2)}+\frac{1}{Z^2}\right)$

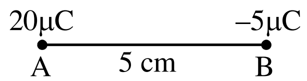
28. Figure shows a rod AB, which is bent in a 120° circular arc of radius R. A charge (–Q) is uniformly distributed over rod AB. What is the electric field $\vec{E}$ at the centre of curvature O ?



(1) $\frac{3\sqrt{3}Q}{8\pi\varepsilon_0 R^2}(\hat{i})$ (2) $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(\hat{i})$

(3) $\frac{3\sqrt{3}Q}{16\pi^2\varepsilon_0 R^2}(\hat{i})$ (4) $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(-\hat{i})$

29. Two particles A and B having charges 20 μC and –5 μC respectively are held fixed with a separation of 5 cm. At what position a third charged particle should be placed so that it does not experience a net electric force?



(1) At 5 cm from 20 μC on the left side of system

(2) At 5 cm from – 5 μC on the right side

(3) At 1.25 cm from – 5 μC between two charges

(4) At midpoint between two charges

30. Choose the **incorrect** statement :

(a) The electric lines of force entering into a Gaussian surface provide negative flux.

(b) A charge 'q' is placed at the centre of a cube. The flux through all the faces will be the same.

(c) In a uniform electric field net flux through a closed Gaussian surface containing no net charge, is zero.

(d) When electric field is parallel to a Gaussian surface, it provides a finite non-zero flux.

Choose the most appropriate answer from the options given below

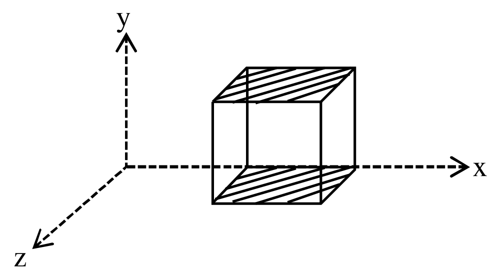
(1) (c) and (d) only

(2) (b) and (d) only

(3) (d) only

(4) (a) and (c) only

31. A cube is placed inside an electric field, $\vec{E} = 150y^2\hat{j}$. The side of the cube is 0.5 m and is placed in the field as shown in the given figure. The charge inside the cube is :



(1) 3.8×10^{-11} C (2) 8.3×10^{-11} C

(3) 3.8×10^{-12} C (4) 8.3×10^{-12} C

SOLUTION

1. Official Ans. by NTA (2)

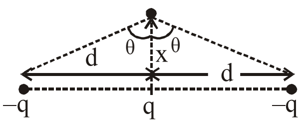
Sol. We can replace –Q charge at origin by +Q and –2Q. Now due to +Q charge at every corner of cube. Electric field at center of cube is zero so now net electric field at center is only due to –2Q charge at origin.

$$\vec{E} = \frac{kq\vec{r}}{r^3} = \frac{1(-2Q)\frac{a}{2}(\hat{x}+\hat{y}+\hat{z})}{4\pi\varepsilon_0\left(\frac{a}{2}\sqrt{3}\right)^3}$$

$$\vec{E} = \frac{-2Q(\hat{x}+\hat{y}+\hat{z})}{3\sqrt{3}\pi a^2\varepsilon_0}$$

2. Official Ans. by NTA (3)

Sol. From the given condition, we have



$$F_{netq} = -\left[2F_{q/q}\cos\theta\right]$$

$$F_{netq} = -2.\frac{1}{4\pi\varepsilon_0}.\frac{q^2}{\left(\sqrt{d^2+x^2}\right)^2}.\frac{x}{\sqrt{d^2+x^2}}$$

$$= -\frac{q^2}{2\pi\varepsilon_0}\frac{x}{(d^2+x^2)^{3/2}}$$

For x << d,

$$F_{net\,q} = -\frac{q^2}{2\pi\varepsilon_0 d^3}x$$

$$\therefore\ a = -\frac{q^2}{2\pi\varepsilon_0.md^3}x$$

Comparing with equation of SHM ($a = -\omega^2 x$)

$$\therefore\ \omega = \sqrt{\frac{q^2}{2\pi\varepsilon_0 md^3}}$$

Hence option (3) is correct

3. Official Ans. by NTA (226)

Sol. From symmetry $\phi = \frac{1}{6}\left(\frac{q}{\varepsilon_0}\right)$

$$= \frac{12\times10^{-6}}{6\times8.85\times10^{-12}} = 225.98\times10^3\ \frac{Nm^2}{s}$$

$$\simeq 226\times10^3\ \frac{Nm^2}{C}$$

4. Official Ans. by NTA (1)

Sol. $\vec{E} = \left(\frac{3E_0}{5}\hat{i} + \frac{4E_0}{5}\hat{j}\right)\frac{N}{C}$

$A_1 = 0.2\ m^2$ [parallel to y – z plane]

$= \vec{A}_1 = 0.2\ m^2\ \hat{i}$

$A_2 = 0.3\ m^2$ [parallel to x – z plane]

$\vec{A}_2 = 0.3\,m^2\,\hat{j}$

Now $\phi_a = \left[\frac{3E_0}{5}\hat{i} + \frac{4E_0}{5}\hat{j}\right]\cdot\left[0.2\hat{i}\right] = \frac{3\times0.2}{5}E_0$

& $\phi_b = \left[\frac{3E_0}{5}\hat{i} + \frac{4E_0}{5}\hat{j}\right]\cdot\left[0.3\hat{j}\right] = \frac{4\times0.3}{5}E_0$

Now $\frac{\phi_a}{\phi_b} = \frac{0.6}{1.2} = \frac{1}{2} = \frac{a}{b}$

$\Rightarrow a : b = 1 : 2 \Rightarrow a = 1$

5. Official Ans. by NTA (128)

Sol. $Q = 512q$

$Volume_i = Volume_f$

$512\times\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$2^9 r^3 = R^3$

$R = 8r$

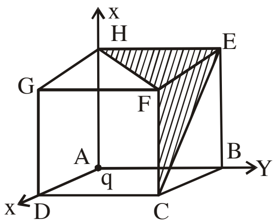
$2 = \frac{kq}{r}$

$V = \frac{kQ}{R} = \frac{k\,512\,q}{8r}$

$V = 128.$

6. **Official Ans. by NTA (2)**

Sol.



flux through cube = $\frac{q}{8 \in_0}$

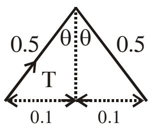
flux through surfaces ABEH, ADGH, ABCD will be zero

ϕ (EFGH) = ϕ (DCFG) = ϕ (EBCF) = $\frac{1}{3}$

$\left(\frac{q}{8 \in_0}\right) = \frac{q}{24 \in_0}$

7. **Official Ans. by NTA (20)**

Sol.



$T \cos\theta = mg = 10 \times 10^{-6} \times 10 = 10^{-4}$

$T \sin\theta = \frac{9\times10^9 \times q^2}{0.04} = F$

$\tan\theta = \frac{0.1}{\sqrt{0.24}} = \frac{F}{mg}$

$q = \frac{2\sqrt{10}}{3\sqrt{\sqrt{24}}} \times 10^{-8}$

$0.95 \times 10^{-8} = \frac{a}{21} \times 10^{-8}$; a = 20

8. **Official Ans. by NTA (36)**

Sol. $q = \frac{(2.1-0.1)}{2}$ nC = 1nC

$f = \frac{9\times10^9\times10^{-18}}{(0.5)^2} = 36 \times 10^{-9}$

9. **Official Ans. by NTA (3)**

Sol. $E = \frac{k\lambda}{a}(\sin\theta_1 + \sin\theta_2)$

$E = \frac{1}{4\pi\varepsilon_0}\times\frac{Q}{L}\times\frac{1}{\left(\frac{\sqrt{3}L}{2}\right)}\times(2\sin\theta)$

$\tan\theta = \frac{L/2}{\frac{\sqrt{3}L}{2}} = \frac{1}{\sqrt{3}}$

$\sin\theta = \frac{1}{2}$

$E = \frac{1}{4\pi\varepsilon_0}\times\frac{2Q}{\sqrt{3}L^2}\times\left(2\times\frac{1}{2}\right)$

$E = \frac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$

10. **Official Ans. by NTA (243)**

Sol. $(27)\left(\frac{4}{3}\pi r^3\right) = \frac{4}{3}\pi R^3$

R = 3r

Potential energy of smaller drop :

$U_1 = \frac{3}{5}\frac{kq^2}{r}$

Potential energy of bigger drop :

$U = \frac{3}{5}\frac{kQ^2}{R}$

$U = \frac{3}{5}\frac{k(27q)^2}{R}$

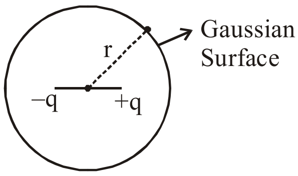
$U = \frac{3}{5}k\frac{(27)(27)q^2}{3r}$

$U = \frac{(27)(27)}{3}\left(\frac{3}{5}\frac{kq^2}{r}\right)$

$U = 243\ U_1$

11. Official Ans. by NTA (2)

Sol.

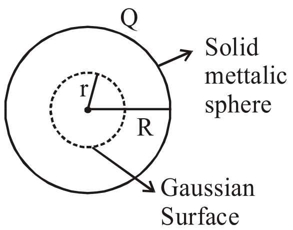


$$\oint \vec{E}.\overrightarrow{ds} = \frac{q_{in}}{\varepsilon_0} = 0 = \phi$$

Flux of $\vec{E}$ through sphere is zero.

But $\oint \vec{E}.\overrightarrow{ds} = 0 \Rightarrow \{\vec{E}.\overrightarrow{ds} \neq 0\}$ for small section ds only

Statement-2



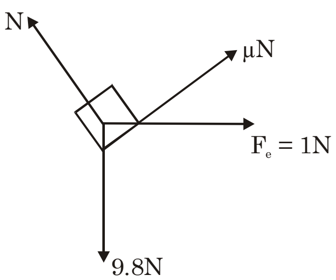
As change encloses within gaussian surface is equal to zero.

$$\phi = \oint \vec{E}.\overrightarrow{ds} = 0$$

Option(2) statement-1 correct statement-2 false.

12. Official Ans. by NTA (4)

Sol. FBD



here N = 9.8 cos 30 + 1 sin 30

≈ 9N

so a = $\dfrac{9.8\sin 30 - 1\cos 30 - \mu N}{1}$

a = 2.233 m/s^2

By S = ut + $\dfrac{1}{2}at^2$

= $\dfrac{1}{2}(2.233)t^2$

sin30°   t ≈ 1.3 sec

13. Official Ans. by NTA (1)

Sol. $\dfrac{2K\lambda}{r} = \dfrac{\sigma}{\varepsilon_0}$ (x = 3m)

$$\sigma = 0.424 \times 10^{-9}\frac{C}{m^2}$$

14. Official Ans. by NTA (640)

Sol. $\phi = E_x A \Rightarrow \dfrac{2}{5} \times 4 \times 10^3 \times 0.4 = 640$

15. Official Ans. by NTA (2)

Sol. qE = Mg

neE = $\rho\left(\dfrac{4}{3}\pi r^3\right) \times g$

n × 1.6 × 10^{-19} × 3.55 × 10^5

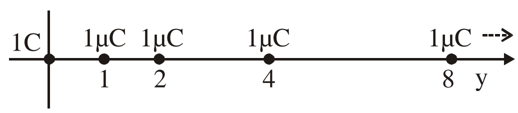
= 3 × 10^3 × $\dfrac{4}{3}$ × π × (2 × 10^{-3})^3 × 9.81

n = 173 × $10^{(3-9-5+19)}$

n = 1.73 × 10^{10}

16. Official Ans. by NTA (12)

Sol.

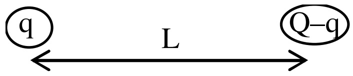


$$F = k(1C)(1\mu C)\left[1 + \frac{1}{2^2} + \frac{1}{4^2} + \frac{1}{8^2} + ...\right]$$

$$= 9 \times 10^3\left[\frac{1}{1 - \frac{1}{4}}\right] = 12 \times 10^3 N$$

17. Official Ans. by NTA (2)

Sol.



$$F_q = \frac{kq(Q-q)}{L^2} = \frac{k}{L^2}\left(qQ - q^2\right)$$

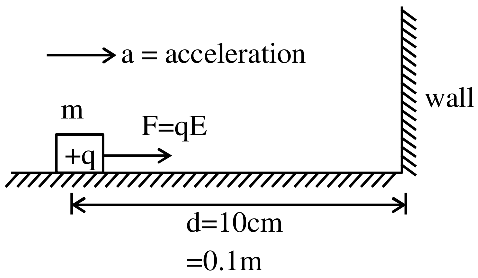
$$\frac{dF}{dq} = 0 \text{ when force is maximum}$$

$$\frac{dF}{dq} = \frac{k}{L^2}[Q - 2q] = 0$$

$\Rightarrow Q - 2q = 0 \Rightarrow Q = 2q$

18. Official Ans. by NTA (1)

Sol.



F = ma

qE = ma

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

$$\text{Now } d = \frac{1}{2}at^2$$

$$t = \sqrt{\frac{2d}{a}}$$

$$t = \sqrt{\frac{2d}{\left(\frac{qE}{m}\right)}}$$

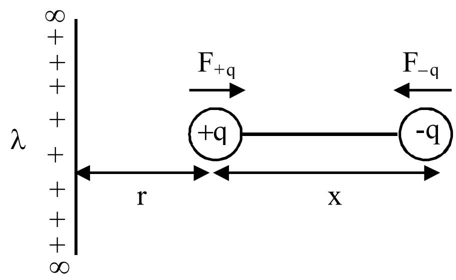
$$t = \sqrt{\frac{2\times 0.1}{\left(\frac{8\times 10^{-6}}{10^{-3}}\right)\times 100}} = \frac{1}{2}$$

$\therefore$ Time period = 2t = 1 sec

Ans. = 1.00

19. Official Ans. by NTA (4)

Sol.



r = 10 mm, x = 2,,

$$\left|\vec{F}_q\right| = \frac{2k\lambda}{r}.q$$

$$\left|\vec{F}_{-q}\right| = \frac{2k\lambda}{r+x}.q$$

$$\Rightarrow \left|\vec{F}_{net}\right| = \frac{2k\lambda q}{r} - \frac{2k\lambda q}{r+x}$$

$$\left|\vec{F}_{net}\right| = \frac{2k\lambda q.x}{r(r+x)}$$

$$4 = \frac{2\times 9\times 10^9 \times 3\times 10^{-6} \times q \times 2mm}{10mm.12mm}$$

$\Rightarrow$ q = 4.44 μC

20. Official Ans. by NTA (4)

Sol. Electric flux density

$$\left(\vec{D}\right) = \frac{\text{charge}}{\text{Area}} \times \hat{r} = \frac{Q}{4\pi r^2}\hat{r} = \epsilon_0\left(\frac{Q}{4\pi\epsilon_0 r^2}\hat{r}\right)$$

$$\Rightarrow \vec{E} = \frac{\vec{D}}{\epsilon_0} = \frac{e^{-x}\sin y\hat{i} - e^{-x}\cos y\hat{j} + 2z\hat{k}}{\epsilon_0}$$

Also by Gauss's law

$$\frac{\rho}{\epsilon_0} = \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right).\vec{E}$$

$$= \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right).\frac{\vec{D}}{\epsilon_0}$$

$$\Rightarrow \rho = \frac{\partial}{\partial x}\left(e^{-x}\sin y\right) + \frac{\partial}{\partial y}\left(-e^{-x}\cos y\right) + \frac{\partial}{\partial z}(2z)$$

$$\rho = -e^{-x}\sin y + e^{-x}\sin y + 2$$

At origin $\rho = -e^{-0}\sin 0 + e^{-0}\sin 0 + 2$

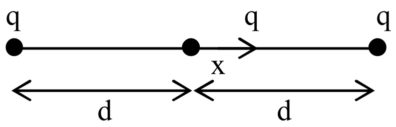
$$\rho = 2C/m^3$$

Charge = ρ × volume = $2 \times 2 \times 10^{-9} = 4 \times 10^{-9}$

= 4nC

21. Official Ans. by NTA (6000)

Sol.



Net force on free charged particle

$$F = \frac{kq^2}{(d+x)^2} - \frac{kq^2}{(d-x)^2}$$

$$F = -kq^2\left[\frac{4dx}{(d^2-x^2)^2}\right]$$

$$a = -\frac{4kq^2d}{m}\left(\frac{x}{d^4}\right)$$

$$a = -\left(\frac{4kq^2}{md^3}\right)x$$

So, angular frequency

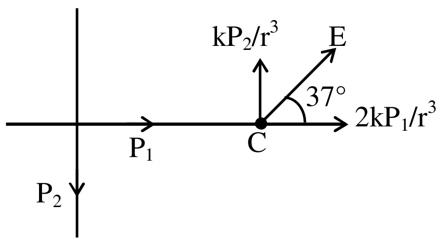
$$\omega = \sqrt{\frac{4kq^2}{md^3}}$$

$$\omega = \sqrt{\frac{4\times 9\times 10^9\times 10}{1\times 10^{-6}\times 1^3}}$$

$\omega = 6 \times 10^8$ rad/sec

22. Official Ans. by NTA (3)

Sol.

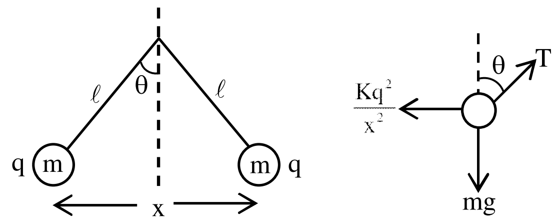


$$\tan 37° = \frac{3}{4} = \frac{\frac{kP_2}{r^3}}{\frac{2kP_1}{r^3}} = \frac{P_2}{2P_1} = \frac{3}{4}$$

$$\frac{P_2}{P_1} = \frac{3}{2}; \qquad \frac{P_1}{P_2} = \frac{2}{3}$$

23. Official Ans. by NTA (2)

Sol.



$T\cos\theta = mg$

$$T\sin\theta = \frac{kq^2}{x^2}$$

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

as $\tan\theta \approx \sin\theta \approx \dfrac{x}{2L}$

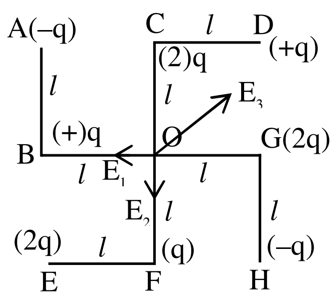
$$\frac{x}{2L} = \frac{Kq^2}{x^2mg}$$

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

24. Official Ans. by NTA (2)

Sol. $E_1 = \dfrac{kq}{\ell^2} = E_2$; $\quad E_3 = \dfrac{kq}{(\sqrt{2}\ell)^2} = \dfrac{kq}{2\ell^2}$

$$E = \frac{\sqrt{2}kq}{\ell^2} - \frac{kq}{2\ell^2} = \frac{kq}{2\ell^2}\left(2\sqrt{2}-1\right)$$

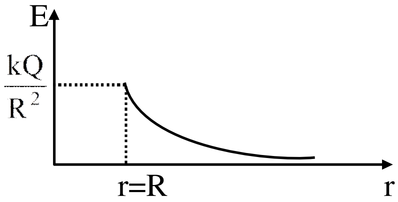


25. Official Ans. by NTA (1)

Sol. Considering outer spherical shell is non-conducting

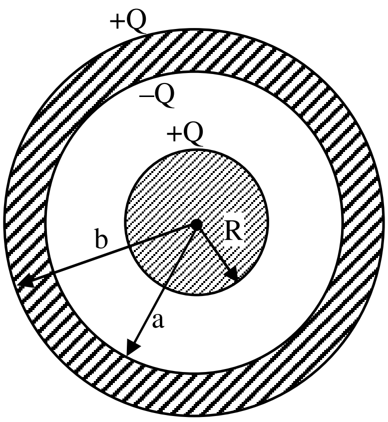
Electric field inside a metal sphere is zero.

$r < R \Rightarrow E = 0$; $r > R \Rightarrow E = \frac{kQ}{r^2}$



Option (2)

Considering outer spherical shell is conducting

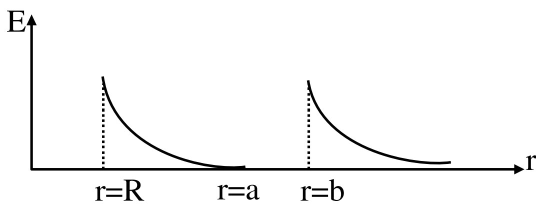


$r < R, E = 0$

$R \le r < a \qquad E = \frac{kQ}{r^2}$

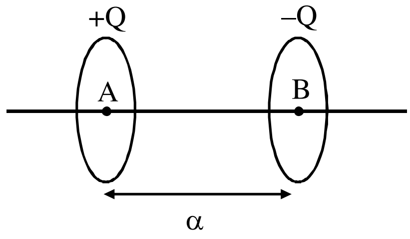
$a \le r < b, \qquad E = 0$

$r \ge b \qquad E = \frac{kQ}{r^2}$



26. Official Ans. by NTA (4)

Sol.



$$V_A = \frac{KQ}{a} - \frac{KQ}{\sqrt{a^2+s^2}}$$

$$V_B = \frac{-KQ}{a} + \frac{KQ}{\sqrt{a^2+s^2}}$$

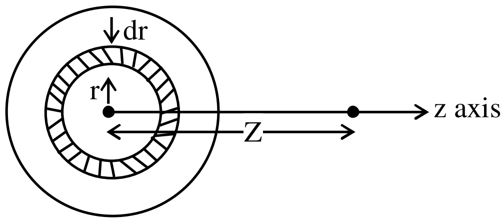
$$V_A - V_B = \frac{2KQ}{a} - \frac{2KQ}{\sqrt{a^2+s^2}}$$

$$= \frac{Q}{2\pi\varepsilon_0}\left(\frac{1}{a} - \frac{1}{s^2+a^2}\right)$$

Ans 4

27. Official Ans. by NTA (1)

Sol. Consider a small ring of radius r and thickness dr on disc.



area of elemental ring on disc

$dA = 2\pi r dr$

charge on this ring $dq = \sigma dA$

$$dEz = \frac{kdqz}{\left(z^2+r^2\right)^{3/2}}$$

$$E = \int_0^R dE_z = \frac{\sigma}{2\in_0}\left[1 - \frac{z}{\sqrt{R^2+z^2}}\right]$$

28. Official Ans. by NTA (2)

Sol. $\varepsilon = \frac{2k\lambda}{R}\sin\left(\frac{\theta}{2}\right)(-\hat{i})$

$\lambda = \left(\frac{-Q}{R\theta}\right) = \left(\frac{-Q}{R.\frac{2\pi}{3}}\right)$

$\lambda = \frac{-3Q}{2\pi R}$

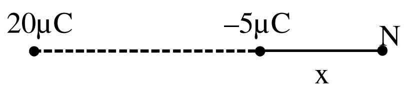
$\varepsilon = \frac{2k}{R}.\frac{-3Q}{2\pi R}.\sin(60°)(-\hat{i})$

$\varepsilon = \frac{3\sqrt{3}Q}{8\pi^2 \in_o R^2}(+\hat{i})$

29. Official Ans. by NTA (2)

Sol.

Null point is possible only right side of –5μC



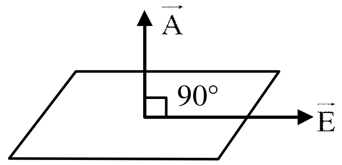
$$E_N = +\frac{k(-5\mu C)}{x^2} + \frac{k(20\mu C)}{(5+x)^2} = 0$$

x = 5 cm

$\therefore$ option (2) is correct

30. Official Ans. by NTA (3)

Sol. Since $\phi = \vec{E}.\vec{A} = EA\cos\theta$



$\theta = 90°$ $\therefore \phi = 0$

31. Official Ans. by NTA (2)

Sol. As electric field is in y-direction so electric flux is only due to top and bottom surface

Bottom surface y = 0

$\Rightarrow E = 0 \Rightarrow \phi = 0$

Top surface y = 0.5 m

$\Rightarrow E = 150\,(.5)^2 = \frac{150}{4}$

Now flux $\phi = EA = \frac{150}{4}(.5)^2 = \frac{150}{16}$

By Gauss's law $\phi = \frac{Q_{in}}{\epsilon_0}$

$\frac{150}{16} = \frac{Q_{in}}{\epsilon_0}$

$Q_{in} = \frac{150}{16} \times 8.85 \times 10^{-12} = 8.3 \times 10^{-11}$ C

Option (2)