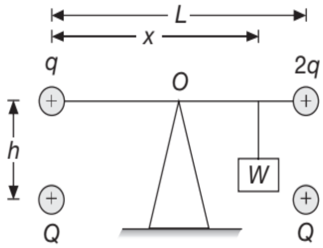
PRACTICE EXERCISES

SINGLE CORRECT CHOICE TYPE QUESTIONS

This section contains Single Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONLY ONE is correct.

1. An insulating long light rod of length L pivoted at its centre O and balanced with a weight W at a distance x from the left end as shown in figure. Charges q and $2q$ are fixed to the ends of the rod. Exactly below each of these charges at a distance h a positive charge Q is fixed. Then x is



(A) $\dfrac{QLq+\varepsilon_0^2h^2LW}{h^2W}$ (B) $\dfrac{QLq+\varepsilon_0h^2LW}{\varepsilon_0h^2W}$

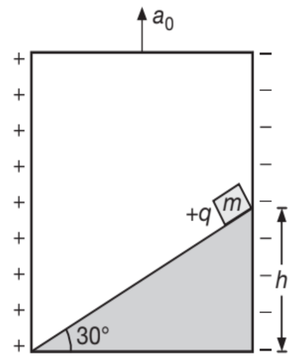
(C) $\dfrac{4QLq+\varepsilon_0h^2LW}{8\pi h^2W}$ (D) $\dfrac{QLq+4\pi\varepsilon_0h^2LW}{8\pi\varepsilon_0h^2W}$

2. Three point charges q_1, q_2 and q_3 are taken such that when q_1 and q_2 are placed close together to form a single point charge, the force on q_3 at distance L from this combination is a repulsion of 2 unit in magnitude. When q_2 and q_3 are so combined the force on q_1 at distance L is an attractive force of magnitude 4 unit. Also q_3 and q_1 when combined exert an attractive force on q_2 of magnitude 18 unit at same distance L. The algebraic ratio of charges q_1, q_2 and q_3 is

(A) $1:2:3$ (B) $2:-3:4$
(C) $4:-3:1$ (D) $4:-3:2$

3. In the process, when two bodies are charged by rubbing against the other, one becomes positively charged while the other becomes negatively charged. Then
(A) mass of each body remains unchanged
(B) mass of each body changes marginally
(C) mass of each body changes slightly and hence the total mass
(D) mass of each body changes slightly but the total mass remains the same

4. A small block of mass m, charge $+q$ is kept at the top of a smooth inclined plane of angle $30°$ placed in an elevator moving upward with an acceleration a_0. Electric field E exists between the vertical side walls of the elevator. The time taken by the block to come to the lowest point of inclined plane is (assuming the surface to be smooth)



(A) $t=\sqrt{\dfrac{2h}{g}}$

(B) $t=\sqrt{\dfrac{2h}{(g-a_0)+\dfrac{qE}{m}}}$

(C) $t=2\sqrt{\dfrac{2h}{(g+a_0)-\dfrac{\sqrt{3}qE}{m}}}$

(D) $t=\sqrt{\dfrac{2h}{(g+a_0)^2-\left(\dfrac{qE}{m}\right)h^2}}$

5. An electron of mass m, initially at rest, moves through a certain distance in a uniform electric field in time t. A proton of mass M, also initially at rest, takes time T to move through an equal distance in this uniform electric field. Neglecting the effect of gravity, the ratio $\dfrac{T}{t}$ is nearly equal to

(A) $\dfrac{2M}{m}$ (B) $\sqrt{\dfrac{m}{M}}$

(C) $\sqrt{\dfrac{M}{m}}$ (D) $\dfrac{M}{m}$

6. A proton of mass m and accelerated by a potential difference V gets into a uniform electric field of a parallel plate capacitor parallel to plates of length l at mid point of its separation between plates. The field strength in it varies with time as $E = at$, where a is a positive constant. Find the angle of deviation of the proton as it comes out of the capacitor. (Assume that it does not collide with any of the plates).

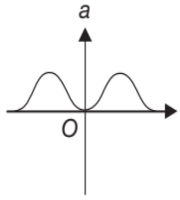
(A) $\theta = \tan^{-1}\left(\frac{al^2}{V}\sqrt{\frac{m}{8eV}}\right)$

(B) $\theta = \tan^{-1}\left(\frac{al^2}{2V}\sqrt{\frac{m}{eV}}\right)$

(C) $\theta = \tan^{-1}\left(\frac{al^2}{4V}\sqrt{\frac{m}{2eV}}\right)$

(D) $\theta = \tan^{-1}\left(\frac{al^2}{V}\sqrt{\frac{m}{2eV}}\right)$

7. Consider two identical positive charges which are fixed on the y-axis, at $(0, a)$ and $(0, -a)$. Let a particle having a negative charge start for the origin O from a point $P(x, 0)$ at a large distance for O, move along the x-axis, passes through O and moves far away from O. Let the acceleration a be taken as positive along its direction of motion. The particle's acceleration a is plotted against its x-coordinate. Then a vs x curve is given by

(A)


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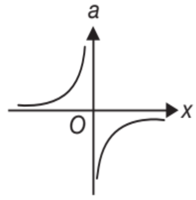
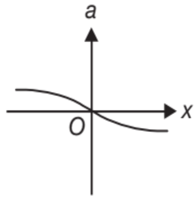
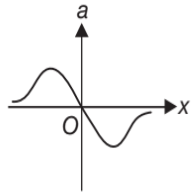


(C)


(D)


8. A non-conducting ring of radius 0.5 m carries a total charge of 1.11×10^{-10} C distributed non–uniformly on its circumference producing an electric field $\vec{E}$ everywhere in space. The value of the line integral $\int_{l=\infty}^{l=0} -\vec{E}\cdot d\vec{l}$, ($l = 0$ being the centre of the ring) in volt is

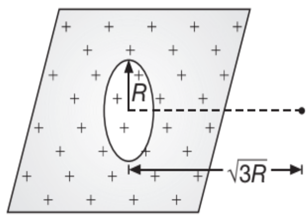
(A) +2 (B) –1
(C) –2 (D) 0

9. In a regular polygon of n sides, each corner is at a distance a from the centre. Identical charges of magnitude q are placed at $(n-1)$ corners. The field at the centre is

(A) $\frac{q}{4\pi\varepsilon_0 a^2}$ (B) $(n-1)\frac{q}{4\pi\varepsilon_0 a^2}$

(C) $\left(\frac{n}{n-1}\right)\frac{q}{4\pi\varepsilon_0 a^2}$ (D) $\left(\frac{n-1}{n}\right)\frac{q}{4\pi\varepsilon_0 a^2}$

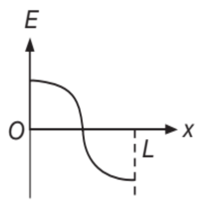
10. An infinite dielectric sheet having charge density σ has a hole of radius R in it. An electron is released on the axis of the hole at a distance $\sqrt{3}R$ from the centre. The speed with which it crosses the centre of the hole.

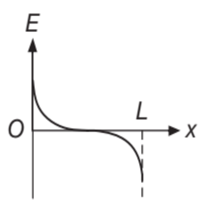


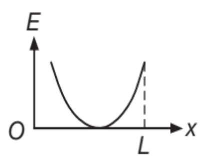
(A) $\sqrt{\frac{\sigma eR}{2m\varepsilon_0}}$ (B) $\sqrt{\frac{\sigma eR}{m\varepsilon_0}}$

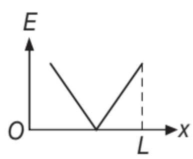
(C) $\sqrt{\frac{2\sigma eR}{m\varepsilon_0}}$ (D) None of these

11. Two identical point charges are placed at a separation of l. P is a point on the line joining the charges, at a distance x from any one charge. The resultant field at P due to them is E. E is plotted against x for values of x from close to zero to slightly less than l. The curve that best represents the resulting plot of E for x values ranging from very close to zero to slightly less than l is

(A)


(B)


(C)


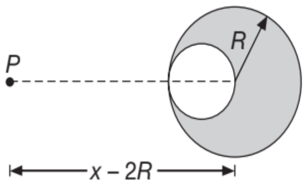
(D)


12. A charge $+q$ is fixed at each of the points $x = x_0, x = 3x_0, x = 5x_0, ...$ ad infinitum on the x-axis and a charge $-q$ is fixed at each of points $x = 2x_0, x = 4x_0, x = 6x_0....$ ad infinitum. Here x_0 is a positive constant. The potential at the origin due to the above system of charges is

(A) zero (B) $\dfrac{q}{8\pi\varepsilon_0 x_0 \log_e 2}$

(C) ∞ (D) $\dfrac{q\log_e 2}{4\pi\varepsilon_0 x_0}$

13. A solid spherical region has a spherical having a diameter R (equal to the radius of the spherical region), has a total charge Q. The electric field and potential at a point P at $x = 2R$ as shown is



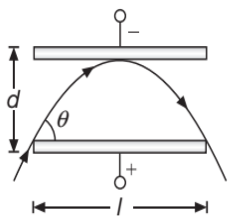
(A) $\dfrac{1}{27}\left(\dfrac{\rho R}{\varepsilon_0}\right), \dfrac{5}{12}\left(\dfrac{\rho R^2}{\varepsilon_0}\right)$

(B) $\dfrac{2}{27}\left(\dfrac{\rho R}{\varepsilon_0}\right), \dfrac{5}{36}\left(\dfrac{\rho R^2}{\varepsilon_0}\right)$

(C) $3\left(\dfrac{\rho R}{\varepsilon_0}\right), \dfrac{5}{6}\left(\dfrac{\rho R^2}{\varepsilon_0}\right)$

(D) $\dfrac{1}{9}\left(\dfrac{\rho R}{\varepsilon_0}\right), \dfrac{1}{9}\left(\dfrac{\rho R^2}{\varepsilon_0}\right)$

14. An electron enters the region between the plates of a parallel-plate capacitor with same initial velocity at an angle θ to the plates. The plate width is l and the plate separation is d. The electron follows the path shown, just missing the upper plate. Neglect gravity.



(A) $\tan\theta = \dfrac{2d}{l}$ (B) $\tan\theta = \dfrac{4d}{l}$

(C) $\tan\theta = \dfrac{6d}{l}$ (D) $\tan\theta = \dfrac{8d}{l}$

15. In a region of space, the electric field is in the x-direction, proportional to x and given by $\vec{E} = \alpha x\hat{i}$, where α is a positive constant. Consider an imaginary cubical volume of edge a, with its edges parallel to the axes of coordinates. The charge inside this cubical volume is

(A) $\varepsilon_0\alpha a^3$ (B) $\dfrac{\alpha a^3}{\varepsilon_0}$

(C) $\dfrac{1}{6}\left(\varepsilon_0\alpha a^2\right)$ (D) zero

16. An electrostatic potential is given by $V = kxy$, where k is a constant. A particle of charge q_0 is first taken from $(0, 0)$ to $(0, a)$ to (a, a), then directly from $(0, 0)$ to (a, a) and lastly from $(0, 0)$ to $(a, 0)$ to (a, a). If W_1, W_2 and W_3 be the work done for the individual paths respectively then

(A) $W_1 = W_2 = W_3 = -q_0 ka^2$

(B) $W_1 = W_3 = -\sqrt{2}q_0 ka^2$

(C) $W_1 = W_3 > W_2$

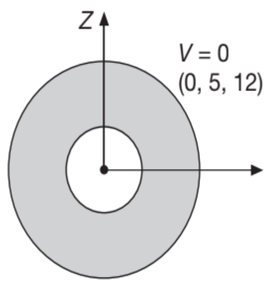
(D) $W_1 > W_2 > W_3$

17. A solid sphere of radius R is charged uniformly. At a point P, a distance r from the surface, the electrostatic potential is observed to be half of the potential at the centre. Then

(A) $r = 2R$ (B) $r = \dfrac{4R}{3}$

(C) $r = R$ (D) $r = \dfrac{R}{3}$

18. A line charge of charge density λ lies along the x-axis and let the surface of zero potential passes through $(0, 5, 12)$ m. The potential at point $(1, 3, -4)$ m is



(A) $\dfrac{\lambda}{2\pi\varepsilon_0}\log_e\left(\dfrac{13}{5}\right)$ (B) $\dfrac{2\lambda}{\pi\varepsilon_0}\log_e\left(\dfrac{13}{3}\right)$

(C) $\dfrac{\lambda}{4\pi\varepsilon_0}\log_e\left(\dfrac{13}{5}\right)$ (D) None of these

19. A point charge q is placed inside a conducting spherical shell of inner radius $2R$ and outer radius $3R$ at a distance of R from the centre of the shell. The electric potential at the centre of shell will be

(A) $\dfrac{q}{3\pi\varepsilon_0 R}$ (B) $\dfrac{q}{8\pi\varepsilon_0 R}$

(C) $\dfrac{q}{6\pi\varepsilon_0 R}$ (D) $\dfrac{5q}{24\pi\varepsilon_0 R}$

20. In a certain charge distribution, all points having zero potential can be joined by a circle C. Points inside C have positive potential, and points outside C have negative potential. A negative charge, which is free to move, is placed inside C. Then the negative charge

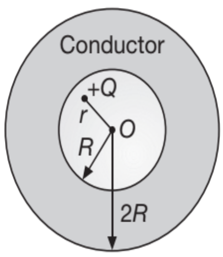
(A) may move, but will ultimately return to its starting point.
(B) will remain in equilibrium.
(C) can move inside C, but it cannot cross C.
(D) must cross C at some time.

21. Two identical thin rings, each of radius a metre are coaxial and placed a metre apart. If Q_1 and Q_2 are respectively the charges uniformly spread on the two rings, the work done in moving a charge q coulomb from the centre of one ring to that of the other is

(A) zero (B) $\dfrac{q(Q_1-Q_2)(\sqrt{2}-1)}{4\sqrt{2}\pi\varepsilon_0 a}$

(C) $\dfrac{q\sqrt{2}(Q_1+Q_2)}{4\pi\varepsilon_0 a}$ (D) $\dfrac{q(Q_1+Q_2)(\sqrt{2}+1)}{4\sqrt{2}\pi\varepsilon_0 a}$

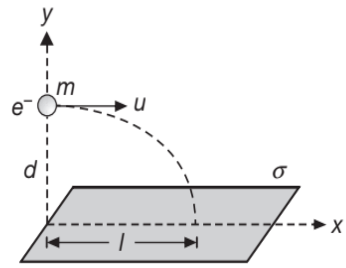
22. A point charge Q is placed at a distance $r(<R)$ from the centre O of a uncharged spherical shell of inner radius R and outer radius $2R$. The electric potential at the centre of the shell is given by



(A) $\dfrac{Q}{8\pi\varepsilon_0 R}$ (B) $\dfrac{Q}{4\pi\varepsilon_0}\left(\dfrac{1}{r}+\dfrac{1}{2R}\right)$

(C) $\dfrac{Q}{4\pi\varepsilon_0 r}$ (D) $\dfrac{Q}{4\pi\varepsilon_0}\left(\dfrac{1}{r}-\dfrac{1}{2R}\right)$

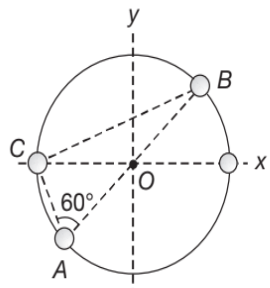
23. An electron is projected from a distance d and with initial velocity u parallel to a uniformly charged flat conducting plate as shown. It strikes the plate after travelling a distance l along the direction of projection. The surface charge density σ of the conducting plate is



(A) $\sigma = \dfrac{d\varepsilon_0 mu^2}{el}$ (B) $\sigma = \dfrac{d\varepsilon_0 mu}{el}$

(C) $\sigma = \dfrac{2d\varepsilon_0 mu^2}{el^2}$ (D) $\sigma = \dfrac{2d\varepsilon_0 mu}{el}$

24. Consider a system of three charges $\dfrac{q}{3}, \dfrac{q}{3}$ and $-\dfrac{2q}{3}$ placed at points A, B and C, respectively, as shown in the figure. Take O to be the centre of the circle of radius R and angle $CAB = 60°$.



(A) The electric field at point O is $\dfrac{q}{8\pi\varepsilon_0 R^2}$ directed along the negative x-axis
(B) The potential energy of the system is zero
(C) The magnitude of the force between the charges at C and B is $\dfrac{q^2}{54\pi\varepsilon_0 R^2}$
(D) The potential at point O is $\dfrac{q}{12\pi\varepsilon_0 R}$

25. Two particles A and B are suspended from the same support. The particles carry negative charges with A having more value of negative charge than B. They diverge and reach equilibrium with A and B making angles α and β with the vertical respectively.

(A) $\alpha > \beta$
(B) $\alpha < \beta$
(C) $\alpha = \beta$
(D) Data is insufficient to arrive at a conclusion.

26. 'Any excess charge on a conductor must reside only on its outer surface.' This statement is true

(A) for spherical conductors only (both solid and hollow).
(B) for hollow spherical conductors only.

(C) for conductors which do not have any sharp points or corners.

(D) for all types of conductors

27. A particle of mass m and charge q is set free a distance d from a perfectly conducting infinite plane. The time taken by the particle to hit the plane is

(A) $\frac{2}{3q}\sqrt{2md^3}$ (B) $\frac{1}{3q}\sqrt{2md^3}$

(C) $\frac{2}{q}\sqrt{2md^3}$ (D) $\frac{1}{q}\sqrt{2md^3}$

28. Two identical positive point charges each of value Q are fixed at the points $(a, 0)$ and $(-a, 0)$ on the x-axis. A particle of mass m and carrying charge $-q$ is released from rest at the point $P(0, \sqrt{3}a)$ on the y-axis. The velocity v_0 of the particle when it passes through the origin O is v_0. Then

(A) $v_0 = \sqrt{\frac{Qq}{\pi\varepsilon_0 ma}}$ (B) $v_0 = \sqrt{\frac{Qq}{2\pi\varepsilon_0 ma}}$

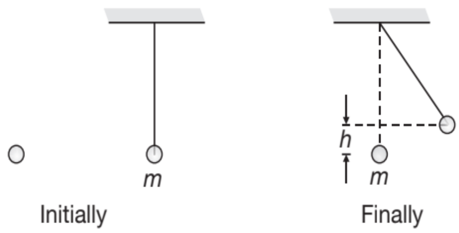
(C) $v_0 = \sqrt{\frac{Qq}{4\pi\varepsilon_0 ma}}$ (D) $v_0 = \sqrt{\frac{Qq}{8\pi\varepsilon_0 ma}}$

29. A charged particle passes through a uniform electric field existing between the parallel plates of a capacitor. The length of each plate is l. Its initial velocity is parallel to the plates. When it emerges from the field, its lateral deflection from its initial path is Δ and its angular deflection from its initial direction is θ. Then, $\tan\theta$ equals

(A) $\frac{\Delta}{l}$ (B) $\frac{2\Delta}{l}$

(C) $\frac{\Delta}{2l}$ (D) None of these

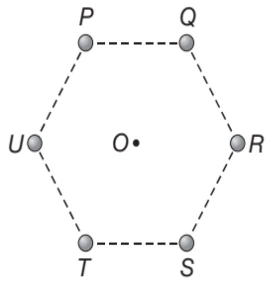
30. A small positively charged ball of mass m is suspended by an insulating thread of negligible mass. Another positively charged small ball is moved very slowly from a large distance until it is in the original position of the first ball. As a result, the first ball rises by h. How much work has been done?



(A) $2mgh$ (B) $3mgh$

(C) mgh (D) $4mgh$

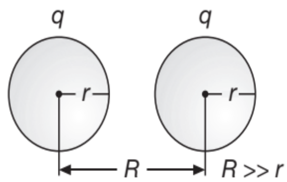
31. Six charges, three positive and three negative of equal magnitude are to be placed at the vertices of a regular hexagon such that the electric field at O is double the electric field when only one positive charge of same magnitude is placed at R. Which of the following arrangements of charge is possible for, P, Q, R, S, T and U respectively?



(A) +, −, +, −, −, + (B) +, −, +, −, +, −

(C) +, +, −, +, −, − (D) −, +, +, −, +, −

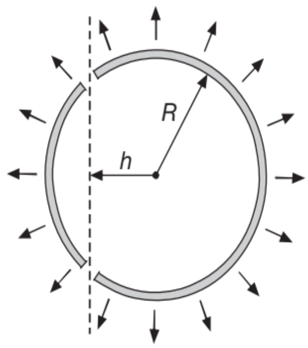
32. The potential energy of the system of two identically charged spheres as shown in the figure is equal to (Assume the charge distribution to be uniform)



(A) $\frac{q^2}{4\pi\varepsilon_0}\left(\frac{1}{R}+\frac{1}{r}\right)$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r(R+r)}$ (D) None of these

33. Consider a metal sphere, of radius R that is cut in two along a plane whose minimum distance from the sphere's centre is h. Sphere is uniformly charged by a total electric charge Q. The force necessary to hold the two parts of the sphere together is



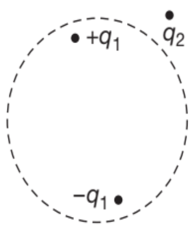
(A) $F = \dfrac{Q^2}{4\pi\varepsilon_0 R^4}(R^2 - h^2)$

(B) $F = \dfrac{Q^2}{4\pi\varepsilon_0 R^2}$

(C) $F = \dfrac{Q^2}{32\pi\varepsilon_0 R^3}(R - h)$

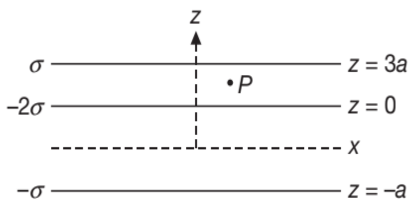
(D) $F = \dfrac{Q^2}{32\pi\varepsilon_0 R^4}(R^2 - h^2)$

34. Consider the charge configuration and a spherical Gaussian surface as shown in the figure. When calculating the flux of the electric field over the spherical surface, the electric field will be due to



(A) q_2
(B) only the positive charges
(C) all the charges
(D) $+q_1$ and $-q_1$

35. Three infinitely long charge sheets are placed as shown in figure. The electric field at point P is



(A) $\dfrac{2\sigma}{\varepsilon_0}\hat{k}$
(B) $-\dfrac{2\sigma}{\varepsilon_0}\hat{k}$

(C) $\dfrac{4\sigma}{\varepsilon_0}\hat{k}$
(D) $-\dfrac{4\sigma}{\varepsilon_0}\hat{k}$

36. The potential on the Nth shell due to N concentric shells having charges $Q, 2Q, 3Q, \ldots\ldots NQ$ and radii $a, 2a, 3a \ldots\ldots\ldots Na$ respectively is

(A) $\dfrac{Q(N+1)}{8\pi\varepsilon_0 a}$
(B) $\dfrac{QN(N+1)}{8\pi\varepsilon_0 a}$

(C) $\dfrac{Q}{2\pi\varepsilon_0 a}$
(D) None of these

37. A hollow sphere of radius $2R$ is charged to a potential V and another smaller sphere of radius R is charged to a potential $\dfrac{V}{2}$. The smaller sphere is now placed inside the bigger sphere without changing the net charge on each sphere. The potential difference between the two spheres is

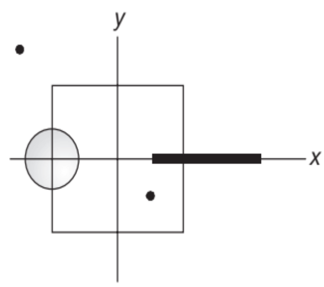
(A) $\dfrac{3V}{2}$
(B) $\dfrac{V}{4}$

(C) $\dfrac{V}{2}$
(D) V

38. A solid conducting sphere having a charge Q is surrounded by an uncharged concentric 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 $-3Q$, the new potential difference between the same two surfaces is

(A) V
(B) $2V$
(C) $4V$
(D) $-2V$

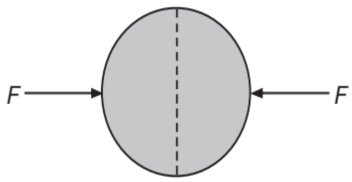
39. A disk of radius $\dfrac{a}{4}$ having a uniformly distributed charge $6C$ is placed in the x-y plane with its centre at $\left(-\dfrac{a}{2}, 0, 0\right)$. A rod of length a carrying a uniformly distributed charge $8C$ is placed on the x-axis from $x = \dfrac{a}{4}$ to $x = \dfrac{5a}{4}$. Two point charges $-7C$ and $3C$ are placed at $\left(\dfrac{a}{4}, -\dfrac{a}{4}, 0\right)$ and $\left(-\dfrac{3a}{4}, \dfrac{3a}{4}, 0\right)$, respectively. Consider a cubical surface formed by six surfaces $x = \pm\dfrac{a}{2}$, $y = \pm\dfrac{a}{2}$, $z = \pm\dfrac{a}{2}$. The electric flux through this cubical surface is



(A) $-\dfrac{2C}{\varepsilon_0}$
(B) $\dfrac{2C}{\varepsilon_0}$

(C) $\dfrac{10C}{\varepsilon_0}$
(D) $\dfrac{12C}{\varepsilon_0}$

40. A uniformly charged thin spherical shell of radius R carries uniform surface charge density of σ per unit area. It is made of two hemispherical shells, held together by pressing them with force F (see figure). F is proportional to



(A) $\frac{1}{\varepsilon_0}\sigma^2R^2$ (B) $\frac{1}{\varepsilon_0}\sigma^2R$

(C) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R}$ (D) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R^2}$

41. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7}\times10^5\ \text{Vm}^{-1}$. When the field is switched off, the drop is observed to fall with terminal velocity $2\times10^{-3}\ \text{ms}^{-1}$. Given $g = 9.8\ \text{ms}^{-2}$, viscosity of the air $= 1.8\times10^{-5}\ \text{Nsm}^{-2}$ and the density of oil $= 900\ \text{kgm}^{-3}$, the magnitude of q is

(A) 1.6×10^{-19} C (B) 3.2×10^{-19} C

(C) 4.8×10^{-19} C (D) 8×10^{-19} C

42. A thin wire ring of radius r has an electric charge q_0. The increment of the force stretching the wire if a point charge $\frac{q_0}{2}$ is placed at the ring's centre is

(A) $\frac{q_0^2}{8\pi^2\varepsilon_0 r^2}$ (B) $\frac{q_0^2}{16\pi^2\varepsilon_0 r^2}$

(C) $\frac{q_0^2}{4\pi\varepsilon_0^2 r^2}$ (D) $\frac{2q_0^2}{\pi\varepsilon_0^2 r^2}$

43. Two point charges $q_1 = 4\ \mu\text{C}$ and $q_2 = 9\ \mu\text{C}$ are placed 20 cm apart. The electric field due to them will be zero on the line joining them at a distance of

(A) 8 cm from q_1 (B) 8 cm from q_2

(C) $\frac{80}{13}$ cm from q_1 (D) $\frac{80}{13}$ cm from q_2

44. A spherical region of space has a distribution of charge such that the volume charge density varies with the radial distance from the centre r as $\rho = \rho_0 r^3$, $0 \le r \le R$ where ρ_0 is a positive constant. The total charge Q on sphere is

(A) $Q = \frac{4}{5}\pi\rho_0R^5$ (B) $Q = \frac{4}{5}\pi\rho_0R^4$

(C) $Q = \frac{2}{3}\pi\rho_0R^3$ (D) $Q = \frac{2}{3}\pi\rho_0R^6$

45. An oil drop is found floating freely between the plates of a parallel plate condenser, the plates being horizontal and the lower plate carrying a charge $+Q$. The area of each plate is A and the distance of separation between them is D. The charge on the oil drop must be (g is the acceleration due to gravity)

(A) $\frac{Ag}{QM}$ (B) $\frac{\varepsilon_0 MgA}{Q}$

(C) $-\frac{AgQ}{D}$ (D) $-\frac{MgAQ}{\varepsilon_0}$

46. Two similar point charges q_1 and q_2 are placed at a distance r apart in air. Assume that a slab of thickness one third the separation between the charges is placed between the charges and it is observed that the Coulomb's repulsive force is reduced in the ratio $25:9$. Then the dielectric constant K of such a slab is

(A) 1 (B) 4

(C) 9 (D) 25

47. A cylinder of radius R and length L is placed in a uniform electric field E parallel to the cylinder axis. The total flux for the surface of the cylinder is given by

(A) $2\pi R^2E$ (B) πR^2E

(C) $\left(\pi R^2 + \pi L^2\right)E$ (D) ZERO

48. Two concentric, thin metallic spheres of radii R_1 and $R_2\ (R_1 > R_2)$ bear charges Q_1 and Q_2 respectively. Then the potential at distance r between R_1 and R_2 will be $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(A) $k\left(\frac{Q_1+Q_2}{r}\right)$ (B) $k\left(\frac{Q_1}{r}+\frac{Q_2}{R_2}\right)$

(C) $k\left(\frac{Q_2}{r}+\frac{Q_1}{R_1}\right)$ (D) $k\left(\frac{Q_1}{R_1}+\frac{Q_2}{R_2}\right)$

49. A wire of length L is placed along x-axis with one end at the origin. The linear charge density of the wire varies with distance x from the origin as $\lambda = \lambda_0\left(\frac{x^3}{L}\right)$, where λ_0 is a positive constant. The total charge Q on the rod is

(A) $Q=\frac{\lambda_0 L^2}{3}$ (B) $Q=\frac{\lambda_0 L^3}{3}$

(C) $Q=\frac{\lambda_0 L^3}{4}$ (D) $Q=\frac{\lambda_0 L^4}{5}$

50. A flat circular disc has a charge $+Q$ uniformly distributed on the disc. A charge $+q$ is thrown with kinetic energy E, towards the disc along its normal axis. The charge q will

(A) hit the disc at the centre
(B) return back along its path after touching the disc
(C) return back along its path without touching the disc
(D) any of the above three situations is possible depending on the magnitude of E

51. The electric intensity due to a uniformly charged infinite cylinder of radius R, at a distance $r(>R)$, from its axis is proportional to

(A) r^2 (B) r^3

(C) $\frac{1}{r}$ (D) $\frac{1}{r^2}$

52. Two identical balls each having a density ρ are suspended from a common point by two insulating strings of equal length. Both the balls have equal mass and charge. In equilibrium each string makes an angle θ with vertical. Now, both the balls are immersed in a liquid. As a result of immersion in the liquid the angle θ does not change. The density of the liquid is σ. The dielectric constant of the liquid is

(A) $\frac{\sigma}{\rho}$ (B) $\frac{\rho}{\sigma}$

(C) $\frac{\sigma}{\sigma-\rho}$ (D) $\frac{\rho}{\rho-\sigma}$

53. The radius of a hollow metallic sphere is R. If the potential difference between its surface and a point at a distance of $3R$ from its centre is V, then the electric field intensity at a distance of $3R$ from its centre is

(A) $\frac{V}{2R}$ (B) $\frac{V}{3R}$

(C) $\frac{V}{4R}$ (D) $\frac{V}{6R}$

54. The electric field due to a point charge at a distance R from it is E. If the same charge is placed on a metallic sphere of radius R, the electric field on the surface of the sphere will be

(A) ZERO (B) $\frac{E}{2}$

(C) E (D) $2E$

55. A positive point charge $50\ \mu C$ is located in the plane xy at the point with radius vector $\vec{r}_0 = 2\hat{i}+3\hat{j}$, where $\hat{i}$ and $\hat{j}$ are the unit vectors of the x and y axes. The electrostatic force $\vec{F}$ and its magnitude on a charge of $2\ \mu C$ placed at the point with radius vector $\vec{r} = 8\hat{i}-5\hat{j}$ is (Here $\vec{r}_0$ and $\vec{r}$ are expressed in metre)

(A) 3 N (B) 9 mN

(C) 9 μN (D) 3 mN

56. Two free charges q and $4q$ are placed at a distance d apart. A third charge Q is placed between them at a distance x from charge q such that the system is in equilibrium. Then

(A) $Q=\frac{4q}{9},\ x=\frac{d}{3}$ (B) $Q=\frac{4q}{9},\ x=\frac{d}{4}$

(C) $Q=-\frac{4q}{9},\ x=\frac{d}{3}$ (D) $Q=-\frac{4q}{3},\ x=\frac{d}{4}$

57. A ring of radius 0.1 m is made out of a thin metallic wire of area of cross-section $10^{-6}\ m^2$. The ring has a uniform charge of π coulomb. The change in the radius of the ring when a charge of 10^{-8} coulomb is placed at the centre of the ring is (Young's modulus of the metal is $2\times10^{11}\ Nm^{-2}$)

(A) $\Delta R = 2.25$ cm (B) $\Delta R = 2.25$ mm

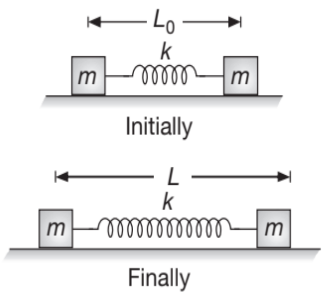
(C) $\Delta R = 22.5$ cm (D) $\Delta R = 22.5$ mm

58. Two isolated, charged conducting spheres of radii R_1 and R_2 produce the same electric field near their surfaces. The ratio of electric potentials on their surfaces is

(A) $\frac{R_1}{R_2}$ (B) $\frac{R_2}{R_1}$

(C) $\frac{R_1^2}{R_2^2}$ (D) $\frac{R_2^2}{R_1^2}$

59. Two identical metallic blocks resting on a frictionless horizontal surface are connected by a light metallic spring having a spring constant k and an unstretched length L_0. A total charge Q is slowly placed on the system, causing the spring to stretch to an equilibrium length $L=\frac{3L_0}{2}$, as shown. The value of Q, assuming that all the charge resides on the blocks and assuming the blocks as point charges is



(A) $Q = 3L_0\sqrt{2\pi\varepsilon_0 L_0}$ (B) $Q = 2L_0\sqrt{3\pi\varepsilon_0 L_0}$

(C) $Q = 3L_0\sqrt{3\pi\varepsilon_0 L_0}$ (D) $Q = 2L_0\sqrt{2\pi\varepsilon_0 L_0}$

60. A charged particle of mass m and charge q is released from rest in a uniform electric field E. The kinetic energy of the particle after time t is

(A) $\frac{2E^2t^2}{mq}$ (B) $\frac{Eq^2m}{2t^2}$

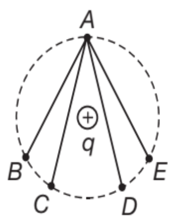
(C) $\frac{E^2q^2t^2}{2m}$ (D) $\frac{Eqm}{2t}$

61. Two identical oppositely charged metallic spheres placed 0.5 m apart, attract each other with a force of 0.108 N. When connected to each other by a copper wire for a short while, they begin to repel each other with a force of 0.036 N. The initial charge on each one of them is

(A) $+1\ \mu C$, $-3\ \mu C$ (B) $-1\ \mu C$, $+3\ \mu C$

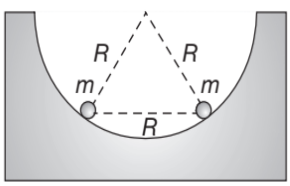
(C) $-3\ \mu C$, $+5\ \mu C$ (D) $5\ \mu C$, $-\frac{3}{5}\ \mu C$

62. In the electric field of a point charge q, a certain charge is carried from point A to B, C, D and E. Then the work done



(A) is least along the path AB
(B) is least along the path AD
(C) is zero along any one of the path AB, AC, AD and AE
(D) is least along AE

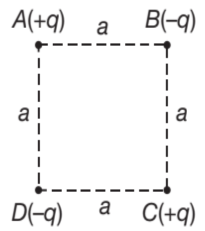
63. Two identical beads each have a mass m and charge q. When placed in a hemispherical bowl of radius R with frictionless, non-conducting walls, the beads move, and at equilibrium they are a distance R apart (shown in figure). The charge on each bead is



(A) $q = 2R\sqrt{\frac{4\pi\varepsilon_0 mg}{\sqrt{3}}}$ (B) $q = 2R\sqrt{\sqrt{3}\pi\varepsilon_0 mg}$

(C) $q = 2R\sqrt{\frac{\pi\varepsilon_0 mg}{\sqrt{3}}}$ (D) None of these

64. Charges $+q$, $-q$, $+q$ and $-q$ are placed at the corners A, B, C and D respectively of a square of side a. The potential energy of the system is $\frac{1}{4\pi\varepsilon_0}$ times



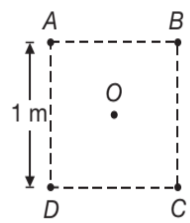
(A) $\frac{q^2}{a}(-4+\sqrt{2})$ (B) $\frac{q^2}{2a}(-4+\sqrt{2})$

(C) $\frac{4q^2}{a}$ (D) $-\frac{4\sqrt{2}q^2}{a}$

65. Two particles each of charge 10^{-7} C and mass 5 g, stay in limiting equilibrium on a horizontal surface. The particles have a separation of 10 cm between them. Assume the coefficient of friction between each particle and the table to be μ. Then μ is

(A) 1.8 (B) 0.018
(C) 0.18 (D) 1.08

66. Three charges, each of $+4\ \mu C$, are placed at the corners B, C, D of a square ABCD of side 1 m. The electric field at the center O of the square is



(A) 7.2×10^4 N towards A

(B) 7.2×10^4 N towards C

(C) 3.6×10^4 N towards A

(D) 3.6×10^4 N towards C

67. The magnitude of the electric field E in the annular region of a charged cylindrical capacitor

(A) is same throughout
(B) is higher near the outer cylinder than near the inner cylinder

(C) varies as $\frac{1}{r}$, where r is the distance from the axis

(D) varies as $\frac{1}{r^2}$, where r is the distance from the axis

68. Four equal positive charges, each of charge Q are arranged at the corners of a square of side ℓ. A unit positive charge of mass m is placed at point P at height h above the centre of the square. Calculate Q, so that the unit charge is in equilibrium.

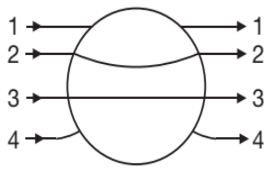
(A) $Q=\frac{\pi\varepsilon_0 mg}{l}\left(l^2+\frac{h^2}{2}\right)^{\frac{3}{2}}$

(B) $Q=\frac{\pi\varepsilon_0 mg}{h}\left(h^2+\frac{l^2}{2}\right)^{\frac{3}{2}}$

(C) $Q=\frac{\pi\varepsilon_0 mg}{4h}\left(h^2+\frac{l^2}{2}\right)^{\frac{3}{2}}$

(D) None of these

69. A metallic sphere is placed in a uniform electric field. The lines of force follow the path(s) shown in the figure as



(A) 1 (B) 2

(C) 3 (D) 4

70. Three charge q, Q and $4q$ are placed in a straight line of length l at points distant 0, $\frac{l}{2}$ and l respectively from one end. In order to make the net force on q zero, the charge Q must be equal to

(A) $-q$ (B) $-2q$

(C) $\frac{-q}{2}$ (D) q

71. Three identical spheres each having a charge $2q$ and radius R are kept such that each touches the other two. Find the magnitude of the electric force on any sphere due to the other two.

(A) $\frac{3q^2}{4\pi\varepsilon_0 R^2}$ (B) $\frac{\sqrt{3}q^2}{2\varepsilon_0 R^2}$

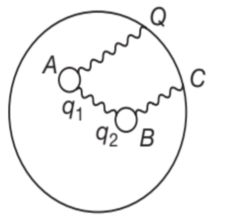
(C) $\frac{\sqrt{3}q^2}{8\pi\varepsilon_0 R^2}$ (D) $\frac{\sqrt{3}q^2}{4\varepsilon_0 R^2}$

72. A point charge q is placed at the midpoint of a cube of side L. The electric flux emerging from the cube is

(A) $\frac{q}{\varepsilon_0}$ (B) $\frac{q}{6L^2\varepsilon_0}$

(C) $\frac{6qL^2}{\varepsilon_0}$ (D) ZERO

73. Two small conductors A and B are given charges q_1 and q_2 respectively. Now they are placed inside a hollow metallic conductor C carrying a charge Q. If all the three conductors A, B and C are connected by a conducting wire as shown, the charges on A, B and C will be respectively



(A) $\frac{q_1+q_2}{2}, \frac{q_1+q_2}{2}, Q$

(B) $\frac{Q+q_1+q_3}{3}, \frac{Q+q_1+q_2}{3}, \frac{Q+q_1+q_2}{3}$

(C) $\frac{q_1+q_2+Q}{2}, \frac{q_1+q_2+Q}{2}, 0$

(D) $0, 0, Q+q_1+q_2$

74. Two small equally charged spheres, each of mass m, are suspended from the same point by light silk threads of length l. The separation between the spheres is $x \ll l$. The rate $\frac{dq}{dt}$ with which the charge leaks off each sphere, if their velocity of approach varies as $v=\frac{6}{\sqrt{x}}$, (where α is a positive constant) is

(A) $\frac{3}{2}\sqrt{\frac{2\pi\varepsilon_0 mg}{l}}$ (B) $4\sqrt{\frac{2\pi\varepsilon_0 mg}{l}}$

(C) $9\sqrt{\frac{2\pi\varepsilon_0 mg}{3l}}$ (D) $9\sqrt{\frac{2\pi\varepsilon_0 mg}{l}}$

75. The electric field in a region of space is given by $\vec{E}=5\hat{i}+2\hat{j}\ \text{NC}^{-1}$. The electric flux due to this field through an area $2\ \text{m}^2$ lying in the YZ plane, in S.I. units, is

(A) 10 (B) 20

(C) $10\sqrt{2}$ (D) $2\sqrt{29}$

76. Consider an annular thin disc of inner radius a and outer radius $b(>a)$. The surface charge density σ varies with the distance r from the centre of the disc as $\sigma = \frac{\sigma_0}{r^2}$ where $a < r < b$ and σ_0 is a positive constant. The total charge on the disc is q, then Q equals

(A) $\sigma_0 \log_e\left(\frac{b}{a}\right)$ (B) $2\sigma_0 \log_e\left(\frac{b}{a}\right)$

(C) $2\pi\sigma_0 \log_e\left(\frac{a}{b}\right)$ (D) $2\pi\sigma_0 \log_e\left(\frac{b}{a}\right)$

77. If E_a be the electric field intensity due to a short dipole at a point on the axis and E_r be that on the right bisector at the same distance from the dipole, then

(A) $E_a = E_r$ (B) $E_a = 2E_r$

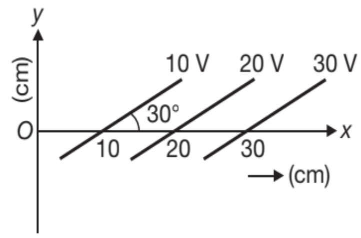
(C) $E_r = 2E_a$ (D) $E_a = \sqrt{2}E_r$

78. Two identical conducting spheres carrying different charges attract each other with a force F when placed in air medium at a distance d apart. The spheres are brought into contact and then taken to their original positions. Now the two spheres repel each other with a force whose magnitude is equal to that of the initial attractive force. The ratio between initial charges on the spheres is

(A) $-(3+\sqrt{8})$ only (B) $-3+\sqrt{8}$ only

(C) $-(3+\sqrt{8})$ or $(-3+\sqrt{8})$ (D) $+\sqrt{3}$

79. Equipotential surfaces are shown in figure. Then the electric field strength will be



(A) $100\ \text{Vm}^{-1}$ along X-axis

(B) $100\ \text{Vm}^{-1}$ along Y-axis

(C) $200\ \text{Vm}^{-1}$ at an angle $120°$ with X-axis

(D) $50\ \text{Vm}^{-1}$ at an angle $120°$ with X-axis

80. A solid sphere of radius R_1 and volume charge density $\rho = \frac{\rho_0}{r}$ is enclosed by a hollow sphere of radius R_2 with negative surface charge density σ, such that the total charge in the system is zero. ρ_0 is a positive constant and r is the distance from the centre of the spheres. The ratio $\frac{R_2}{R_1}$ is

(A) $\frac{\sigma}{\rho_0}$ (B) $\sqrt{\frac{2\sigma}{\rho_0}}$

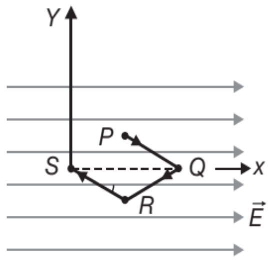
(C) $\sqrt{\frac{\rho_0}{2\sigma}}$ (D) $\frac{\rho_0}{\sigma}$

81. An electric charge is placed at the centre of a cube of side a. The electric flux through one of its faces will be

(A) $\frac{q}{6\varepsilon_0}$ (B) $\frac{q}{\varepsilon_0 a^2}$

(C) $\frac{q}{4\pi\varepsilon_0 a^2}$ (D) $\frac{q}{\varepsilon_0}$

82. Point charge q moves from point P to point S along the path PQRS (figure shown) in a uniform electric field E pointing coparallel to the positive direction of the X-axis. The coordinates of the points P, Q, R and S are $(a, b, 0)$, $(2a, 0, 0)$, $(a, -b, 0)$ and $(0, 0, 0)$ respectively. The work done by the field in the above process is given by the expression



(A) qEa (B) $-qEa$

(C) $qEa\sqrt{2}$ (D) $qE\sqrt{(2a)^2 + b^2}$

83. A positively charged disc is placed on a horizontal plane. A charged particle is released from a certain height on its axis. The particle just reaches the center of the disc. Select the correct alternative.

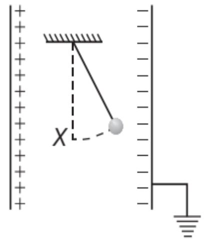
(A) Particle has negative charge on it.

(B) Total potential energy (gravitational + electrostatic) of the particle first increases then decreases.

(C) Total potential energy of the particle first decreases then increases.

(D) Total potential energy of the particle continuously decreases.

84. A simple pendulum has a length l, mass of bob m. The bob is given a charge q. The pendulum is suspended between the vertical plates of charged parallel plate capacitor. If E is the field strength between the plates, then time period T equals



(A) $2\pi\sqrt{\frac{l}{g}}$ (B) $2\pi\sqrt{\frac{l}{g+\frac{qE}{m}}}$

(C) $2\pi\sqrt{\frac{l}{g-\frac{qE}{m}}}$ (D) $2\pi\sqrt{\frac{l}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$

85. Two positive point charges are 3 m apart and their combined charge is $20\ \mu$C. If the force between them is 0.075 N, the charges are

(A) $10\ \mu$C, $10\ \mu$C (B) $15\ \mu$C, $5\ \mu$C

(C) $12\ \mu$C, $8\ \mu$C (D) $14\ \mu$C, $6\ \mu$C

86. Four charges of $6\ \mu$C, $2\ \mu$C, $-12\ \mu$C and $4\ \mu$C are placed at the corners of a square of side 1 m. The square is in x-y plane and its center at its origin. Electric potential due to these charges is zero everywhere on the line

(A) $x = y,\ z = 0$ (B) $x = 0 = z$

(C) $x = 0 = y$ (D) $x = z,\ y = 0$

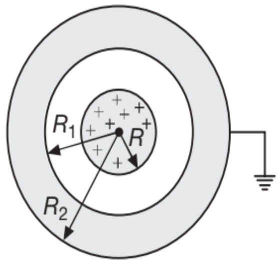
87. Two vertical metallic plates carrying equal and opposite charges are kept parallel to each other like a parallel plate capacitor. A small spherical metallic ball is suspended by a long insulated thread such that is hangs freely in the centre of the two metallic plates. The ball, which is uncharged, is taken slowly towards the positively charged plate and is made to touch that plate. Then the ball will

(A) stick to the positively charged plate
(B) come back to its original position and will remain there
(C) oscillate between the two plates touching each plate in turn
(D) oscillate between the two plates without touch them

88. As the electric charge on the surface of a hollow metal sphere increases, the electric field intensity inside the sphere

(A) decreases
(B) increases
(C) remains the same
(D) may increase or decrease depending on the radius of the sphere

89. A charge q is distributed uniformly over the volume of a insulating solid sphere of radius R. It is enclosed by an earthed conducting spherical shell of inner radius R_1 and outer radius R_2. The charge on the outer surface of the shell will be



(A) $+q$ (B) $\frac{R_2}{R_1}q$

(C) $\frac{R}{R_2}q$ (D) zero

90. A hollow metal sphere of radius 5 cm is charged so that the potential on its surface is 10 V. The potential at the centre of the sphere is

(A) ZERO
(B) 10 V
(C) same as at a point 5 cm away from the surface
(D) same as at a point 25 cm away from the surface

91. A rod of length L has a total charge q distributed uniformly along its length. It is bent in the shape of a semicircle. The electric potential at the center of the semicircle is

(A) $\frac{1}{4\pi\varepsilon_o}\frac{q}{L}$ (B) $\frac{q}{4\varepsilon_o L}$

(C) $\frac{q}{2\varepsilon_o L}$ (D) $\frac{1}{\pi\varepsilon_o}\frac{q}{L}$

92. Two charged conducting spheres of radii R_1 and R_2, separated by a large distance, are connected by a long wire. The ratio of the charges on them is

(A) $\frac{R_1}{R_2}$ (B) $\frac{R_2}{R_1}$

(C) $\frac{R_1^2}{R_2^2}$ (D) $\frac{R_2^2}{R_1^2}$

93. In PROBLEM 92, the ratio of the electric fields on the surfaces of the two spheres is

(A) $\frac{R_1}{R_2}$ (B) $\frac{R_2}{R_1}$

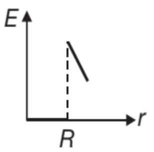
(C) $\frac{R_1^2}{R_2^2}$ (D) $\frac{R_2^2}{R_1^2}$

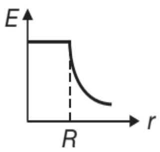
94. A spherical volume contains a uniformly distributed charge of density ρ. The electric field inside the sphere at a distance r from the center is

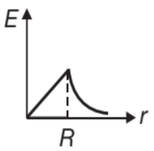
(A) $\frac{\rho r}{3\varepsilon_o}$ (B) $\frac{\rho r}{4\pi\varepsilon_o}$

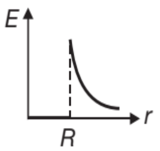
(C) $\frac{\rho}{\varepsilon_o r}$ (D) $\frac{\rho r}{4\pi\varepsilon_o}$

95. Which one of the following graphs represents the variation of electric field strength E with distance r from the centre of a uniformly charged non-conducting sphere

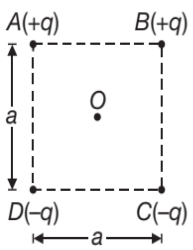
(A) 

(B) 

(C) 

(D) 

96. Four charges $+q$, $+q$, $-q$ and $-q$ are placed respectively at the corners A, B, C and D of a square of side a. The potential and field at the centre O of the square are respectively $\frac{1}{4\pi\varepsilon_0}$ times



(A) ZERO, $\frac{4q}{a^2}$ (B) ZERO, $\frac{4\sqrt{2}q}{a^2}$

(C) $\frac{4\sqrt{2}q}{a}$, $\frac{4q}{a^2}$ (D) $\frac{4\sqrt{2}q}{a}$, $\frac{4\sqrt{2}q}{a^2}$

97. Two fixed charges $-2Q$ and $+Q$ are located at points $(-3a, 0)$ and $(+3a, 0)$ respectively. Then

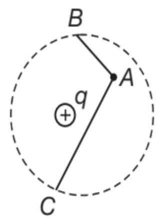
(A) points where the electric potential due to the two charges is zero, lie on a circle of radius $4a$ and center $(5a, 0)$

(B) potential is zero at $x = a$ and $x = 9a$

(C) If a particle of charge $+q$ is released from the center of the circle obtained in part (A) it will eventually cross the circle

(D) All of the above

98. In the electric field of a point charge q shown, a charge is carried from A to B and from A to C. Compare the work done



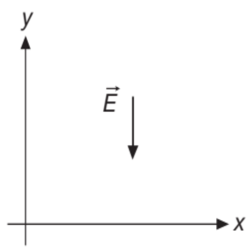
(A) work done is greater along the path AC than along AB

(B) work done is the same in both the cases

(C) work done is greater along the path AB than along AC

(D) work done is zero in both the cases

99. A particle of mass m and charge $-q$ is projected from the origin with a horizontal speed v into an electric field of intensity E directed downward. Select the incorrect statement.



(A) The kinetic energy after a displacement y is qEy

(B) The horizontal and vertical components of acceleration are $a_x = 0$, $a_y = \frac{qE}{m}$

(C) The equation of trajectory is $y = \frac{1}{2}\left(\frac{qEx^2}{mv^2}\right)$

(D) The horizontal and vertical displacements x and y after a time t are $x = vt$ and $y = \frac{1}{2}a_y t^2$

100. A positively charged thin metal ring of radius R is fixed in the X-Y plane with its centre at the origin O. A negatively charged particle P is released from rest at point $(0, 0, z_0)$ where $z_0 > 0$. Then the motion of P is

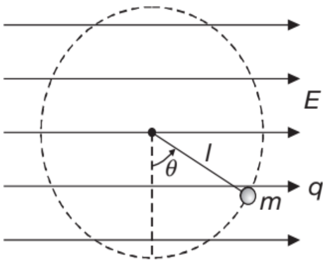
(A) simple harmonic for all values of z_0 satisfying $0 < z_0 < \infty$

(B) simple harmonic for all values of z_0 satisfying $0 < z_0 \leq R$

(C) approximately simple harmonic provided $z_0 << R$

(D) such that P crosses O and continues to move along the negative Z-axis towards $z = -\infty$

101. A small ball of mass m and charge $+q$ tied with a string of length l, is rotating in a vertical circle under gravity and a uniform horizontal electric field E as shown. The tension in the string will be minimum for



(A) $\theta = \tan^{-1}\left(\frac{qE}{mg}\right)$ (B) $\theta = \pi$

(C) $\theta = \pi - \tan^{-1}\left(\frac{qE}{mg}\right)$ (D) $\theta = \pi + \tan^{-1}\left(\frac{qE}{mg}\right)$

102. A solid metallic sphere has a charge $+3Q$. Concentric with this sphere is a conducting spherical shell having charge $-Q$. The radius of the sphere is a and that of the spherical shell is $b(b > a)$. The electric field at a distance R $(a < R < b)$ from the centre is

(A) $\frac{Q}{2\pi\varepsilon_0 R}$ (B) $\frac{3Q}{2\pi\varepsilon_0 R}$

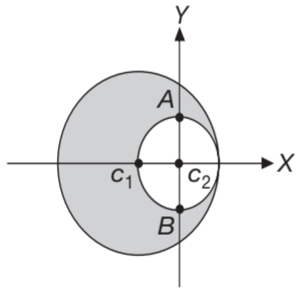
(C) $\frac{3Q}{4\pi\varepsilon_0 R^2}$ (D) $\frac{4Q}{4\pi\varepsilon_0 R^2}$

103. Two infinitely long parallel wires having linear charge densities λ_1 and λ_2 respectively are placed at a distance R metre. The force per length on either wire will be $\left(K = \frac{1}{4\pi\varepsilon_0}\right)$

(A) $K\left(\frac{2\lambda_1\lambda_2}{R^2}\right)$ (B) $K\left(\frac{2\lambda_1\lambda_2}{R}\right)$

(C) $K\left(\frac{\lambda_1\lambda_2}{R^2}\right)$ (D) $K\left(\frac{\lambda_1\lambda_2}{R}\right)$

104. A uniformly charged sphere of radius $R = 2$ m and volume charge density ρ has a spherical cavity as shown. A point object of mass $m = 1$ g and charge $q = 2 \times 10^{-4}$ C is thrown, from point A. The minimum velocity required at A for it to reach point B is $\left(\rho = 3\varepsilon_0 \times 10^{-3}\ \text{Cm}^{-3}\right)$



(A) $0.02\ \text{ms}^{-1}$ (B) $0.2\ \text{ms}^{-1}$

(C) $0.4\ \text{ms}^{-1}$ (D) $0.04\ \text{ms}^{-1}$

105. The potential energy of an electric dipole in a uniform electric field is U. The magnitude of the torque acting on the dipole due to the field is N. Then

(A) U is minimum and N is zero when the dipole is parallel to the field.

(B) U is zero and N is zero when the dipole is perpendicular to the field.

(C) U is minimum and N is maximum when the dipole is perpendicular to the field

(D) U is minimum and N is zero when the dipole is anti-parallel to the field

106. Five point charges ($+q$ each) are placed at the five vertices of a regular hexagon of side $2a$. What is the magnitude of the net electric field at the centre of the hexagon?

(A) $\frac{1}{4\pi\varepsilon_o}\frac{q}{a^2}$ (B) $\frac{q}{16\pi\varepsilon_o a^2}$

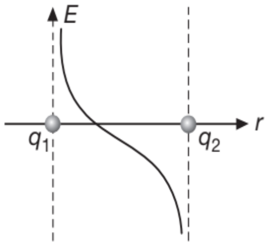
(C) $\frac{\sqrt{2}q}{4\pi\varepsilon_o a^2}$ (D) $\frac{5q}{16\pi\varepsilon_o a^2}$

107. A charge Q is divided into two parts and the two parts are separated by a certain distance. The force between them will be maximum if one of the charges is

(A) $\frac{Q}{2}$ (B) $\frac{Q}{3}$

(C) $\frac{Q}{4}$ (D) None of these

108. The variation of electric field between the two charges q_1 and q_2 along the line joining the charges is plotted against distance from q_1 (taking rightward direction of electric field as positive) as shown in the figure. Then the correct statement is



(A) q_1 and q_2 are positive and $q_1 < q_2$

(B) q_1 and q_2 are positive and $q_1 > q_2$

(C) q_1 is positive and q_2 is negative and $q_1 < q_2$

(D) q_1 and q_2 are negative and $q_1 < q_2$

109. A and B are two spherical conductors of same extent and size. A is solid and B is hollow. Both are charged to the same potential. If the charges on A and B are Q_A and Q_B respectively, then

(A) Q_A is less then Q_B

(B) Q_A is greater than Q_B but not double

(C) $Q_A = Q_B$

(D) $Q_A = 2Q_B$

110. Three point charges q, $2q$ and $8q$ are to be placed on a straight line 9 cm long. The system possesses minimum potential energy when

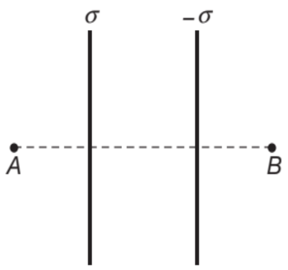
(A) $2q$ and q lie at ends with $8q$ at 3 cm from $2q$.

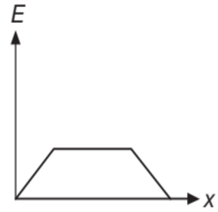
(B) $2q$ and $8q$ lie at ends with q at 6 cm from $8q$.

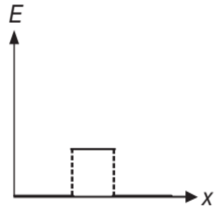
(C) q and $8q$ lie at ends with $2q$ at 6 cm from q.

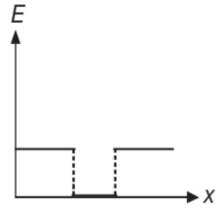
(D) $2q$ and $8q$ lie at ends with q at 3 cm from $8q$.

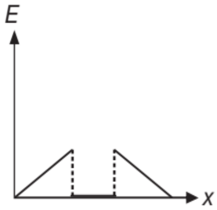
111. Two large parallel planes charged uniformly with surface charge density σ and $-\sigma$ are located as shown in the figure. Which one of the following graphs shows the variation of electric field along a line perpendicular to the planes as one moves from A to B?



(A)


(B)


(C)


(D)


112. An infinite number of charges, each equal to q coulomb, are placed along the x-axis at x (in metres) = 1, 2, 4, 8,....... and so on. The potential and field in SI units at $x = 0$ due to this set of charges are respectively $\frac{1}{4\pi\varepsilon_0}$ times

(A) $2q$, $4q$

(B) $\frac{2q}{3}$, $4q$

(C) $\frac{2q}{3}$, $\frac{4q}{3}$

(D) $2q$, $\frac{4q}{3}$

113. In PROBLEM 112, if the consecutive charges have opposite signs, then the potential and field at $x = 0$ are respectively $\frac{1}{4\pi\varepsilon_0}$ times

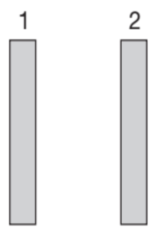
(A) $\frac{2q}{3}$, $\frac{4q}{7}$

(B) $\frac{2q}{5}$, $\frac{4q}{5}$

(C) $\frac{2q}{3}$, $\frac{4q}{5}$

(D) $\frac{2q}{5}$, $\frac{4q}{7}$

114. Two conducting plates 1 and 2 each having large surface area A (on one side) are placed parallel to each other. The plate A is given a charge q, while the plate 2 is neutral. Then the electric field at a point in between the plates is



(A) $\frac{q}{2A\varepsilon_0}$

(B) $\frac{q}{A\varepsilon_0}$

(C) $\frac{2q}{A\varepsilon_0}$

(D) $\frac{3}{2}\frac{q}{A\varepsilon_0}$

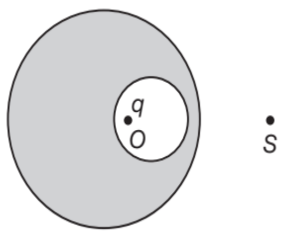
115. Two concentric metallic spherical shells are given positive charges of different value. Then
(A) the outer sphere is always at a higher potential
(B) the inner sphere is always at a higher potential
(C) both the spheres are at the same potential
(D) no prediction can be made about their potentials unless the actual values of charges and radii are known

116. Two thin infinite parallel plates have uniform charge densities $+\sigma$ and $-\sigma$. The electric field in the space between them is

(A) $\dfrac{\sigma}{2\varepsilon_0}$ (B) $\dfrac{\sigma}{\varepsilon_0}$

(C) $\dfrac{2\sigma}{\varepsilon_0}$ (D) ZERO

117. A charge q is placed at O in the cavity in a spherical uncharged conductor. Point S lies outside the conductor. If the charge is displaced from O towards S still remaining within the cavity, then



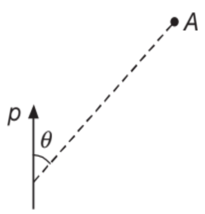
(A) electric field at S will increase
(B) electric field at S will decrease
(C) electric field at S will first increase and then decrease
(D) electric field at S will not change

118. The electric potential (in volt) in a region is given by

$$V = 6x - 8xy^2 - 8y + 6yz - 4x^2$$

Then electric force acting on a point charge of 2 C placed at the origin will be
(A) 2 N (B) 6 N
(C) 8 N (D) 20 N

119. The electric field at a point A due to dipole p is perpendicular to p. The angle θ is



(A) 0° (B) 90°

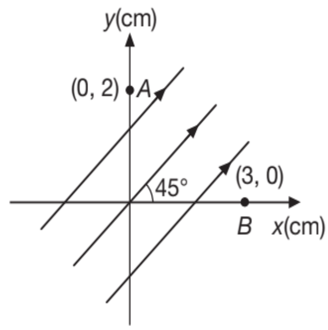
(C) $\tan^{-1}(2)$ (D) $\tan^{-1}(\sqrt{2})$

120. Equal charges q are placed at the four corners A, B, C, D of a square of side a. The magnitude of the force on the charge at C will be

(A) $\dfrac{3q^2}{4\pi\varepsilon_0 a^2}$ (B) $\dfrac{4q^2}{4\pi\varepsilon_0 a^2}$

(C) $\left(\dfrac{1+2\sqrt{2}}{2}\right)\dfrac{q^2}{4\pi\varepsilon_0 a^2}$ (D) $\left(2+\dfrac{1}{\sqrt{2}}\right)\dfrac{q^2}{4\pi\varepsilon_0 a^2}$

121. A uniform electric field of $400\ \text{Vm}^{-1}$ is directed at $45°$ above the x-axis as shown in the figure. The potential difference $V_A - V_B$ is given by



(A) 0 (B) 4 V
(C) 6.4 V (D) 2.8 V

122. A charge Q is distributed over two concentric hollow spheres of radii r and $R(R>r)$ such that the surface densities are equal. The potential at the common centre is $\dfrac{1}{4\pi\varepsilon_0}$ times

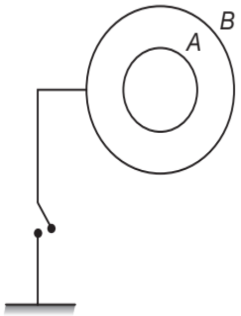
(A) $Q\left(\dfrac{r+R}{r^2+R^2}\right)$ (B) $\dfrac{Q}{2}\left(\dfrac{r+R}{r^2+R^2}\right)$

(C) $2Q\left(\dfrac{r+R}{r^2+R^2}\right)$ (D) zero

123. An electric dipole is placed at the origin along the x-axis. The electric field at any point, whose position vector makes an angle θ with the x-axis, makes an angle
(A) α (B) θ
(C) $\theta+\alpha$ (D) $\theta+2\alpha$

with the x-axis, where $\tan\alpha = \dfrac{1}{2}\tan\theta$.

124. Initially the spheres A and B are at potentials V_A and V_B respectively. Now sphere B is earthed by closing the switch. The potential of A becomes



(A) 0 (B) V_A

(C) $V_A - V_B$ (D) V_B

125. A charge Q is placed at each of the two opposite corners of a square. A charge q is placed at each of the other two corners. If the resultant force on Q is zero, then

(A) $Q = \sqrt{2}q$ (B) $Q = -\sqrt{2}q$

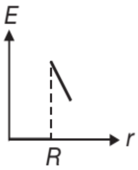
(C) $Q = 2\sqrt{2}q$ (D) $Q = -2\sqrt{2}q$

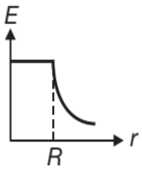
126. Electric charges q, q and $-2q$ are placed at the three corners of an equilateral triangle of side l. The magnitude of the electric dipole moment of the system is

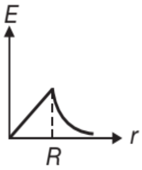
(A) ql (B) $2ql$

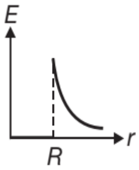
(C) $\sqrt{3}ql$ (D) $4ql$

127. Which one of the following graphs represents, variation of the electric field strength E with distance r from the centre of a charged conducting sphere?

(A)


(B)


(C)


(D)


128. A charged particle of mass m and charge q is released from rest from position $(x_0, 0)$ in a uniform electric field $E_0\hat{j}$. The angular momentum of the particle about origin

(A) is zero (B) is constant

(C) increases with time (D) decreases with time

129. An insulating solid sphere of radius R is charged in a non-uniform manner such that volume charge density $\rho = \frac{A}{r}$, where A is a positive constant and r the distance from centre. Electric field strength at any inside point at distance r_1 is

(A) $\frac{1}{4\pi\varepsilon_0}\left(\frac{4\pi A}{r_1}\right)$ (B) $\frac{1}{4\pi\varepsilon_0}\left(\frac{A}{r_1}\right)$

(C) $\frac{A}{\pi\varepsilon_0}$ (D) $\frac{A}{2\varepsilon_0}$

130. An electric dipole is placed at the origin and is directed along the x-axis. At a point P, far away from the dipole, the electric field is parallel to the y-axis. OP makes an angle θ with the x-axis, then

(A) $\tan\theta = \sqrt{3}$ (B) $\tan\theta = \sqrt{2}$

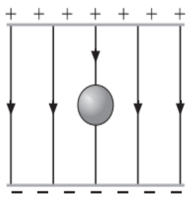
(C) $\theta = 45°$ (D) $\tan\theta = \left(\frac{1}{\sqrt{2}}\right)$

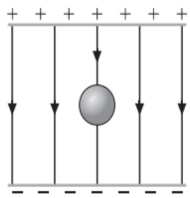
131. Two identical balls having like charges and placed at certain distance apart repel each other with a certain force. They are brought in contact and then moved apart to a distance equal to half their initial separation. The force of repulsion between them increases 4.5 times in comparison with the initial value. The ratio of the initial charges of the balls is

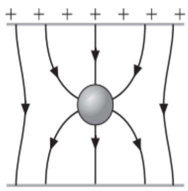
(A) 2 (B) 3

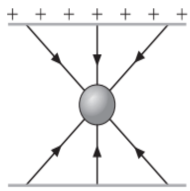
(C) 4 (D) 6

132. An uncharged sphere of metal is placed in uniform electric field produced by two oppositely charged plates. The lines of force will appear as

(A)


(B)


(C)


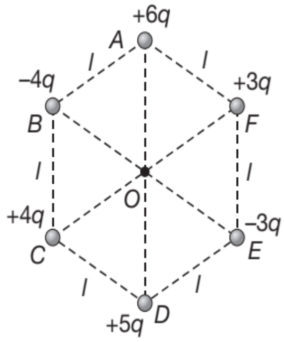
(D)


133. Two small identical spheres having charges $+10\ \mu C$ and $-90\ \mu C$ attract each other with a force of F newton. If they are kept in contact and then separated by the same distance, the new force between them is

(A) $\frac{F}{6}$ (B) $16F$

(C) $\frac{16F}{9}$ (D) $9F$

134. The magnitude of electric field at the centre O of regular hexagon produced by the system of charges will be



(A) $\dfrac{q}{4\pi\varepsilon_0\ell^2}$ (B) $\dfrac{\sqrt{2}q}{4\pi\varepsilon_0\ell^2}$

(C) $(2+\sqrt{2})\dfrac{q}{4\pi\varepsilon_0\ell^2}$ (D) 0

135. Two equal and opposite charges are placed at a certain distance, the force between them is F. If 25% of one charge is transferred to other, then the force between them is

(A) F (B) $\dfrac{9F}{16}$

(C) $\dfrac{15F}{16}$ (D) $\dfrac{4F}{5}$

136. The electric field inside a sphere which carries a charge density proportional to the distance from the origin $\rho = \alpha r$, where (α is a constant) is

(A) $\dfrac{\alpha r^3}{4\varepsilon_0}$ (B) $\dfrac{\alpha r^2}{4\varepsilon_0}$

(C) $\dfrac{\alpha r^2}{3\varepsilon_0}$ (D) None of these

137. A regular polygon has 20 sides. Equal charges, each Q, are placed at 19 vertices of the polygon and a charge q is placed at the centre of polygon. If the distance of each vertex from the centre O is a, net force experienced by q is

(A) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{20Qq}{a^2}$ (B) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Qq}{a^2}$

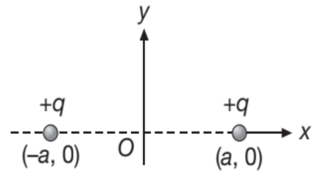
(C) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{19Qq}{a^2}$ (D) zero

138. Two particles of masses m and $2\,\text{m}$ and charges $2q$ and $2q$ are placed in a uniform electric field E and allowed to move for the same time. The ratio of kinetic energies will be

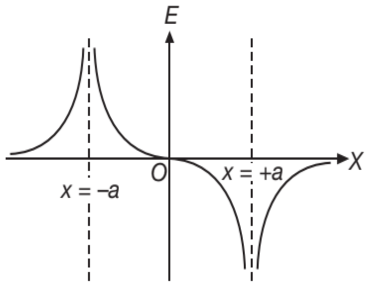
(A) $2:1$ (B) $8:1$

(C) $4:1$ (D) $1:4$

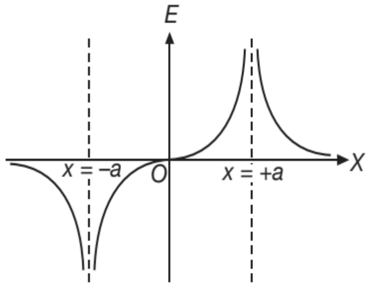
139. Two identical point charges q are placed at $x=-a$ and $x=a$, as shown in figure. The graph showing the variation of E along the x-axis is (assuming positive E to be taken along the $+x$-axis)



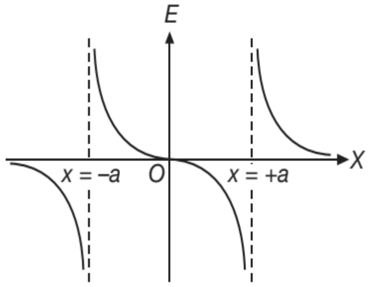
(A)



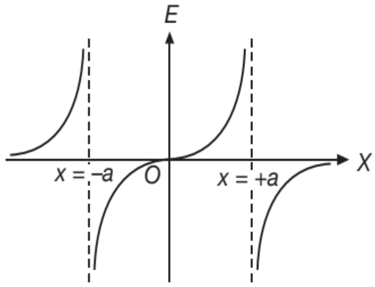
(B)



(C)



(D)



140. The number of electrons that should be removed from a coin of mass 1.6 g, so that it may float in electric field intensity $10^9\ \text{NC}^{-1}$ directed upwards is

(A) 9.8×10^7 (B) 9.8×10^5

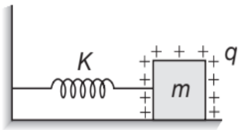
(C) 9.8×10^3 (D) 9.8×10^1

141. Two identical metallic spheres A and B carry charges $+Q$ and $-2Q$ respectively. The force between them is F Newton, when they are separated by a distance d in air. The spheres are allowed to touch each other and are moved back to their initial positions. The force between them now is

(A) $\frac{F}{2}$ (B) $\frac{F}{4}$

(C) $\frac{F}{8}$ (D) zero

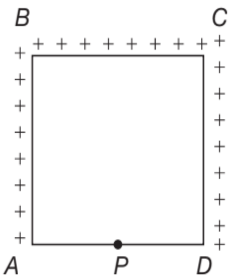
142. Initially the spring is in unstreched condition. An electric field (E) is switched on in right direction. The maximum extension in the spring will be



(A) $\frac{2qE}{K}$ (B) $\sqrt{\frac{2qE}{K}}$

(C) $\frac{qE}{K}$ (D) $\sqrt{\frac{qE}{K}}$

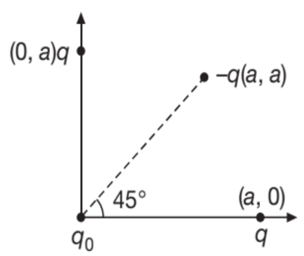
143. Three wires AB, BC, CD of equal length l are charged uniformly with linear charged density λ and are placed as shown. P is a point which lies at a distance l from the wire BC on its perpendicular bisector. The electric field at P is



(A) $\frac{\lambda}{2\sqrt{5}\varepsilon_0 l}\left(2\sqrt{5}-1\right)$ (B) $\frac{2\lambda}{2\sqrt{5}\varepsilon_0 l}\left(\sqrt{5}-1\right)$

(C) $\frac{\lambda}{4\sqrt{5}\varepsilon_0 l}\left(2\sqrt{5}-3\right)$ (D) $\frac{\lambda}{4\sqrt{5}\varepsilon_0 l}$

144. The net force acting on the charge q_0 present at the origin is



(A) $\frac{qq_0}{4\pi\varepsilon_0 a^2}\times\sqrt{2}$ (B) $\frac{qq_0}{4\pi\varepsilon_0\sqrt{2}a^2}+\frac{qq_0}{8\pi\varepsilon_0 a^2}$

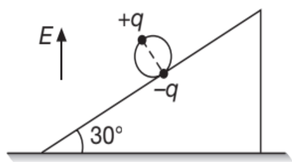
(C) $\frac{qq_0}{4\pi\varepsilon_0 a^2}\left(\sqrt{2}-\frac{1}{2}\right)$ (D) $\frac{qq_0}{4\pi\varepsilon_0 a^2}\left(\frac{1}{2}-\sqrt{2}\right)$

145. A neutral sphere of radius r and density ρ is intended to be suspended with an electric field E existing on the earth's surface directed vertically up. What fraction of the electrons should be removed from the sphere. Given that, the atomic number and atomic mass of the material of the sphere are Z & A respectively. Avogadro number is N_A. Assume that the sphere is able to hold the necessary charge without any leakage

(A) $\frac{2g}{eEZAN_A}$ (B) $\frac{3gA}{eEZ}$

(C) $\frac{gA}{eEZN_A}$ (D) $\frac{2gA}{eEZN_A}$

146. A wheel having mass m has charges $+q$ and $-q$ fixed at diametrically opposite ends. For the wheel to be in equilibrium on a rough inclined plane in the presence of uniform vertical electric field E, the magnitude of E is



(A) $\frac{3mg}{2q}$ (B) $\frac{mg}{2q}$

(C) $\frac{\sqrt{3}mg}{2q}$ (D) $\frac{3mg}{4q}$

147. Seven identical charge particles each having charge q are placed on the vertices of a cube of edge ℓ, then the magnitude of electric field at centre of cube is

(A) $\frac{q}{4\pi\varepsilon_0\ell^2}$ (B) $\frac{q}{3\pi\varepsilon_0\ell^2}$

(C) $\frac{q}{8\pi\varepsilon_0\ell^2}$ (D) $\frac{q}{6\pi\varepsilon_0\ell^2}$

148. A simple pendulum of mass m and charge q is hanging from roof of a car moving on a circular track of radius r with constant speed v and string makes angle θ with vertical. Magnitude of horizontal electric field required so that string makes same angle θ on other side of vertical is

(A) $\frac{4mv^2}{qr}$ (B) $\frac{3mv^2}{qr}$

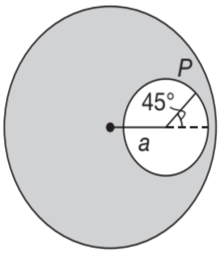
(C) $\frac{2mv^2}{qr}$ (D) $\frac{mv^2}{qr}$

149. Two identical charges repel each other with a force equal to 10 mg wt, when they are 0.6 m apart in air. The value of each charge is $\left(g=10\ \text{ms}^{-2}\right)$

(A) 2 mC (B) 2×10^{-7} C

(C) 2 nC (D) 2 μC

150. A cavity of radius r is made inside a solid sphere. The volume charge density of the remaining sphere is ρ. An electron (charge e, mass m) is released from rest inside the cavity from point P as shown in figure. The centre of sphere and centre of cavity are separated by a distance a. The time after which the electron again touches the sphere is



(A) $\sqrt{\frac{6\sqrt{2}r\varepsilon_0 m}{e\rho a}}$ (B) $\sqrt{\frac{\sqrt{2}r\varepsilon_0 m}{6\rho a}}$

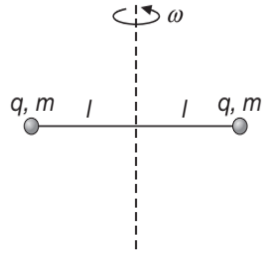
(C) $\sqrt{\frac{6r\varepsilon_0 m}{e\rho a}}$ (D) $\sqrt{\frac{r\varepsilon_0 m}{e\rho a}}$

151. A charged soap bubble having surface charge density σ and radius R. If pressure inside soap bubble and pressure outside it is same then the surface tension for soap bubble is

(A) $T=\frac{\sigma^2 R}{8\varepsilon_0}$ (B) $T=\frac{\sigma^2 R}{4\varepsilon_0}$

(C) $T=\frac{\sigma^2 R}{2\varepsilon_0}$ (D) $T=\frac{\sigma^2 R}{\varepsilon_0}$

152. Two identical point charges each q of mass m are connected by a insulating string of length 2ℓ and the system are rotated about an axis passing through mid point of string and perpendicular to its length as shown. Then neglecting gravity, tension in the string is (Assume only coulombic force between the charges)



(A) $\frac{q^2}{4\pi\varepsilon_0\ell^2}-m\ell\omega^2$ (B) $\frac{q^2}{4\pi\varepsilon_0\ell^2}+m\ell\omega^2$

(C) $\frac{q^2}{16\pi\varepsilon_0\ell^2}-m\ell\omega^2$ (D) $\frac{q^2}{16\pi\varepsilon_0\ell^2}+m\ell\omega^2$

153. A short dipole is placed along x-axis with centre at origin. The electric field at a point P, which is at a distance r from origin such that $\overrightarrow{OP}=\vec{r}$ makes an angle of 45° with x-axis, is directed along a direction making

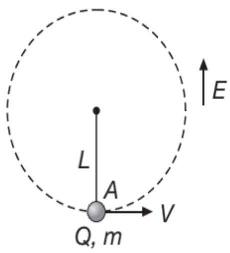
(A) $\tan^{-1}(0.5)$ with x-axis

(B) $\frac{\pi}{4}+\tan^{-1}(0.5)$ with x-axis

(C) $\frac{\pi}{4}+\tan^{-1}(0.5)$ with y-axis

(D) $\tan^{-1}(0.5)$ with y-axis

154. A particle of mass m and charge Q is attached to a string of length L. It is whirled into a vertical circle in field E. The speed of the particle at point A, so that the tension in the string at A is ten times the weight of particle, is (g = acceleration due to gravity)



(A) $\sqrt{5gL}$ (B) $\sqrt{\frac{QEL}{m}}$

(C) $\sqrt{L\left(9g+\frac{QE}{m}\right)}$ (D) None of these

155. In an experiment to demonstrate Coulomb's law in electrostatics, the force F between two small charged spheres is measured for various distances r between their centres. A graph is plotted of $\log_e F$ (y-axis) against $\log_e r$ (x-axis). The slope of this graph is

(A) -2 (B) $+\frac{1}{2}$

(C) $-\frac{1}{2}$ (D) $+2$

156. Two point like charges Q_1 and Q_2 of whose strength are equal in absolute value of are placed at a certain distance from each other. Assuming the field strength to be positive in the positive direction of x-axis, the signs of the charges Q_1 and Q_2 for the graphs (field strength versus distance) shown in figure 1, 2, 3, and 4 are

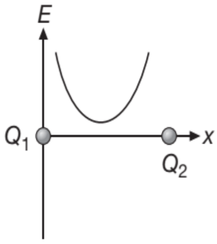


Figure 1

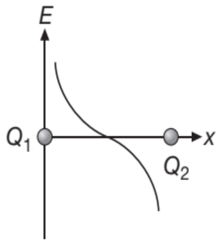


Figure 2

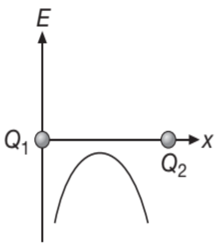


Figure 3

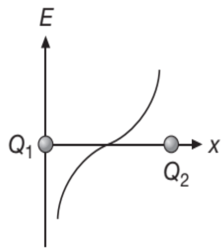


Figure 4

(A) Q_1 positive; Q_2 negative; both positive; Q_1 negative; Q_2 positive; both negative

(B) Q_1 negative; Q_2 positive; Q_1 positive; Q_2 negative; both positive; both negative

(C) Q_1 positive; Q_2 negative; both negative; Q_1 negative; Q_2 positive; both positive

(D) both positive; Q_1 positive; Q_2 negative; Q_1 negative; Q_2 positive; both negative

157. Two point charges q and $-q$ are at positions $(0, 0, d)$ and $(0, 0, -d)$ respectively. The electric field at $(a, 0, 0)$ is

(A) $\frac{2qd}{4\pi\varepsilon_0\left(d^2+a^2\right)^{\frac{3}{2}}}\hat{k}$ (B) $\frac{qd}{4\pi\varepsilon_0\left(d^2+a^2\right)^{\frac{3}{2}}}\hat{k}$

(C) $\frac{-2qd}{4\pi\varepsilon_0\left(d^2+a^2\right)^{\frac{3}{2}}}\hat{k}$ (D) $\frac{-qd}{4\pi\varepsilon_0\left(d^2+a^2\right)^{\frac{3}{2}}}\hat{k}$

158. A uniformly charged and infinitely long line having a linear charge density λ is placed at a normal distance y from a point O. Consider a sphere of radius R with O as centre and $R > y$. Electric flux through the surface of the sphere is

(A) zero (B) $\frac{2\lambda R}{\varepsilon_0}$

(C) $\frac{2\lambda\sqrt{R^2-y^2}}{\varepsilon_0}$ (D) $\frac{\lambda\sqrt{R^2+y^2}}{\varepsilon_0}$

159. Two charges of $-4\,\mu C$ and $+4\,\mu C$ are placed at points $A(1, 0, 4)$ and $B(2, -1, 5)$ located in an electric field $\vec{E} = 0.20\hat{i}$ Vcm^{-1}. The torque acting on the dipole is

(A) 8×10^{-5} Nm (B) $\frac{8}{\sqrt{2}}\times10^{-5}$ Nm

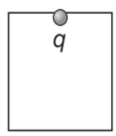
(C) $8\sqrt{2}\times10^{-5}$ Nm (D) $2\sqrt{2}\times10^{-5}$ Nm

160. The inward and outward electric flux from a closed surface are respectively 8×10^3 and 4×10^3 units. Then the net charge inside the closed surface is

(A) -4000 coulomb (B) 4000 coulomb

(C) $-\frac{4000}{\varepsilon_0}$ coulomb (D) $-4000\varepsilon_0$ coulomb

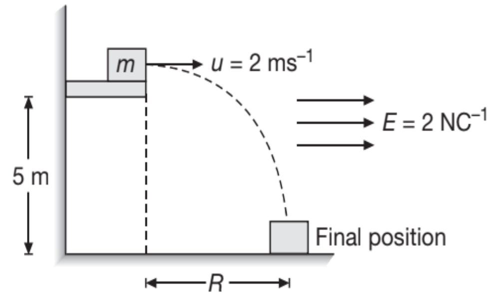
161. A charge q is placed at the centre of the open end of a cylindrical vessel. The flux of the electric field through the surface of the vessel is



(A) zero (B) $\frac{q}{\varepsilon_0}$

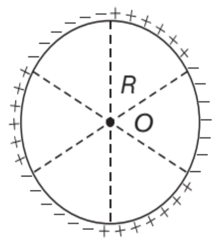
(C) $\frac{q}{2\varepsilon_0}$ (D) $\frac{2q}{\varepsilon_0}$

162. The block shown in the diagram has a mass of 2 microgram and a charge of 2×10^{-9} coulomb. If the block is given an initial velocity of $2\ ms^{-1}$ in x direction at $t = 0$ and an electric field of $2\ NC^{-1}$ in x direction is switch on at that moment, then R will be $\left(g = 10\ ms^{-2}\right)$



(A) 4 m (B) 1 m
(C) 2 m (D) 3 m

163. A ring of radius R is marked in six equal parts and these parts are charged uniformly each with a charge of magnitude Q but positive and negative alternately as shown. The electric field at centre of ring will be



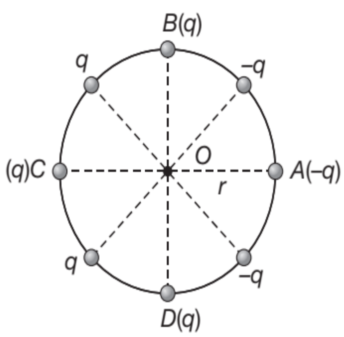
(A) $\frac{\lambda}{4\pi\varepsilon_0 r}$ where $\lambda = \frac{3Q}{\pi R}$

(B) $\frac{2\lambda}{4\pi\varepsilon_0 r}$ where $\lambda = \frac{3Q}{\pi R}$

(C) $\frac{3\lambda}{4\pi\varepsilon_0 r}$ where $\lambda = \frac{3Q}{\pi R}$

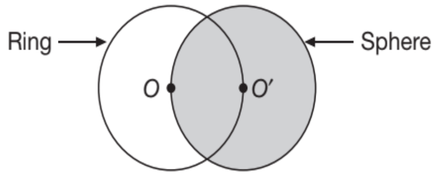
(D) $\frac{3\lambda}{2\pi\varepsilon_0 R}$, where $\lambda = \frac{3Q}{\pi R}$

164. Some point charges are placed on the circumference of circle at equal distance. (see figure) The direction of electric field at centre O will be along



(A) OA (B) OB
(C) OC (D) OD

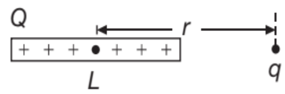
165. A charge Q is distributed uniformly on a ring of radius r. A sphere of equal radius r is constructed with its centre at the periphery of the ring. Find the flux of the electric field through the surface of the sphere



(A) $\frac{Q}{4\varepsilon_0}$ (B) $\frac{Q}{6\varepsilon_0}$

(C) $\frac{Q}{3\varepsilon_0}$ (D) $\frac{Q}{2\varepsilon_0}$

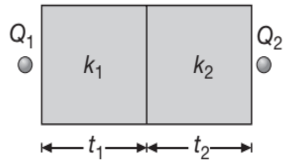
166. A charge Q is distributed over a line of length L. Another point charge q is placed at a distance r from the centre of the line distribution. Then the force experienced by q is



(A) $\frac{qQ}{4\pi\varepsilon_0 (r^2 - L^2)}$ (B) $\frac{qQ}{\pi\varepsilon_0 (4r^2 - L^2)}$

(C) $\frac{qQ}{4\pi\varepsilon_0 r^2}$ (D) $\frac{qQL}{4\pi\varepsilon_0 r^3}$

167. Two charges Q_1 and Q_2 are distance d apart. Two dielectrics of thickness t_1 and t_2 and dielectric constant k_1 and k_2 are introduced as shown. Find the force between the charges



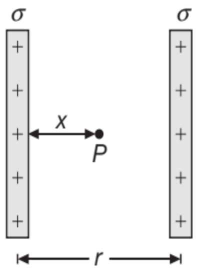
(A) $\frac{Q_1 Q_2}{4\pi\varepsilon_0 [d - (t_1 + t_2) + k_1 t_1 + k_2 t_2]^2}$

(B) zero

(C) $\frac{Q_1 Q_2}{4\pi\varepsilon_0 (d + \sqrt{k_1}\, t_1 + \sqrt{k_2}\, t_2)^2}$

(D) $\frac{Q_1 Q_2}{4\pi\varepsilon_0 [(\sqrt{k_1} - 1)t_1 + (\sqrt{k_2} - 1)t_2]^2}$

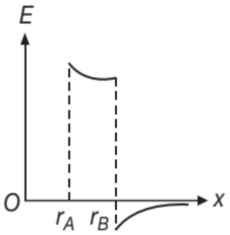
168. For two infinitely charged parallel sheets the electric field at P will be

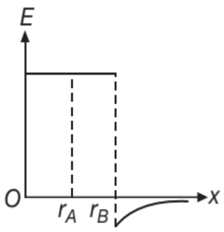


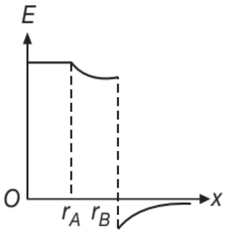
(A) $\frac{\sigma}{2x}-\frac{\sigma}{2(r-x)}$ (B) $\frac{\sigma}{2\varepsilon_0 x}+\frac{\sigma}{2\pi(r-x)\varepsilon_0}$

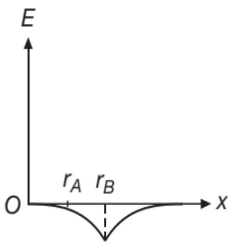
(C) $\frac{\sigma}{\varepsilon_0}$ (D) zero

169. Two concentric conducting thin spherical shells A, and B having radii r_A and $r_B\,(r_B>r_A)$ are charged to Q_A and $-Q_B\,(|Q_B|>|Q_A|)$. The variation of electric field (E) with distance r from centre is best represented by

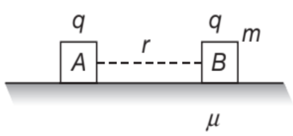
(A)


(B)


(C)


(D)


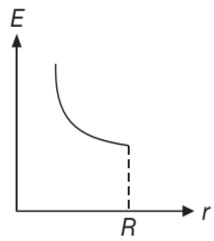
170. The minimum value of μ for which small block B of mass m remain at rest on horizontal is (Assume that block A is fixed and small block has identical charge q and separation is r)

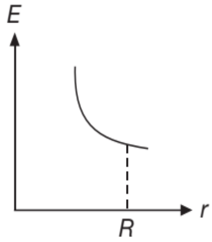


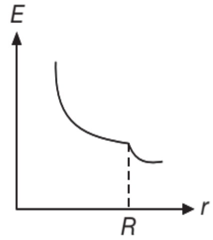
(A) $\frac{q^2}{8\pi\varepsilon_0 mgr^2}$ (B) $\frac{q^2}{4\pi\varepsilon_0 mgr^2}$

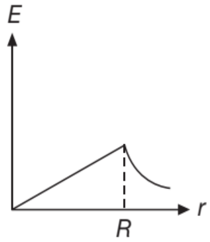
(C) $\frac{q^2}{2\pi\varepsilon_0 mgr^2}$ (D) $\frac{2q^2}{\pi\varepsilon_0 mgr^2}$

171. A conducting shell of radius R carries charge $-Q$. A point charge $+Q$ is placed at the centre of shell. The electric field E varies with distance r (from the centre of the shell) as

(A)


(B)


(C)


(D)


172. Two balls with equal charges are in a vessel with ice at −10 °C at a distance of 25 cm from each other. On forming water at 0 °C, the balls are brought nearer to 5 cm for the interaction between them to be same. If the dielectric constant of water at 0 °C is 80, the dielectric constant of ice at −10 °C is

(A) 40 (B) 3.2

(C) 20 (D) 6.4

173. The electric field varies along the x-direction as $\vec{E}=(E_0 x)\hat{i}$. Consider an imaginary cubical volume of edge l, with its edges parallel to the axes of coordinates. The charge inside this volume is

(A) zero (B) $\varepsilon_0 E_0 l^3$

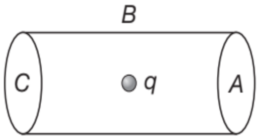
(C) $\frac{1}{\varepsilon_0}E_0 l^3$ (D) $\frac{1}{6}\varepsilon_0 E_0 l^2$

174. Four point charges, each $+q$, are fixed at the corners of a square of side a. Another point charge q_0 is placed at a height h vertically above the centre of square, assuming the square to be in a horizontal plane. Magnitude of force experienced by q_0 is

(A) $\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{\left(h^2+\frac{a^2}{2}\right)}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{\left(h^2+\frac{a^2}{2}\right)^{\frac{3}{2}}}$

(C) $\frac{1}{\pi\varepsilon_0}\frac{qq_0 h}{\left(h^2+\frac{a^2}{2}\right)^{\frac{3}{2}}}$ (D) zero

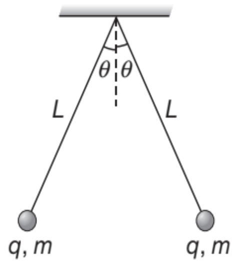
175. A hollow cylinder has a charge q coulomb within it. If ϕ is the electric flux in units of voltmeter associated with the curved surface B, the flux linked with the plane surface A in units of voltmeter will be



(A) $\frac{q}{2\varepsilon_0}$ (B) $\frac{\phi}{3}$

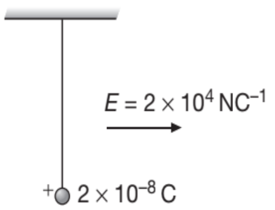
(C) $\frac{q}{\varepsilon_0}-\phi$ (D) $\frac{1}{2}\left(\frac{q}{\varepsilon_0}-\phi\right)$

176. Two small spheres each of mass m and charge q are tied from the same rigid support with the help of silk threads of length L. They make angle θ with the vertical as shown in the figure. If length L is decreased then angle θ with the vertical



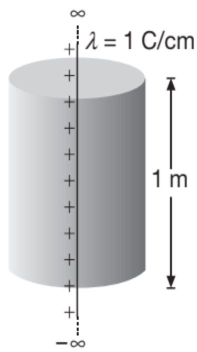
(A) increases (B) decreases
(C) unaffected (D) cannot say

177. A charge is suspended from a light thread in a uniform field as shown. The tension in the thread at equilibrium is



(A) 8.8 N
(B) 8.8×10^{2} N
(C) 8.8×10^{-4} N
(D) 8.8×10^{-3} N

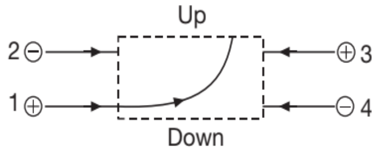
178. Total flux coming out of the cylindrical Gaussian surface is



(A) $\phi=100$ (B) $\phi=1$

(C) $\phi=\frac{1}{\varepsilon_0}$ (D) $\frac{100}{\varepsilon_0}$

179. The path of a positively charged particle 1 through a rectangular region of uniform electric field as shown in the figure. The direction of electric field and the direction of deflection of particles 2, 3 and 4 will be

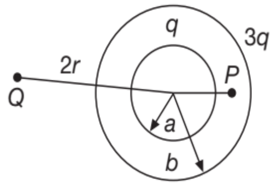


(A) Up, down, up, down
(B) Up, down, down, up
(C) Down, up, up, down
(D) Down, up, down, down

180. In a region of space the electric field is given by $\vec{E}=8\hat{i}+4\hat{j}+3\hat{k}$. The electric flux through a surface of area of 100 units in x-y plane is

(A) 800 units (B) 300 units
(C) 400 units (D) 1500 units

181. Ratio of electric field intensity at P & Q in the shown arrangement is



(A) 1 : 2 (B) 2 : 1
(C) 1 : 1 (D) 4 : 3

182. An oil drop carrying a charge of two electrons has a mass of 3.2×10^{-17} kg. It is falling freely in air with terminal speed. The electric field required to make the drop move upwards with the same speed is (neglect buoyant force)

(A) 2×10^{3} Vm^{-1} (B) 4×10^{3} Vm^{-1}

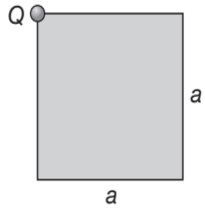
(C) 3×10^{3} Vm^{-1} (D) 8×10^{3} Vm^{-1}

183. A charge q is located at the centre of a cube the electric flux through any face is

(A) $\frac{4\pi q}{6(4\pi\varepsilon_0)}$ (B) $\frac{\pi q}{6(4\pi\varepsilon_0)}$

(C) $\frac{q}{6(4\pi\varepsilon_0)}$ (D) $\frac{2\pi q}{6(4\pi\varepsilon_0)}$

184. A point charge Q is placed at the corner of a square plate of side a then the flux through the square plate is $90°$ and hence $\phi = 0$



(A) $\frac{Q}{8\varepsilon_0}$ (B) $\frac{Q}{4\varepsilon_0}$

(C) $\frac{Q}{\varepsilon_0}$ (D) zero

185. An isolated and charged spherical soap bubble has a radius r and the pressure inside is atmospheric. If T is the surface tension of soap solution, then charge on drop is

(A) $2\sqrt{\frac{2rT}{\varepsilon_0}}$ (B) $8\pi r\sqrt{2rT\varepsilon_0}$

(C) $8\pi r\sqrt{rT\varepsilon_0}$ (D) $8\pi r\sqrt{\frac{2rT}{\varepsilon_0}}$

186. If a small sphere of mass m and charge q is hanged from a silk thread at an angle θ with the surface of a vertical charged conducting plate, then for equilibrium of sphere the surface charge density of the plate is

(A) $\frac{\varepsilon_0 mg\tan\theta}{q}$ (B) $\frac{\varepsilon_0 2mg\tan\theta}{q}$

(C) $\varepsilon_0 mgq\tan\theta$ (D) $\frac{\varepsilon_0 mg\tan\theta}{3q}$

187. Two similar point charges q_1 and q_2 are placed at a distance r, apart in air. The force between them is F_1. A dielectric slab of thickness $t(<r)$ and dielectric constant K is placed between the charges. Then the force between the same charges is F_2. The ratio $\frac{F_1}{F_2}$ is

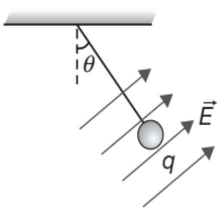
(A) 1 (B) K

(C) $\left(\frac{r-t+t\sqrt{K}}{r}\right)^2$ (D) $\left(\frac{r}{r-t+t\sqrt{K}}\right)^2$

MULTIPLE CORRECT CHOICE TYPE QUESTIONS

This section contains Multiple Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONE OR MORE is/are correct.

1. A charged cork ball of mass 1 g is suspended on a light string in the presence of a uniform electric field as shown. When $\vec{E} = (3\hat{i} + 5\hat{j}) \times 10^5\ \text{NC}^{-1}$, the ball is in equilibrium at $\theta = 37°$. T is the tension in the string and q is the charge on the ball (Take $\sin 37° = 0.60$ and $g = 10\ \text{ms}^{-2}$)



(A) $q = 11$ nC (B) $q = 12$ nC

(C) $T = 5.55 \times 10^{-3}$ N (D) $T = 4.55 \times 10^{-3}$ N

2. Consider a point charge Q placed at the origin O of the coordinate system. Let $\vec{E}_A$, $\vec{E}_B$ and $\vec{E}_C$ be the electric fields at three points $A(1, 2, 3)$ m, $B(1, 1, -1)$ m and $C(2, 2, 2)$ m due to charge Q. Then

(A) $\vec{E}_A \perp \vec{E}_B$ (B) $\vec{E}_A \parallel \vec{E}_C$

(C) $|\vec{E}_B| = 4|\vec{E}_C|$ (D) $|\vec{E}_B| = 8|\vec{E}_C|$

3. Equipotential surfaces representing a uniform electric field must be

(A) plane surfaces.

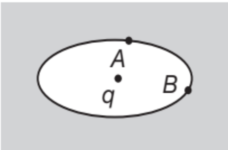
(B) normal to the direction of the field.

(C) spaced such that surfaces having equal differences in potential are separated by equal distances.

(D) having potentials decreasing in the direction of the field.

4. Consider two equipotential surfaces A and B having different potentials. Then
   (A) A and B cannot intersect.
   (B) A and B cannot both be plane surfaces.
   (C) In the region between A and B, the field is maximum where equipotential surfaces are closest to each other.
   (D) A line of force from A to B must be perpendicular to both.

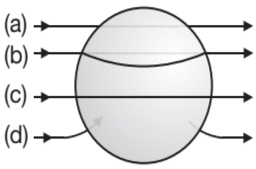
5. An ellipsoidal cavity is carved within a perfect conductor (see figure). A positive charge q is placed at the centre of the cavity. The points A and B are on the cavity surface as shown in figure. Then,



   (A) electric field near A in the cavity = electric field near B in the cavity.
   (B) charge density at A = charge density at B.
   (C) potential at A = potential at B.
   (D) total electric flux through the surface of the cavity is $\frac{q}{\varepsilon_0}$.

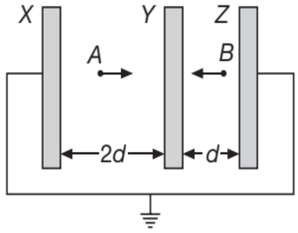
6. Consider two large, identical, parallel conducting plates have surfaces X and Y, facing each other. The charge per unit area on X is σ_1 and charge per unit surface area on Y is σ_2. Then,
   (A) $\sigma_1 = -\sigma_2$ only if a charge is given to either X or Y
   (B) $\sigma_1 = \sigma_2 = 0$ if equal charges are given to both X and Y
   (C) $\sigma_1 > \sigma_2$ if X is given a charge more than that given to Y
   (D) $\sigma_1 = -\sigma_2$ in all cases

7. A solid metallic sphere is place in a uniform electric field. Which of the curves shown in the figure represent the lines of force correctly?



   (A) (a) (B) (b)
   (C) (c) (D) (d)

8. X, Y and Z are parallel plates. Y is given some positive charge. Two electrons A and B start with zero initial velocity from X and Z respectively and reach Y in times t and T respectively.



   (A) $t = T$ (B) $t = \sqrt{2}T$
   (C) $2t = T$ (D) $t = 2T$

9. In the set up of PROBLEM 8, an electron E moves from X to Y and a proton P moves from Y to Z. Both particles start from rest.
   (A) E reaches Y with greater energy than P.
   (B) P reaches Y with greater energy than E.
   (C) P and E reach Y with equal energies.
   (D) P reaches Y with greater momentum than E.

10. A charged particle of mass m, charge q moves with a speed v in a circular path of radius r around a long uniformly charged conductor having charge density λ. Then
   (A) $v \propto \sqrt{q}$ (B) $v \propto \sqrt{\lambda}$
   (C) $v \propto \frac{1}{\sqrt{m}}$ (D) $v \propto \frac{1}{\sqrt{r}}$

11. Two charges Q_1 and Q_2 are placed at the points A and B having separation r lying inside and outside the uncharged conducting shell. The force on Q_1 is F and that on Q_2 is f. Then
   (A) $F = 0$ (B) $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$
   (C) $f = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$ (D) $f = 0$

12. A particle of charge q and mass m is moving in an electric field
   (A) must undergo change in velocity.
   (B) must undergo change in speed.
   (C) may not undergo change in velocity.
   (D) may not undergo change in speed.

13. Two charges Q_1 and Q_2 have their respective placements at the inside and the outside of a closed surface S. If E be the field at any point on S and ϕ be the flux of E over the surface S, then if
   (A) Q_1 changes, both E and ϕ will change.
   (B) Q_2 changes, E will change but ϕ will not change.
   (C) $Q_1 = 0$ and $Q_2 \neq 0$ then $E \neq 0$ but $\phi = 0$.
   (D) $Q_1 \neq 0$ and $Q_2 = 0$ then $E = 0$ but $\phi \neq 0$.

14. A particle having specific charge s starts from rest in a region where the electric field has constant direction but magnitude varying with time t as $E = E_0 t$. In time t, it is observed that the particle acquires a velocity v after covering a distance x, then

(A) $x = \frac{1}{2}(E_0 s)t^3$ (B) $x = \frac{1}{6}(E_0 s)t^3$

(C) $v = (E_0 s)t^2$ (D) $v = \frac{1}{2}(E_0 s)t^2$

15. At a point in space, let the field and potential be having values E and V respectively. Out of the following assertions which one(s) is/are correct?

(A) For $V = 0$, E must be zero

(B) For $V \neq 0$, E cannot be zero

(C) For $E \neq 0$, V cannot be zero

(D) None of these

16. In a parallel plate capacitor, the potential difference between the plates is V. A particle of mass m and charge $-Q$ leaves the negative plate and reaches the positive plate at distance d in time t with a momentum p. Then

(A) $p = \sqrt{mQV}$ (B) $p = \sqrt{2mQV}$

(C) $t = \sqrt{\frac{md^2}{QV}}$ (D) $t = \sqrt{\frac{2md^2}{QV}}$

17. A ring with a uniform charge Q and radius R, is placed in the yz plane with its centre at the origin O of the coordinates. Let V_O and E_O be the potential and the field at the origin, V and E be the potential and field at all points on the positive x axis, other than the origin, then

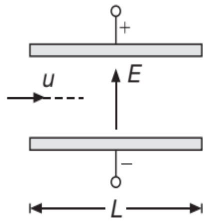
(A) $E_O = 0$

(B) $V_O = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$

(C) $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{\sqrt{x^2 + R^2}}$

(D) $E = \frac{1}{4\pi\varepsilon_0}\frac{Qx}{(R^2 + x^2)^{\frac{3}{2}}}$ and is maximum at $x = \frac{R}{\sqrt{2}}$

18. There is a uniform electric field E in the region between two parallel plates. A charged particle with a specific charge s enters the region with a speed u, in a direction parallel to the plates. The length of each plate is L. The time taken to come out of the plates is t and it suffers a vertical displacement Δ. Also as the particle crosses the plates, its direction of motion changes by an angle θ, then



(A) $\Delta = \frac{EsL^2}{2u^2}$ (B) $t = \frac{L}{u}$

(C) $\theta = \tan^{-1}\left(\frac{EsL}{u^2}\right)$ (D) $\theta = \tan^{-1}\left(\frac{Est}{u}\right)$

19. Three concentric metallic shells A, B and C are arranged such that shell A is the innermost and shell C is the outermost. Now, A is given some charge. Then the

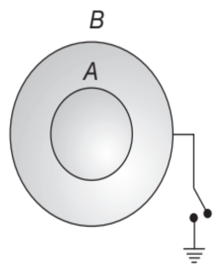
(A) inner surfaces of B and C have the same charge density.

(B) inner surfaces of B and C have the same charge.

(C) outer surfaces of A, B and C have the same charge density.

(D) outer surfaces of A, B and C have the same charge.

20. Two concentric shells A and B have radii R and $2R$, charges q_A and q_B and potentials $2V$ and $\frac{3V}{2}$ respectively. Now, the shell B is earthed and the new charges on them become q'_A and q'_B. Then



(A) $\frac{q_A}{q_B} = \frac{1}{2}$

(B) $\frac{q'_A}{q'_B} = 1$

(C) Potential difference between A and B after earthing becomes $\frac{3V}{2}$

(D) Potential difference between A and B after earthing becomes $\frac{V}{2}$

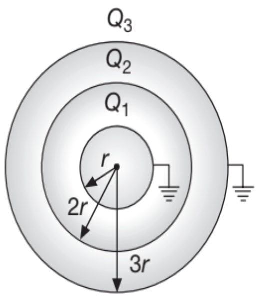
21. In a uniform electric field,

(A) all points are at the same potential.

(B) no two points can have the same potential.

(C) pairs of points separated by the same distance must have the same difference in potential.
(D) None of the above.

22. Three concentric conducting spherical shells A, B and C have radii r, $2r$ and $3r$ and possess charges Q_1, Q_2 and Q_3 respectively. The innermost and the outermost shells are earthed as shown in the figure. Select the mathematical relations between the charges that are correct.



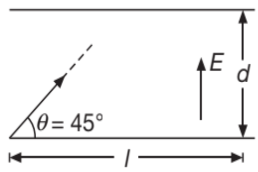
(A) $Q_1 + Q_3 = -Q_2$ (B) $Q_1 = -\frac{Q_2}{4}$
(C) $\frac{Q_3}{Q_1} = 3$ (D) $\frac{Q_3}{Q_2} = -\frac{1}{3}$

23. A spherical conductor A lies inside a hollow spherical conductor B. Charges Q_1 and Q_2 are given to A and B respectively.
(A) Charge Q_1 will appear on the outer surface of A.
(B) Charge Q_2 will appear on the outer surface of B.
(C) Charge $-Q_1$ will appear on the inner surface of B.
(D) Charge $Q_1 + Q_2$ will appear on the outer surface of B.

24. A particle of charge Q having a mass m moves rectilinearly under the action of an electric field that varies with distance x from the initial position of rest of the particle $E = \alpha - \beta x$, where α and β are positive constants. Then
(A) the motion of the particle is oscillatory
(B) the amplitude of the particle is $\frac{\alpha}{\beta}$
(C) the mean position of the particle is at $x = \frac{\alpha}{\beta}$
(D) the maximum acceleration of the particle is $\frac{q\alpha}{m}$

25. Two identical charges each having a charge $+Q$ are fixed at a separation $2a$. A small particle P having a charge of magnitude q is placed midway between them. Now, P is given a displacement $\Delta\,(\ll a)$, such that it undergoes simple harmonic motion. For this, we have the following (q, Δ) combinations.
(A) positive, along the line joining the two identical charges.
(B) positive, perpendicular to the line joining the two identical charges.
(C) negative, perpendicular to the line joining the two identical charges.
(D) negative, along the line joining the two identical charges.

26. An electron is projected between two plates at separation $d = 3$ cm each having length $l = 11$ cm as shown in figure, at a speed of 6×10^6 ms^{-1} at an angle of 45° in a uniform field $E = 2000$ Vm^{-1} directed upwards. The electron strikes the



(A) upper plate
(B) lower plate
(C) lower plate at the edge
(D) nowhere

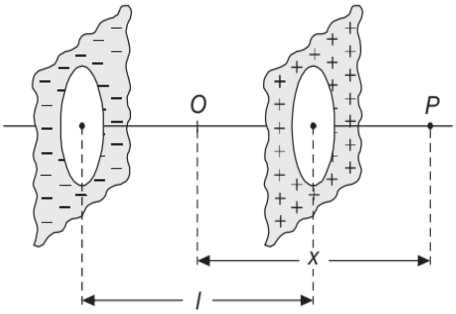
27. Two identical particles of mass m carry a charge Q each. Initially one is at rest on a smooth horizontal plane and the other is projected along the plane directly towards the first particle from a large distance with a speed v. If d is the distance of closest approach then
(A) $d \propto Q^2$ (B) $d \propto \frac{1}{v^2}$
(C) $d \propto \frac{1}{v}$ (D) $d \propto \frac{1}{m}$

28. An electron moving with a speed of 5×10^6 ms^{-1} is shot parallel to an electric field of strength 1000 Vm^{-1}, arranged so as to retard its motion. The electron travels a distance s in the field before coming momentarily to rest in time t. It is observed that the electric field ends abruptly after 0.8 cm and due to this the electron loses a percentage fraction f of its initial energy, then
(A) $s = 0.14$ m (B) $s = 0.07$ m
(C) $t = 0.03\ \mu$s (D) $f = 11\%$

29. A positively charged thin metal ring of radius R is fixed in the xy plane, with its centre at the origin O. A negatively charged particle P is released from rest at the point $(0, 0, z_0)$, where $z_0 > 0$. Then the motion of P is
(A) periodic, for all value of z_0 satisfying $0 < z_0 < \infty$.
(B) simple harmonic, for all values of z_0 satisfying $0 < z_0 \le R$.

(C) approximately simple harmonic, provided $z_0 \ll R$.
(D) such that P crosses O and continues to move along the negative z-axis towards $z = -\infty$.

30. Two infinitely large plane sheets separated by a distance l carry a uniform surface charge densities $+\sigma$ and $-\sigma$. The planes have identical coaxial holes each of radius $R (l \gg R)$. The potential and the field at a point on the axis of the holes at a distance x from the midpoint O between the holes is V and E respectively. Then



(A) $V = \dfrac{\sigma l x}{2\varepsilon_0\sqrt{R^2+x^2}}$ (B) $E = \dfrac{\sigma l R^2}{2\varepsilon_0 (R^2+x^2)^{3/2}}$

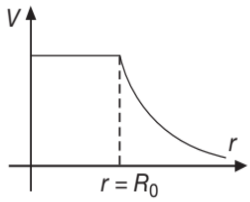
(C) $V = \dfrac{\sigma}{2\varepsilon_0 x^2}$ (D) $E = -\dfrac{\sigma}{2\varepsilon_0 R^5}$

31. At the corners of a square, four particles having charges of the same magnitude are placed. If the electrostatic potential and field at the centre of the square due to these four charges is V and E respectively, then by suitably selecting the signs of the four charges of identical magnitude, which of the following conditions can be achieved?
(A) $V = 0$, $E = 0$ (B) $V = 0$, $E \neq 0$
(C) $V \neq 0$, $E = 0$ (D) $V \neq 0$, $E \neq 0$

32. A pendulum bob of mass $m = 71$ mg, carrying a charge of $Q = 2\times10^{-8}$ C, is at rest in a horizontal, uniform electric field $E = 20000$ Vm^{-1}. The tension T in the thread of the pendulum is T and the angle it makes with the vertical is θ. Then
(A) $\theta = 27°$ (B) $T = 880\ \mu$N
(C) $T = 803\ \mu$N (D) $\theta = 30°$

33. Four identical charges each having a charge q are placed at the points $(a, 0, 0)$, $(0, a, 0)$, $(-a, 0, 0)$ and $(0, -a, 0)$. Let V_0 and E_0 be the potential and the field at the origin, V and E be the potential and field at all points on the z axis, other than the origin, then
(A) $V_0 \neq 0$ (B) $E_0 = 0$
(C) $V \neq 0$ (D) $E \neq 0$, along z-axis

34. For spherical symmetrical charge distribution, variation of electric potential with distance from centre is given in diagram. Given that $V = \dfrac{q}{4\pi\varepsilon_0 R_0}$ for $r \le R_0$ and $V = \dfrac{q}{4\pi\varepsilon_0 r}$ for $r \ge R_0$



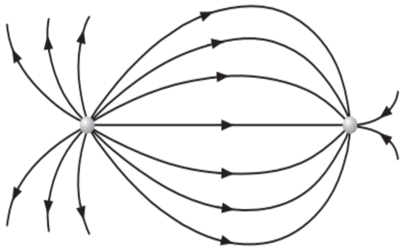
Then which option(s) is/are correct
(A) Total charge within $2R_0$ is q.
(B) Total electrostatic energy for $r \le R_0$ is zero.
(C) At $r = R_0$ electric field is discontinuous.
(D) There will be no charge anywhere except at $r = R_0$.

35. In a region of space three charged particles are observed to be in equilibrium under their mutual electrostatic forces only. Then the particles
(A) must be collinear.
(B) cannot possess the same magnitude.
(C) cannot possess the same sign.
(D) will be in unstable equilibrium.

36. Under the influence of the Coulomb field of charge $+Q$, a charge $-q$ is moving around it in an elliptical orbit. Find out the correct statement(s).
(A) The angular momentum of the charge $-q$ is constant.
(B) The linear momentum of the charge $-q$ is constant.
(C) The angular velocity of the charge $-q$ is constant.
(D) The linear speed of the charge $-q$ is constant.

37. At the corners of an equilateral triangle of side l, three point charges are placed such that the only interaction force between them is the electrostatic force. Then this system of three charges will be
(A) in equilibrium if the charges have the same magnitude but all do not have the same sign.
(B) in equilibrium if the charges have different magnitudes but all do not have the same sign.
(C) in equilibrium if the charges rotate about the centroid of the triangle.
(D) never in equilibrium.

38. A few electric field lines for a system of two charges Q_1 and Q_2 fixed at two different points on the x-axis are shown in the figure. These lines suggest that



(A) $|Q_1| > |Q_2|$

(B) $|Q_1| < |Q_2|$

(C) at a finite distance to the left of Q_1 the electric field is zero

(D) at a finite distance to the right of Q_2 the electric field is zero

39. Which of the following is/are incorrect statement?

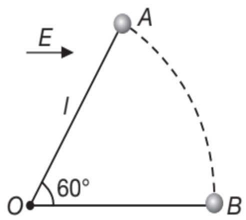
(A) Electric field is always conservative

(B) Electric field due to a varying magnetic field is non-conservative

(C) Electric field due to a stationary charge is conservative.

(D) Electric field lines are always closed loops.

40. A particle of mass m and charge q is fastened to one end of a string of length l. The other end of the string is fixed to the point O. The whole system lies on a frictionless horizontal plane. Initially, the mass is at rest at A. A uniform electric field in the direction shown is then switched on. Then



(A) the speed of the particle when it reaches B is $\sqrt{\frac{2qEl}{m}}$

(B) the speed of the particle when it reaches B is $\sqrt{\frac{qEl}{m}}$

(C) the tension in the string when particles reaches at B is qE

(D) the tension in the string when the particle reaches at B is $2qE$

41. A, B and C are three concentric metallic shells. Shell A is the inner most and shell C is the outermost. A is given some charge and shell C is earthed. Select the correct statement(s).

(A) The inner surfaces of B and C will have the same charge

(B) The inner surface of B and C will have same charge density

(C) The outer surface of A, B and C will have the same charge

(D) The outer surface of C will have no charge density

42. Two charge Q_1 & Q_2 placed at $(0, 0, 0)$ and $(a, 0, 0)$ are such that x component of field is zero at $\left(\frac{a}{2}, a, 0\right)$. Then

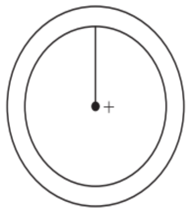
(A) y component of field is zero at $\left(\frac{a}{2}, 0, a\right)$

(B) $\frac{Q_1}{Q_2} = \frac{2}{1}$

(C) $\frac{Q_1}{Q_2} = 1$

(D) y component of field is zero at $\left(\frac{a}{2}, a, 0\right)$

43. An electrically isolated, hollow conducting sphere has a small positively charged ball suspended by an insulating rod from its inside surface, as shown. This causes the appearance of negative charge on the inner surface of the sphere. The electric field outside and far from the conducting sphere is approximately



(A) zero

(B) the same as if the sphere was not there

(C) half what it would be if the sphere was not there

(D) $\frac{Q}{4\pi\varepsilon_0 r^2}$, where r is the distance from centre of sphere

44. Two identical conducting balls have positive charges q_1 & q_2 respectively. The balls are brought together so that they touch and then put back in their original positions. The force between the balls may be

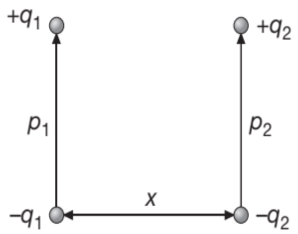
(A) The same as it was before the balls had been touched.

(B) greater than the force before the balls had been touched

(C) less than the force before the balls had been touched

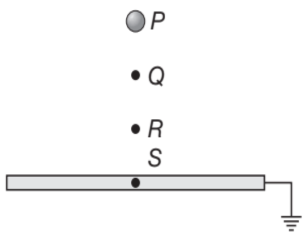
(D) zero

45. Figure shows two dipole moments parallel to each other and placed at a distance x apart (where x is very large compared to size of dipoles) then



(A) they will repel each other
(B) they will attract each other
(C) force of interaction is of magnitude of $\dfrac{3p_1p_2}{4\pi\varepsilon_0 x^4}$
(D) force of interaction is of magnitude of $\dfrac{6p_1p_2}{4\pi\varepsilon_0 x^4}$

46. A positive point charge is placed at P in front of an earthed metal sheet S. Two points Q and R lie between P and S as shown. If the electric field strength at Q and R are respectively E_Q and E_R and potential at Q and R are respectively V_Q and V_R, then



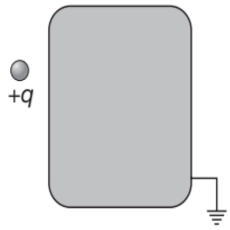
(A) $E_Q > E_R$ (B) $E_Q < E_R$
(C) $V_Q > V_R$ (D) $V_Q < V_R$

47. A particle of mass 2 kg and charge 1 mc is projected vertically with a velocity $10\ \text{ms}^{-1}$. There is a uniform horizontal electric field of $10^4\ \text{NC}^{-1}$. Select the correct statements.
(A) The horizontal range of the particle is 10 m.
(B) The time of flight of the particle is 2 s.
(C) The maximum height reached is 5 m.
(D) The horizontal range of the particle is zero.

48. A certain spherical region contains no charge, then
(A) Electric field at any point in the sphere must be zero.
(B) Electric field at any point in the sphere may not be zero.
(C) Electric potential at any point in the sphere must be zero.
(D) Electric potential at any point in the sphere may not be zero.

49. A dipole is placed in the electric field created by a uniformly charged long wire. It is possible that the dipole experiences
(A) No net force but a net torque
(B) No net force and no net torque
(C) A net force but no net torque
(D) A net force and a net torque

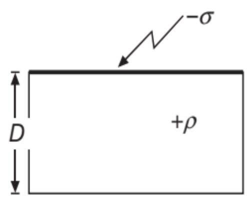
50. In front of an earthed conductor, a point charge $+q$ is placed as shown in figure. Select the correct statement(s).



(A) On the surface of conductor the net charge is always negative.
(B) On the surface of conductor at some points the charges are negative and at some points the charges may be positive distributed non uniformly.
(C) Inside the conductor electric field due to point charge is non-zero.
(D) None of these

51. A charged particle q is placed at a distance d from the centre of conducting sphere of radius $R(<d)$, then in static condition at the centre of sphere $\left(k = \dfrac{1}{4\pi\varepsilon_0}\right)$, we have
(A) magnitude of electric field due to induced charge is $\dfrac{kq}{d^2}$
(B) magnitude of electric field due to induced charge is $\dfrac{kq}{R^2}$
(C) magnitude of electric field due to induced charge is zero
(D) magnitude of electric field due to charge q is $\dfrac{kq}{d^2}$

52. We have an infinite non-conducting sheet of negligible thickness carrying a uniform surface charge density $-\sigma$ and next to it, an infinite parallel slab of thickness D with uniform volume charge density $+\rho$. All charges are fixed.



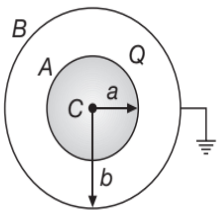
(A) Magnitude of electric field at a distance h above the negatively charged sheet is $\frac{\rho D-\sigma}{2\varepsilon_0}$

(B) Magnitude of electric field inside the slab at a distance h below the negatively charged sheet $(h<D)$ is $\frac{\sigma+\rho(D-2h)}{2\varepsilon_0}$

(C) Magnitude of electric field at a distance h below the bottom of the slab is $-\frac{\rho D-\sigma}{4\varepsilon_0}$

(D) Magnitude of electric field at a distance h below the bottom of the slab is $\frac{\rho D-\sigma}{2\varepsilon_0}$

53. A conducting sphere A of radius a, with charge Q, is placed concentrically inside a conducting shell B of radius b. B is earthed. C is the common centre of A and B, then the



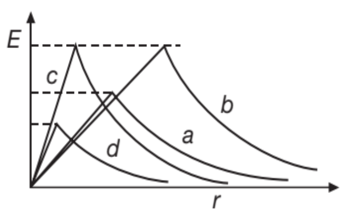
(A) field at a distance r from C, where $a\le r\le b$, is $\frac{Q}{4\pi\varepsilon_0 r^2}$

(B) potential at a distance r from C, where $a\le r\le b$, is $\frac{Q}{4\pi\varepsilon_0 r}$

(C) potential difference between A and B is $\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{a}-\frac{1}{b}\right)$

(D) potential at a distance r from C, where $a\le r\le b$, is $\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{b}\right)$

54. Four spheres each of different radii named a, b, c, d are given. Each is solid, insulating and uniformly charged. The variation of electric field with distance r from the centre is given. Straight portion of curve c and d is overlapping and straight portion of curve a and b is overlapping. Select the correct statement(s).



(A) Radius of sphere $a>$ Radius of sphere b

(B) Radius of sphere $a<$ Radius of sphere b

(C) Volume charged density of $c>$ volume charged density of b

(D) Volume charged density of $c<$ volume charged density of b

55. A conductor A is given a charge $+Q$ and then placed inside a deep metal can B, without touching it. Then

(A) potential of A does not change when it is placed inside B

(B) if B is earthed, $+Q$ amount of charge flows from it into the earth

(C) if B is earthed, the potential of A is reduced

(D) if B is earthed, the potential of A is increased

56. A positive charge of q_1 is located 3 m to the left of a negative charge $-q_2$. Magnitude of charge q_1 greater than magnitude of negative charge q_2. The net electric field intensity is zero at a point on the line passing through charges and 1 m to the right of $-q_2$. On this line there are also points where the potential is zero. Location of these two points relative to the negative charge is/are

(A) at 0.2 m left of negative charge

(B) at 0.2 m right of negative charge

(C) at $\frac{3}{17}$ m left of negative charge

(D) at $\frac{3}{17}$ m right of negative charge

57. Select the correct statement(s).

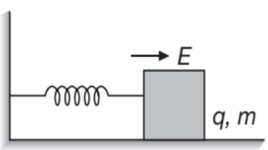
(A) When a positively charged sphere is brought near a metallic sphere, it is observed that a force of attraction exists between two, which means the metallic sphere become negative charged.

(B) A given conducting sphere cannot be charged to a potential greater than a certain value.

(C) Potential difference between two points lying in a uniform electric field may be equal to zero.

(D) Potential difference between two points lying in a non-uniform electric field may be equal to zero.

58. A block having mass m and charge q is connected by spring of force constant k. The block lies on a frictionless horizontal track and a uniform electric field E acts on system as shown. The block is released from rest when spring is unstretched (at $x=0$). Then



(A) Maximum stretch in the spring is $\frac{2qE}{k}$

(B) In equilibrium position, stretch in the spring is $\frac{qE}{k}$

(C) Amplitude of oscillation of block is $\frac{qE}{k}$

(D) Amplitude of oscillation is $\frac{2qE}{k}$

59. A uniform electric field of magnitude E_0 exists in a region at an angle $45°$ with x-axis. There are two point $A\ (a, 0)$ and $B\ (0, b)$ having potential V_A and V_B respectively, then

(A) $V_A > V_B$ if $a > b$ (B) $V_A = V_B$ if $a = b$

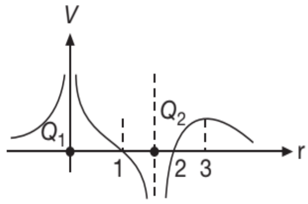
(C) $V_A > V_B$ if $a < b$ (D) $V_A < V_B$ if $a > b$

60. A simple pendulum of length ℓ has a bob of mass m, with a charge q on it. A vertical sheet of charge, with charge σ per unit area, passes through the point of suspension of the pendulum. At equilibrium, the string makes an angle θ with vertical. Its time period of oscillation is T in this position. Then

(A) $\tan\theta = \frac{\sigma q}{2\varepsilon_0 mg}$ (B) $\tan\theta = \frac{\sigma q}{\varepsilon_0 mg}$

(C) $T < 2\pi\sqrt{\frac{l}{g}}$ (D) $T > 2\pi\sqrt{\frac{l}{g}}$

61. Two point charges Q_1 and Q_2 lie along a line at a distance from each other. Figure show the potential variation along the line of charges



(A) Q_1 is positive and Q_2 is negative.
(B) Q_1 is negative and Q_2 is positive.
(C) Magnitude of Q_1 is more than magnitude of Q_2.
(D) Electric field is zero at 3.

REASONING BASED QUESTIONS

This section contains Reasoning type questions, each having four choices (A), (B), (C) and (D) out of which ONLY ONE is correct. Each question contains STATEMENT 1 and STATEMENT 2. You have to mark your answer as

Bubble (A) If both statements are TRUE and STATEMENT 2 is the correct explanation of STATEMENT 1.
Bubble (B) If both statements are TRUE but STATEMENT 2 is not the correct explanation of STATEMENT 1.
Bubble (C) If STATEMENT 1 is TRUE and STATEMENT 2 is FALSE.
Bubble (D) If STATEMENT 1 is FALSE but STATEMENT 2 is TRUE.

1. **Statement-1:** If there exists coulombic attraction between two bodies both of them may not be charges.
Statement-2: In coulombic attraction two bodies are always oppositely charged.

2. **Statement-1:** Two charges q_1 and q_2 are placed at separation r. Then magnitude of force on each charge is $F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$.
Statement-2: Now a third charge q_3 is placed near q_1 and q_2. Then force on q_1 due to q_2 remains F.

3. **Statement-1:** While going away from a point charge or a small electric dipole, electric field decreases at the same rate in both the cases.
Statement-2: Electric field is inversely proportional to square of distance from the point charge.

4. **Statement-1:** The potential of an uncharged conducting sphere of radius R, for a point charge q located at distance r from its centre $(r > R)$ is $\frac{q}{4\pi\varepsilon_0 r}$.
Statement-2: Electric field intensity inside the conductor is zero therefore potential at each point on conductor is zero.

5. **Statement-1:** When a neutral body is charged negatively, its mass increases slightly.
Statement-2: When a body is charged negatively, it gains some electrons and electron has finite mass : though quite small

6. **Statement-1:** Electric field at a point is always inversely proportional to $(\text{distance})^2$
Statement-2: Electric field due to a line charge at a point is inversely proportional to distance.

7. **Statement-1:** Any charge will move from electric potential V_1 to V_2 by its own only when $V_1 < V_2$.

Statement-2: Electron moves from $V_1 = 2V$ towards $V_2 = 4$ V.

8. **Statement-1:** Electric field intensity within an isolated conductor will be zero.

Statement-2: No net charge can exist within an isolated conductor.

9. **Statement-1:** Excess charge on a conductor resides entirely on the outer surface.

Statement-2: Like charges repel each another.

10. **Statement-1:** The surface of a charged conductor is always equipotential.

Statement-2: Electric field lines are always perpendicular to the equipotential surface.

11. **Statement-1:** When a charged body is brought near to an uncharged conducting body, equal and opposite charge is induced on the nearer surface of the conducting body.

Statement-2: Net electric field inside the conductor is zero.

12. A charge is launched with a velocity perpendicular to uniform electric field then

Statement-1: Initial power delivered by electric field is zero.

Statement-2: Path of charged particle is circular.

13. **Statement-1:** A charge conductor may have charged particle inside it.

Statement-2: There can't exist electric field line inside the conductor.

14. **Statement-1:** Electric field intensity at surface of uniformly charge spherical shell is E. If shell is punctured at a point then intensity at punctured point become $\frac{E}{2}$.

Statement-2: Electric field intensity due to spherical charge distribution can be found out by using Gauss Law.

15. **Statement-1:** For practical purposes, the earth is used as a reference at zero potential in electrical circuits.

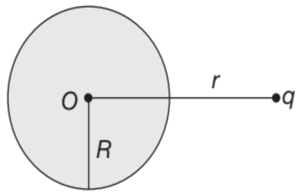
Statement-2: The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$.

16. **Statement-1:** Induced charge does not contribute to electric field or potential at a given point.

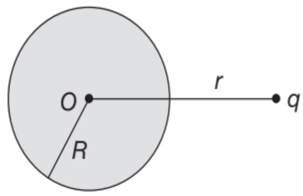
Statement-2: A point charge q_0 is kept outside a solid metallic sphere, the electric field inside the sphere is zero.

17. **Statement-1:** A point charge q is placed in front of a solid conducting sphere. Electric field due to induced charges at the centre of sphere is zero.

Statement-2: Electric field at a point inside the solid body of conductor is zero.



18. **Statement-1:** Consider a conducting sphere of radius R. Now a charge q is placed in front of sphere. Electric potential at point O is $\frac{q}{4\pi\varepsilon_0 r}$.



Statement-2: Electric potential at the centre of sphere due to induced charges is zero.

19. **Statement-1:** A metallic shield in form of a hollow shell may be built to block an electric field.

Statement-2: In a hollow spherical shield, the electric field inside it is zero at every point.

20. **Statement-1:** If a point charge q is placed in front of an infinite grounded conducting plane surface, the point charge will experience a force.

Statement-2: This force is due to the induced charge on the conducting surface, which is at zero potential.

LINKED COMPREHENSION TYPE QUESTIONS

This section contains Linked Comprehension Type Questions or Paragraph based Questions. Each set consists of a Paragraph followed by questions. Each question has four choices (A), (B), (C) and (D), out of which only one is correct. (For the sake of competitiveness there may be a few questions that may have more than one correct options)

Comprehension 1

In the classical model of a hydrogen atom, the electron revolves around the proton in a circle of radius $r = 0.53$ Å. The magnitude of the charge of the electron and proton is $e = 1.6\times10^{-19}$ C. Based on the above facts, answer the following questions.

1. The magnitude of the electric force between the proton and the electron is
   (A) 8.2×10^{-6} N (B) 8.2×10^{-7} N
   (C) 8.2×10^{-8} N (D) None of these

2. The magnitude of the electric field due to the proton at distance r is
   (A) 5.76×10^{12} NC^{-1} (B) 5.76×10^{11} NC^{-1}
   (C) 5.76×10^{10} NC^{-1} (D) None of these

3. The ratio of the magnitudes of the electrical and gravitational force between electron and proton is
   (A) 2.2×10^{39}, dependent on r
   (B) 2.2×10^{36}, dependent on r
   (C) 2.2×10^{39}, independent of r
   (D) 2.2×10^{36}, independent of r

Comprehension 2

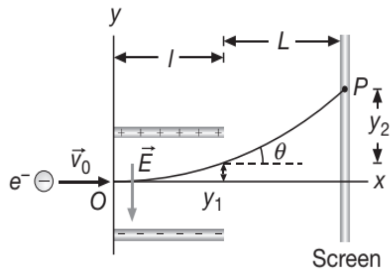
An oil drop of radius $r = 1.64\times10^{-6}$ m having mass density $\rho_{oil} = 8.51\times10^{2}$ kgm^{-3} is allowed to fall from rest. It, then enters into a region of constant external field $\vec{E}$ applied in the downward direction. The oil drop has an unknown electric charge q. The magnitude of the electric field is adjusted till the gravitational force, $\vec{F}_g = m\vec{g} = -mg\,\hat{j}$ on the oil drop is exactly balanced by the electric force, $\vec{F}_e = q\vec{E}$. Suppose this balancing occurs when the value of electric field is given by $\vec{E} = -E_y\hat{j} = -(1.92\times10^{5}\ \text{NC}^{-1})\hat{j}$, with $E_y = 1.92\times10^{5}$ NC^{-1}. Based on the above facts, answer the following questions.

4. The mass of the oil drop is
   (A) 1.57×10^{-14} kg (B) 1.57×10^{-13} kg
   (C) 1.57×10^{-12} kg (D) 1.57×10^{-11} kg

5. The oil drop falls short of electrons or has the excess electrons amounting to N. Then
   (A) $N(=4)$, short of electrons
   (B) $N(=5)$, short of electrons
   (C) $N(=4)$, excess of electrons
   (D) $N(=5)$, excess of electrons

Comprehension 3

An electron is injected $(\text{at } t = 0)$ horizontally into a uniform field produced by two oppositely charged plates having length l and separation d, as shown in figure. The particle has an initial velocity $\vec{v}_0 = v_0\hat{i}$ perpendicular to $\vec{E} = E\hat{j}$.



Based on the above facts, and the figure provided, answer the following questions.

6. The path followed by the electron is a/an
   (A) straight line (B) ellipse
   (C) cycloid (D) parabola

7. The time t_1 taken by the electron to leave the plate is t_1. Then
   (A) $t_1 = \sqrt{\dfrac{2lm}{eE}}$ (B) $t_1 = \dfrac{l}{v_0}$
   (C) $t_1 = \sqrt{\dfrac{2md}{eE}}$ (D) $t_1 = \dfrac{d}{v_0}$

8. The velocity of the electron at time t_1 when it leaves the plates is
   (A) $\left(\dfrac{eE}{m}\right)\dfrac{l}{v_0}$ (B) v_0
   (C) $\dfrac{1}{mv_0}\sqrt{m^2v_0^4 + e^2l^2E^2}$ (D) None of these

9. The vertical displacement of the electron, y_1 after time t_1 when it leaves the plates is
   (A) $y_1 = \dfrac{eEl^2}{mv_0}$ (B) $y_1 = \dfrac{eEl^2}{mv_0^2}$
   (C) $y_1 = \dfrac{eEl^2}{2mv_0^2}$ (D) $y_1 = \dfrac{eEl^2}{m^2v^2}$

10. The electron makes an angle θ with the horizontal, when leaving the plates at time t_1, then

(A) $\sin\theta = \dfrac{eEl}{mv_0^2}$ (B) $\sin\theta = \dfrac{eEl}{2mv_0^2}$

(C) $\tan\theta = \dfrac{eEl}{mv_0^2}$ (D) $\tan\theta = \dfrac{eEl}{2mv_0^2}$

11. The electron hits the screen located a distance L from the end of the plates at a time t_2. The total vertical displacement of the electron from time $t = 0$ until it hits the screen at t_2 is y. Then

(A) $y = \dfrac{eEl}{mv_0^2}\left(\dfrac{L}{2}+l\right)$ (B) $y = \dfrac{eEl}{mv_0^2}\left(\dfrac{l}{2}+L\right)$

(C) $y = \dfrac{eEl}{2mv_0^2}(L+l)$ (D) $y = \dfrac{eEl}{2mv_0^2}\left(L+\dfrac{l}{2}\right)$

Comprehension 4

Two parallel plates having charges of equal magnitude but opposite sign are separated by 12 cm. Each plate has a surface charge density of 36 nCm^{-1}. A proton is released from rest at the positive plate. Based on the above facts, answer the following questions.

12. The potential difference between the plates is

(A) 288 V (B) 388 V
(C) 244 V (D) 488 V

13. The kinetic energy of the proton when it reaches the negative plate is

(A) 3.9×10^{-17} J (B) 7.8×10^{-17} J
(C) 4.6×10^{-17} J (D) 6.2×10^{-17} J

14. The speed of the proton just before it strikes the negative plate is

(A) 106 kms^{-1} (B) 235 kms^{-1}
(C) 306 kms^{-1} (D) 216 kms^{-1}

15. The acceleration of the proton is

(A) 3.9×10^{11} ms^{-2} (B) 4.68×10^{10} ms^{-2}
(C) 2.3×10^{11} ms^{-2} (D) 1.95×10^{11} ms^{-2}

16. The force acting on the proton

(A) 6.51×10^{-16} N (B) 7.81×10^{-17} N
(C) 3.84×10^{-16} N (D) 3.25×10^{-16} N

Comprehension 5

Two positive point charges each of magnitude q are placed on the y-axis at the points $(0, a)$ and $(0, -a)$. A positively charged particle of charge q_0 and mass m, when displaced slightly from the origin in the direction of the negative x-axis attains a speed v_0 at infinity. When the particle is projected towards the left along the x-axis from a point at a large distance towards the right of the origin with a velocity half the value of v_0, then it comes to rest at a point $P(x, 0)$. Again, if a negatively charged particle from the rest (assume the negatively charged particle to be at very large distance towards the left of origin), then this negatively charged particle crosses the origin with a speed v. Based on the above facts, answer the following questions.

17. The value of v_0 is

(A) $\sqrt{\dfrac{qq_0}{2\pi\varepsilon_0 ma}}$ (B) $\sqrt{\dfrac{qq_0}{\pi\varepsilon_0 ma}}$

(C) $\sqrt{\dfrac{qq_0}{3\pi\varepsilon_0 ma}}$ (D) None of these

18. The value of x is

(A) $\sqrt{3}a$ (B) $4a$
(C) $\sqrt{2}a$ (D) $\sqrt{15}a$

19. The value of v is

(A) $\dfrac{v_0}{3}$ (B) $\dfrac{v_0}{2}$

(C) v_0 (D) $\dfrac{v_0}{4}$

Comprehension 6

A particle of mass m_2 carrying a charge Q_2 is fixed on the surface of Earth. Another particle, mass m_1 and charge Q_1, is positioned right above the first one at an altitude $h \ll R$, with R the radius of the Earth. The charges Q_1 and Q_2 have the same sign. Based on the above facts, answer the following questions.

20. The velocity of m_1 at a point P very close to Q_2, a distance h_1 from the surface of earth, if the initial velocity of m_1 was zero and air drag and earth's electric field being ignored, is

(A) $\sqrt{2gh - \dfrac{Q_1Q_2}{2\pi\varepsilon_0 h_1 m_1}}$ (B) $\sqrt{2gh - \dfrac{Q_1Q_2}{4\pi\varepsilon_0 h_1 m_1}}$

(C) $\sqrt{2gh}$ (D) None of these

21. The magnitude of charge Q_2 at which the velocity of m_1, at altitude h_2 is zero is given by

(A) $Q_2 = \frac{\pi\varepsilon_0 m_1 ghh_2}{Q_1}$ (B) $Q_2 = \frac{4\pi\varepsilon_0 m_1 ghh_2}{Q_1}$

(C) $Q_2 = \frac{2\pi\varepsilon_0 m_1 ghh_2}{Q_1}$ (D) $Q_2 = \frac{\pi\varepsilon_0 m_1 ghh_2}{4Q_1}$

22. At what altitude h_3 will object m_1 be in equilibrium and what will be the nature of the object's oscillations if it is disturbed from equilibrium?

(A) $h_3 = \sqrt{\frac{Q_1Q_2}{4\pi\varepsilon_0 m_1 g}}$, periodic

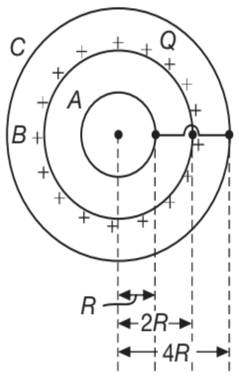
(B) $h_3 = \sqrt{\frac{Q_1Q_2}{2\pi\varepsilon_0 m_1 g}}$, periodic and oscillatory

(C) $h_3 = \sqrt{\frac{Q_1Q_2}{4\pi\varepsilon_0 m_1 g}}$, periodic and oscillatory

(D) None of these

Comprehension 7

Figure shows three concentric spherical conductors A, B and C with radii R, $2R$ and $4R$ respectively. A and C are connected by a conducting wire and B is having a uniform charge $+Q$.



Based on the above facts, answer the following questions.

23. Charge on the conductor A is q_A and that on C is q_C. Then

(A) $q_A = q_C = -\frac{Q}{3}$

(B) $q_A = \frac{Q}{3}$ and $q_C = \frac{2Q}{3}$

(C) $q_A = \frac{Q}{3}$ and $q_C = -\frac{Q}{3}$

(D) $q_A = -\frac{Q}{3}$ and $q_C = \frac{Q}{3}$

24. The potential of A is

(A) $-\frac{Q}{4\pi\varepsilon_0 R}$ (B) $-\frac{Q}{12\pi\varepsilon_0 R}$

(C) $\frac{Q}{16\pi\varepsilon_0 R}$ (D) None of these

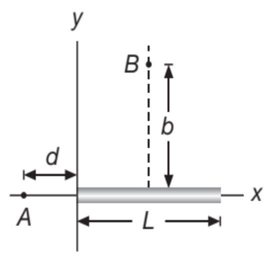
25. The potential of B is

(A) $\frac{Q}{4\pi\varepsilon_0 R}$ (B) $\frac{5Q}{12\pi\varepsilon_0 R}$

(C) $\frac{3Q}{6\pi\varepsilon_0 R}$ (D) $\frac{5Q}{48\pi\varepsilon_0 R}$

Comprehension 8

A rod of length L is placed along the x-axis with its left end at the origin and has a non-uniform charge density varying as $\lambda = \alpha x$, where α is a positive constant.



Based on the above facts and the figure provided, answer the following questions.

26. The dimensional formula for α is

(A) $M^{-2}T^{-1}A$ (B) $M^0L^{-2}TA$

(C) $M^0L^{-1}TA$ (D) $M^0L^{-2}T^{-1}A$

27. The electric potential at A, for $d = \frac{L}{4}$ is given by

(A) $\frac{\alpha}{4\pi\varepsilon_0}(L - \log_e 5)$ (B) $\frac{\alpha}{4\pi\varepsilon_0}(L + \log_e 5)$

(C) $\frac{\alpha}{4\pi\varepsilon_0}(1 - \log_e 5)$ (D) $\frac{\alpha}{4\pi\varepsilon_0}(1 + \log_e 5)$

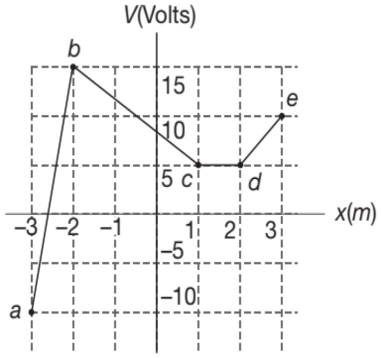
28. The electric potential at point B that lies along the perpendicular bisector of the rod a distance $b = \frac{\sqrt{3}L}{2}$ above the x-axis is given by

(A) $\frac{\alpha L}{4\pi\varepsilon_0}\log_e(3)$ (B) $\frac{\alpha L}{4\pi\varepsilon_0}\log_e(6)$

(C) $\frac{\alpha L}{8\pi\varepsilon_0}\log_e(3)$ (D) $\frac{\alpha L}{8\pi\varepsilon_0}\log_e(6)$

Comprehension 9

Suppose that the electric potential varies along the x-axis as shown in Figure below.



The potential does not vary in the y or z-direction. Of the intervals shown (ignore the behaviour at the end points of the intervals). The field E_x has a maximum absolute value of **FB1** Vm^{-1} in region **FB2**. Its value in the region CD is **FB3** Vm^{-1}. Based on the above facts, answer the following questions.

29. The value that fills **FB1** is

(A) $\frac{25}{2}$ (B) 25

(C) $\frac{15}{2}$ (D) –25

30. The region that fills **FB2** is

(A) ab (B) de

(C) bc (D) None of these

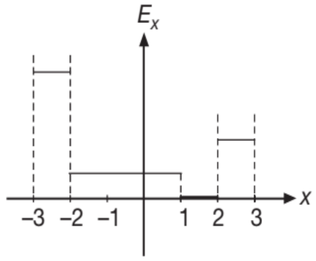
31. The value that fills **FB3** is

(A) 1 (B) 2

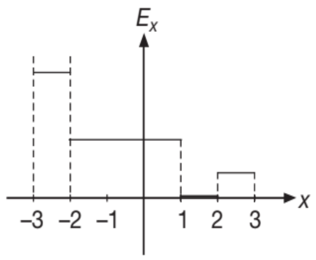
(C) 3 (D) ZERO

32. The plot of E_x vs x is

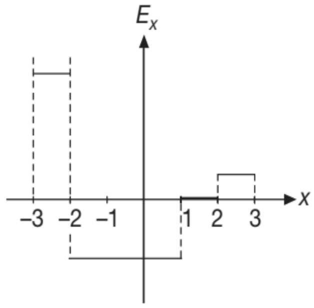
(A)



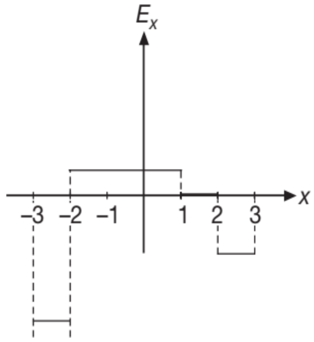
(B)



(C)



(D)



33. In the V vs x curve, the potential possesses a zero value at

(A) $x=-\frac{12}{5}$ m (B) $x=-\frac{5}{13}$ m

(C) $x=-\frac{13}{5}$ m (D) $x=-\frac{14}{5}$ m

Comprehension 10

A particle of charge $+3\times10^{-9}$ C is in a uniform field directed toward left. It is released from rest and moves a distance of 5 cm after which its kinetic energy is found to be 4.5×10^{-5} J. Based on the information supplied, answer the following questions.

34. What is the work that is being done by the electrical force?

(A) 90 μJ (B) 45 μJ

(C) 15 μJ (D) None of the above

35. The magnitude of the electric field is

(A) 0.3 MNC^{-1} (B) 3 MNC^{-1}

(C) 0.5 MNC^{-1} (D) 1.5 MNC^{-1}

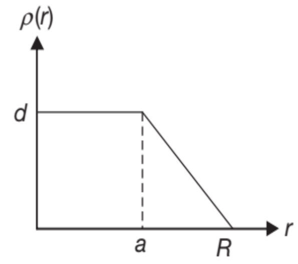
36. The potential of starting point w.r.t. the end point is

(A) 1 kV (B) 10 kV

(C) 1.5 kV (D) 15 kV

Comprehension 11

The nuclear charge (Ze) is non-uniformly distributed within a nucleus of radius R. The charge density $\rho(r)$ (charge per unit volume) is depended only on the radial distance r from the centre of the nucleus as shown in figure. The electric field is only along the radial direction.



37. The electric field at $r = R$ is
(A) independent of a
(B) directly proportional to a
(C) directly proportional to a^2
(D) inversely proportional to a

38. For $a = 0$, the value d (maximum value of ρ as shown in the figure) is

(A) $\frac{3Ze^2}{4\pi R^3}$ (B) $\frac{3Ze}{\pi R^3}$

(C) $\frac{4Ze}{3\pi R^3}$ (D) $\frac{Ze}{3\pi R^3}$

39. The electric field within the nucleus is generally observed to be linearly dependent on r. This implies

(A) $a = 0$ (B) $a = \frac{R}{2}$

(C) $a = R$ (D) $a = \frac{2R}{3}$

Comprehension 12

A region in space contains a total positive charge Q that is distributed spherically such that the volume charge density is given by

$$\rho(r) = \begin{cases} \alpha \text{ for } r \le \frac{R}{2} \\ 2\alpha\left(1 - \frac{r}{R}\right) \text{ for } \frac{R}{2} \le r \le R \end{cases}$$

where α is a positive constant and $\rho(r) = 0$ for $r \ge R$.

Based on the above facts, answer the following questions.

40. The fraction of total charge contained in the region $r \le \frac{R}{2}$ is

(A) $\frac{4}{15}$ (B) $\frac{8}{15}$

(C) $\frac{7}{15}$ (D) $\frac{11}{15}$

41. If an electron is placed at the centre of this arrangement and slightly displaced then it will execute SHM. The time period of oscillation assuming $x < \frac{R}{2}$ is

(A) $2\pi\sqrt{\frac{\varepsilon_0 \pi m R^3}{8Qe}}$ (B) $2\pi\sqrt{\frac{15\pi\varepsilon_0 m R^3}{8Qe}}$

(C) $2\pi\sqrt{\frac{7\pi\varepsilon_0 m R^3}{8Qe}}$ (D) $2\pi\sqrt{\frac{13\pi\varepsilon_0 m R^2}{6Qe}}$

42. The electric field in a region $\frac{R}{2} < r < R$ is

(A) $\frac{\alpha R^3}{24 r^2 \varepsilon_0} + \frac{2\alpha r}{3\varepsilon_0}\left(1 - \frac{r}{R}\right)$

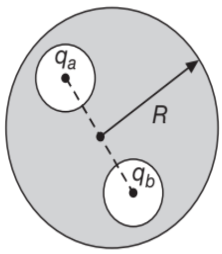
(B) $\frac{\alpha R^3}{8 r^2 \varepsilon_0} + \frac{2\alpha r}{6\varepsilon_0}\left(1 - \frac{r}{R}\right)$

(C) $-\frac{\alpha R^3}{16 r^2 \varepsilon_0} + \frac{2\alpha r}{3\varepsilon_0}\left(1 - \frac{r}{R}\right)$

(D) $-\frac{\alpha R^3}{96 \varepsilon_0 r^2} + \frac{2\alpha r}{3\varepsilon_0}\left(1 - \frac{3r}{4R}\right)$

Comprehension 13

Two spherical cavities, of radii a and b are hollowed out from the interior of a neutral conducting sphere of radius R. At the centre of each cavity, a point charge is placed. Call these charges q_a and q_b, distance between q_a and q_b is r.



Based on the above facts, answer the following questions.

43. The force on charge q_a is.

(A) $\frac{q_a q_b}{4\pi\varepsilon_0 r^2}$ (B) $\frac{q_a(q_a + q_b)}{4\pi\varepsilon_0 R^2}$

(C) $\frac{(q_a)(q_a + q_b)}{4\pi\varepsilon_0 r^2}$ (D) zero

44. The field outside the conductor at any point P at a distance $r_0 (> R)$ from centre of conductor?

(A) $\frac{q_a}{4\pi\varepsilon_0 r_0^2}$ (B) $\frac{q_a+q_b}{4\pi\varepsilon_0 R^2}$

(C) $\frac{q_a+q_b}{4\pi\varepsilon_0 r_0^2}$ (D) $\frac{q_b}{4\pi\varepsilon_0 r_0^2}$

45. In each cavity, there is certain electric field say E. If another charge q_c were brought near the conductor then E

(A) increases.
(B) decreases.
(C) remains same.
(D) depends on the nature of charge q_c.

Comprehension 14

A small plastic ball of mass m covered with a thin zinc coating, is suspended by means of an insulating thread from a fixed point. There exists an electric field of magnitude E directed along horizontal. Now ultraviolet light is made to incident on the ball due to which it acquires a positive charge. Acceleration due to gravity is g. Based on the above facts, answer the following questions.

46. What is the origin of positive charge acquired by the ball?

(A) Excess of protons in plastic ball
(B) Deficiency of electrons in zinc coating
(C) Deficiency of electrons in plastic ball
(D) Some positively charged particles given by ultraviolet light

47. If the string makes an angle θ with the vertical, when the ball comes to equilibrium, the number of electrons lost by the ball is

(A) $\frac{mg}{eE}$ (B) $\frac{mg\sin\theta}{eE}$

(C) $\frac{mg\tan\theta}{eE}$ (D) $\frac{mg\cot\theta}{eE}$

48. If the charge that suddenly appears on the ball is q, what is the maximum angle by which the string gets deflected?

(A) $\tan^{-1}\left(\frac{mg}{qE}\right)$ (B) $\tan^{-1}\left(\frac{2mg}{qE}\right)$

(C) $2\tan^{-1}\left(\frac{qE}{mg}\right)$ (D) $\tan^{-1}\left(\frac{qE}{mg}\right)$

Comprehension 15

A ball of radius R carries a positive charge whose volume charge density depends only on the distance r form the ball's centre as.

$$\rho = \rho_0\left(1-\frac{r}{R}\right)$$

where ρ_0 is a constant. Assume ε as the permittivity of the ball, answer the following questions.

49. The magnitude of the electric field as a function of the distance r outside the ball is given by

(A) $E=\frac{\rho_0 R^3}{8\varepsilon r^2}$ (B) $E=\frac{\rho_0 R^3}{12\varepsilon r^2}$

(C) $E=\frac{\rho_0 R^2}{8\varepsilon r^3}$ (D) $E=\frac{\rho_0 R^2}{12\varepsilon r^3}$

50. The value of distance r_m, at which electric field intensity is maximum, is given by

(A) $r_m=\frac{R}{3}$ (B) $r_m=\frac{3R}{2}$

(C) $r_m=\frac{2R}{3}$ (D) $r_m=\frac{4R}{3}$

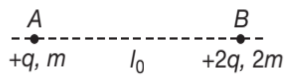
51. The maximum electric field intensity is

(A) $E_m=\frac{\rho_0 R}{9\varepsilon}$ (B) $E_m=\frac{\rho_0\varepsilon}{9R}$

(C) $E_m=\frac{\rho_0 R}{3\varepsilon}$ (D) $E_m=\frac{\rho_0 R}{6\varepsilon}$

Comprehension 16

Two positive point charges A and B have charge $+q$ and $2q$, mass m and $2m$ respectively as shown.



Both the charges are released from rest when they are at a distance l apart. Neglect gravity and also assume the only force acting on either charge is the electrostatic force due to each other. Based on the above facts, answer the following questions.

52. The speed of charge A at the instant separation between both charges is $2l_0$ is

(A) $\sqrt{\frac{q^2}{12\pi\varepsilon_0 ml}}$ (B) $\sqrt{\frac{q^2}{6\pi\varepsilon_0 ml}}$

(C) $\sqrt{\frac{q^2}{4\pi\varepsilon_0 ml}}$ (D) $\sqrt{\frac{q^2}{3\pi\varepsilon_0 ml}}$

53. The work done by electrostatic force on charge A while the separation between both charges changes from l to $2l$ is

(A) $\frac{q^2}{12\pi\varepsilon_0 l}$ (B) $\frac{q^2}{6\pi\varepsilon_0 l}$

(C) $\frac{q^2}{4\pi\varepsilon_0 l}$ (D) $\frac{q^2}{24\pi\varepsilon_0 l}$

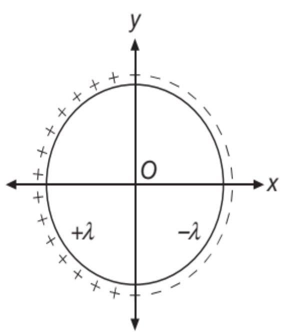
54. Total work done by electrostatic force on charge $A+$ charge B while the separation between both charges changes from l to $2l$ is

(A) $\frac{q^2}{12\pi\varepsilon_0 l}$ (B) $\frac{q^2}{6\pi\varepsilon_0 l}$

(C) $\frac{q^2}{4\pi\varepsilon_0 l}$ (D) $\frac{q^2}{24\pi\varepsilon_0 l}$

Comprehension 17

A thin ring of radius R metre is placed in x-y plane such that its centre lies at origin O. The half ring in region $x<0$ carries uniform linear charge density $+\lambda$ cm^{-1} and the remaining half ring in region $x>0$ carries uniform linear charge density $-\lambda$ cm^{-1}.



Based on the above facts, answer the following questions.

55. The electric potential (in volt) at point P whose coordinates are $\left(0, \frac{R}{2}\right)$ m is

(A) $\frac{\lambda}{2\pi\varepsilon_0}$ (B) 0

(C) $\frac{\lambda}{4\pi\varepsilon_0}$ (D) $\frac{\lambda}{6\pi\varepsilon_0}$

56. The direction of electric field at point P whose coordinates are $\left(0, \frac{R}{2}\right)$ m is

(A) along positive x-direction
(B) along negative x-direction
(C) along negative y-direction
(D) not possible to be determined.

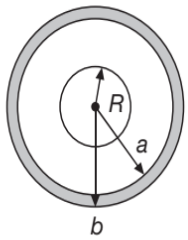
57. The dipole moment of the ring in Cm is

(A) $-(2\pi R^2\lambda)\hat{i}$ (B) $(2\pi R^2\lambda)\hat{i}$

(C) $-(4R^2\lambda)\hat{i}$ (D) $(4R^2\lambda)\hat{i}$

Comprehension 18

A metal sphere of radius R, carrying charge q_1 is surrounded by a thick concentric metal shell (inner radius a, outer radius b). The shell carries no net charge.



Based on the above facts, answer the following questions.

58. The surface charge density σ at $r=R$, $r=a$ and $r=b$ is

(A) $\sigma_R = \frac{q}{4\pi R^2}$, $\sigma_a = \frac{q}{4\pi a^2}$, $\sigma_b = \frac{q}{4\pi b^2}$

(B) $\sigma_R = \frac{q}{4\pi R^2}$, $\sigma_a = \frac{-q}{4\pi a^2}$, $\sigma_b = \frac{q}{4\pi b^2}$

(C) $\sigma_R = \frac{-q}{4\pi R^2}$, $\sigma_a = \frac{q}{4\pi a^2}$, $\sigma_b = \frac{q}{4\pi b^2}$

(D) $\sigma_R = \frac{q}{4\pi R^2}$, $\sigma_a = \frac{q}{4\pi a^2}$, $\sigma_b = \frac{-q}{4\pi b^2}$

59. The potential at the centre, assuming potential to be zero at infinity is

(A) $\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{R}-\frac{1}{a}\right)$ (B) $\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{R}+\frac{1}{a}+\frac{1}{b}\right)$

(C) $\frac{q}{4\pi\varepsilon_0 R}$ (D) $\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{b}-\frac{1}{a}+\frac{1}{R}\right)$

60. Now the outer surface is touched to a grounding wire, which lowers its potential to zero. Now the potential at the centre (Assume at infinity also potential is zero)

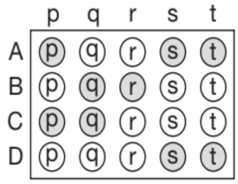
(A) $\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{R}-\frac{1}{a}\right]$ (B) $\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{R}+\frac{1}{a}+\frac{1}{b}\right]$

(C) $\frac{q}{4\pi\varepsilon_0 R}$ (D) $\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{b}-\frac{1}{a}+\frac{1}{R}\right]$

MATRIX MATCH/COLUMN MATCH TYPE QUESTIONS

Each question in this section contains statements given in two columns, which have to be matched. The statements in **COLUMN-I** are labelled A, B, C and D, while the statements in **COLUMN-II** are labelled p, q, r, s (and t). Any given statement in **COLUMN-I** can have correct matching with **ONE OR MORE** statement(s) in **COLUMN-II**. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following examples:

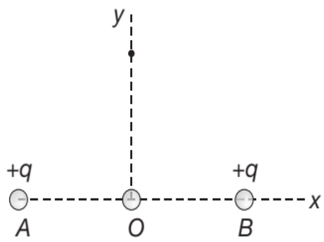
If the correct matches are A → p, s and t; B → q and r; C → p and q; and D → s and t; then the correct darkening of bubbles will look like the following:



1. Match the forces given in **COLUMN-I** with the properties given in **COLUMN-II**

COLUMN-I	COLUMN-II
(A) Electrostatic force of a nucleus on an electron	(p) Conservative
(B) The force attracting a man towards the centre of the earth	(q) Action-reaction force
(C) Force between earth and sun	(r) Depends on the nature of medium between the interacting objects
(D) Force between two protons	(s) Principle of Superposition is applicable
	(t) Repulsive

2. In the arrangement shown, identical charges, each $+q$ are fixed at A and B respectively. O is the midpoint of $AB = 2l$. A charge Q is placed at O and can be displaced slightly either along x-axis or along y-axis and then released. Assume Q to move only along the axis along which it had been displaced. Now match the options in **COLUMN-I** to the information in **COLUMN-II** (regarding Q at O)



COLUMN-I	COLUMN-II
(A) $Q = +q$, displaced along x-axis	(p) Force on Q before being displaced is zero
(B) $Q = -q$, displaced along x-axis	(q) Potential energy of the system is maximum
(C) $Q = q$, displaced along y-axis	(r) Potential energy of the system is minimum
(D) $Q = -q$, displaced along y-axis	(s) The charge Q is in stable equilibrium
	(t) Executes SHM about O

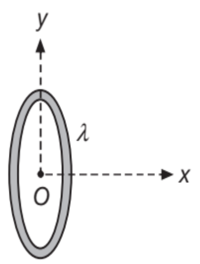
3. Match **COLUMN-I** with **COLUMN-II**

COLUMN-I	COLUMN-II
(A) Force on an electron in an atom	(p) Gravitational force
(B) Force between a proton and a neutron inside nucleus	(q) Strong force
(C) Force between a proton and proton inside nucleus	(r) Coulomb force
(D) Conservative force	(s) Electric force
	(t) Spring force

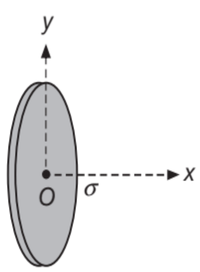
4. Match the facts given in **COLUMN-I** with the systems given in **COLUMN-II**

COLUMN-I	COLUMN-II
(A) Electric field strength is zero in the volume	(p) A non conducting solid sphere charged uniformly
(B) Electric field strength is non-zero in the volume but zero at the centre	(q) A conducting spherical shell charged uniformly
(C) Electric field strength is maximum on the surface	(r) A non conducting hollow sphere charged uniformly
(D) Electric field strength outside the system varies inversely as the square of the distance from the centre	(s) A conducting solid sphere charged uniformly

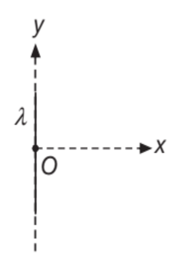
5. Figure (A) and (B) show a uniformly charged ring and a uniformly charged disc of large radius R, Figure (C) is a uniformly charged infinite thread and figure (D) shows a uniformly charged infinite sheet. In each figure let us consider the point O as the reference and then move away from O along the $+x$ axis. If E_1, E_2, E_3 and E_4 be the respective fields, then match the contents of **COLUMN-I** with those of **COLUMN-II**.



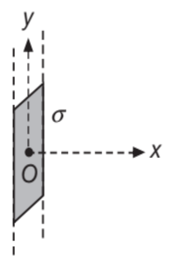
Ring of finite radius
(A)



Disc of large radius
(B)



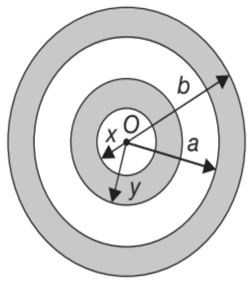
Infinite line of charge
(C)



Infinite sheet of charge
(D)

COLUMN-I	COLUMN-II
(A) E_2	(p) decreases
(B) E_4	(q) is constant near it and then decreases
(C) E_1	(r) is discontinuous at O
(D) E_3	(s) is constant
	(t) first increases and then decreases

6. In figure a conducting spherical shell of inner radius x and outer radius y is concentric with a larger conducting spherical shell of inner radius a and outer radius b. The inner shell has a total charge $+3Q$ and the outer shell has a total charge $+5Q$. Consider a point P arbitrarily taken in the regions of the system of these two shells. Based on the facts provided, match the contents of **COLUMN-I** with the locations of the point P mentioned in **COLUMN-II**.

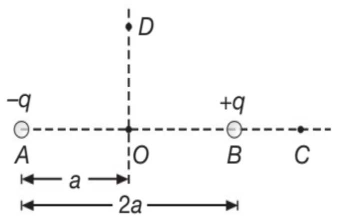


COLUMN-I	COLUMN-II
(A) Electric field strength is zero	(p) Outer surface of the larger spherical shell
(B) Electric field strength is non-zero	(q) Inner surface of the larger spherical shell
(C) Magnitude of charge on this surface is $3Q$	(r) Outer surface of the smaller spherical shell
(D) Charge on this surface is $+8Q$	(s) Region between inner and outer surface of bigger shell

(Continued)

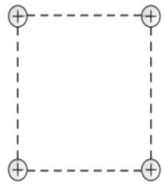
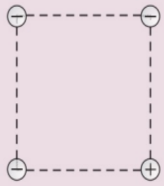
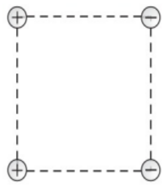
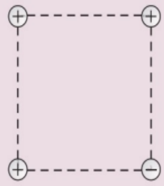
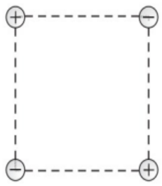
COLUMN-I	COLUMN-II
	(t) Region between inner and outer surface of smaller shell

7. For the electric dipole shown in figure, match the facts in **COLUMN-I** with the facts in **COLUMN-II**



COLUMN-I	COLUMN-II
(A) Electric potential is zero	(p) Point A
(B) Direction of electric field strength is opposite to the direction of electric dipole moment of the dipole	(q) Point C (on the axial line)
(C) Direction of electric field strength is the same as that of electric dipole moment	(r) Point O
(D) Electric field strength at C and D for $OC \gg a$ and $OD \gg a$ are E_C and E_D	(s) Any point on the equatorial line of the dipole.
	(t) $E_C > E_D$

8. Four charges, all having same magnitude are placed at the corners of a square of side a. At the centre of the square, the electrostatic field and potential due to the system of four charges is E and V respectively. Match the cases in **COLUMN-I** with the situations in **COLUMN-II**

COLUMN-I	COLUMN-II
(A) $E \neq 0, V \neq 0$	(p) 
(B) $E = 0, V \neq 0$	(q) 
(C) $E = 0, V = 0$	(r) 
(D) $E \neq 0, V = 0$	(s) 
	(t) 

9. Match **COLUMN-I** with **COLUMN-II**

COLUMN-I	COLUMN-II
(A) $E \propto \frac{1}{r}$	(p) At large distance from the centre of the dipole
(B) $E \propto \frac{1}{r^2}$	(q) At large distance from the centre, at the axis of a uniformly charged ring.
(C) $E \propto \frac{1}{r^3}$	(r) Due to an infinite charged conducting plate.
(D) $E \propto \frac{1}{r^0}$	(s) At large distance from the axis of a thin conducting charged cylinder

(Continued)

COLUMN-I	COLUMN-II
	(t) At a distance r from the axis of a thin conducting cylinder

10. Match **COLUMN-I** with the standard quantities/symbols in **COLUMN-II**

COLUMN-I	COLUMN-II
(A) Jm^{-3}	(p) ε_0
(B) metre	(q) P_e
(C) $C^2J^{-1}m^{-1}$	(r) $\frac{U}{V^2}$
(D) farad	(s) $\frac{V}{E}$
	(t) $\frac{1}{2}\varepsilon_0 E^2$

11. A particle of charge $-q$, mass m moves in a region of space between two plates from a plate at potential $-V$ to the plate at potential $+V$. The plate separation is d. If K, U, T and E be the respective kinetic energy, potential energy, total mechanical energy of the particle and E be the electric field between the plates, then match the facts in **COLUMN-I** with those in **COLUMN-II**

COLUMN-I	COLUMN-II
(A) K	(p) constant
(B) U	(q) first increase and then decrease
(C) T	(r) increase
(D) E	(s) decrease
	(t) other than those in (p), (q), (r) or (s)

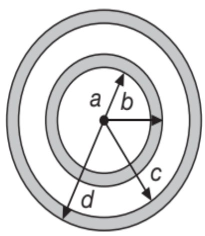
12. Match the dimensional formula in **COLUMN-I** with the quantities in **COLUMN-II**

COLUMN-I	COLUMN-II
(A) $M^{-1}L^{-3}T^4A^2$	(p) V
(B) $ML^3T^{-3}A^{-1}$	(q) E

(Continued)

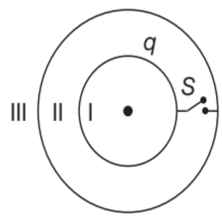
COLUMN-I	COLUMN-II
(C) $MLT^{-3}A^{-1}$	(r) ϕ_E
(D) $ML^2T^{-3}A^{-1}$	(s) ε_0
	(t) $\frac{\sigma}{2\varepsilon_0}$

13. A small conducting spherical shell with inner radius a and outer radius b is concentric with a larger conducting spherical shell with inner radius c and outer radius d as shown in figure. The inner shell has total charge $+2q$ and the outer shell has charge $-4q$. Match the column for the electric field (magnitude and direction) in term of q and distance r from the common centre of two shells.



COLUMN-I	COLUMN-II
(A) $r < a$	(p) $\|E\| = 0$
(B) $b < r < c$	(q) $\|E\| = \frac{q}{2\pi\varepsilon_0 r^2}$
(C) $c < r < d$	(r) radially inward
(D) $r > d$	(s) radially outward

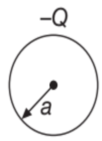
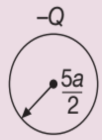
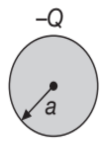
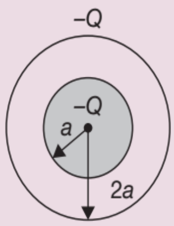
14. A charged sphere is enclosed by a concentric neutral conducting sphere as shown. The three region are marked as I, II and III. Region I is inside hollow charged sphere, region II is outside charged sphere and inside uncharged (outer) sphere, while region III is outside to both. Match the entries of **COLUMN-I** with the entries of **COLUMN-II**. All answers have to be given in steady state.



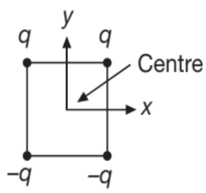
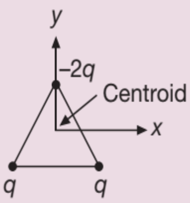
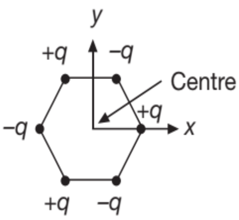
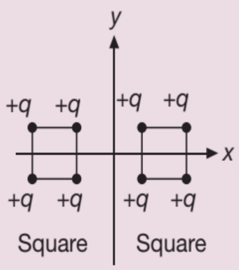
COLUMN-I	COLUMN-II
(A) When S is open, then in region II	(p) Electric field intensity is zero
(B) When S is open, then in region III	(q) Electric potential is zero

COLUMN-I	COLUMN-II
(C) When S is closed, then in region I	(r) Electric field intensity is non zero
(D) When S is closed, then in region II	(s) Electrical potential is non zero

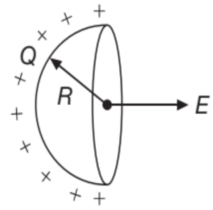
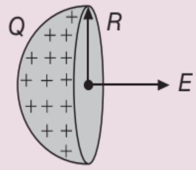
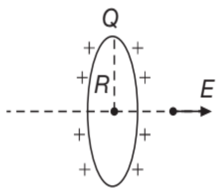
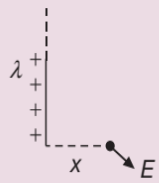
15. In each situation of **COLUMN-I**, some charge distributions are given with all details explained. The electrostatic potential energy and its nature is given situation in **COLUMN-II**. Then match situation in **COLUMN-I** with the corresponding results in **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) A thin shell of radius a and having a charge $-Q$ uniformly distributed over its surface as shown 	(p) $\dfrac{Q^2}{8\pi\varepsilon_0 a}$ in magnitude
(B) A thin shell of radius $\dfrac{5a}{2}$ and having a charge $-Q$ uniformly distributed over its surface and a point charge $-Q$ placed at its centre as shown 	(q) $\dfrac{3Q^2}{20\pi\varepsilon_0 a}$ in magnitude
(C) A solid sphere of radius a and having a charge $-Q$ uniformly distributed throughout its volume as shown 	(r) $\dfrac{2Q^2}{5\pi\varepsilon_0 a}$ in magnitude
(D) A solid sphere of radius a and having a charge $-Q$ uniformly distributed throughout its volume. The solid sphere is surrounded by a concentric thin uniformly charged spherical shell of radius $2a$ and carrying charge $-Q$ as shown 	(s) Positive in sign
	(t) Negative in sign

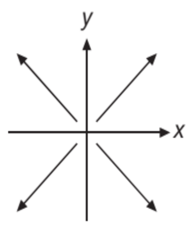
16. In **COLUMN-I** various configuration of charges are given and in **COLUMN-II** Information about electric field E and electric potential V is given. Match **COLUMN-I** with **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) Square 	(p) Potential at any point on z-axis is zero.
(B) Equilateral triangle 	(q) y-component of electric field intensity at any point on z-axis is zero.
(C) Regular hexagon 	(r) Potential energy of system is negative.
(D) Both squares are equidistant from origin 	(s) z-component of electric field intensity at any point on z-axis is zero.
	(t) Potential is zero but electric field intensity is non-zero at z-axis.

17. Match the column for electric field given in **COLUMN-II** for the uniformly charged bodies in **COLUMN-I**.

COLUMN-I	COLUMN-II
(A) Hollow hemisphere, at its centre 	(p) $\dfrac{\lambda}{2\sqrt{2}\pi\varepsilon_0 x}$
(B) Solid hemisphere, at its centre 	(q) $\dfrac{Q}{8\pi\varepsilon_0 R^2}$
(C) On the axis of ring, near its centre 	(r) $\dfrac{3Q}{8\pi\varepsilon_0 R^2}$
(D) Semi-infinite wire 	(s) $\dfrac{\lambda x}{2\varepsilon_0 R^2}\left(1-\dfrac{3x^2}{2R^2}\right)$

18. In a certain region of x-y plane, potential function is given in **COLUMN-I** and corresponding electric lines of force are given in **COLUMN-II**. Match the potential function of **COLUMN-I** with their respective field line representation in **COLUMN-II**.

COLUMN-I (Potential Function)	COLUMN-II (Electric Lines of Force)
(A) $V = x^2 - y^2$	(p) 

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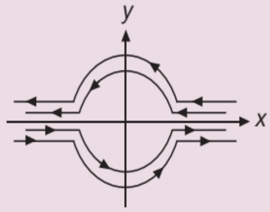
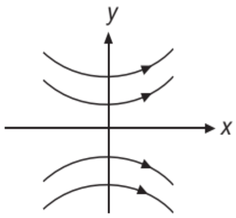
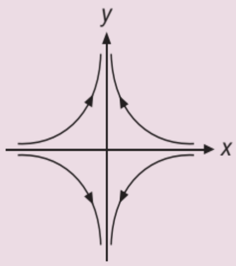
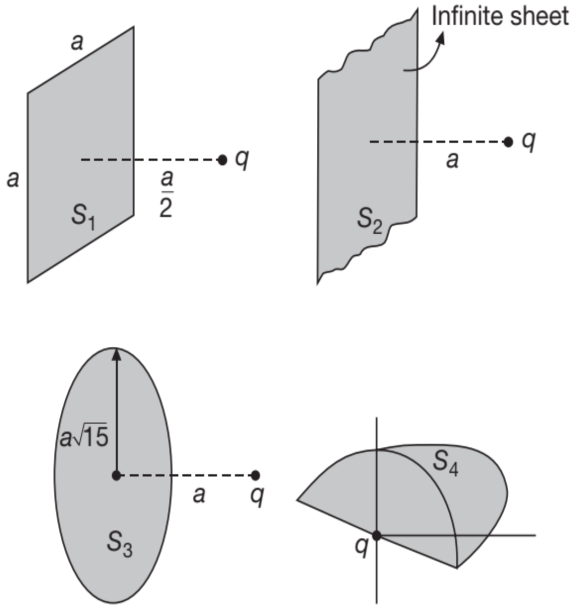
COLUMN-I (Potential Function)	COLUMN-II (Electric Lines of Force)
(B) $V = xy$	(q) 
(C) $V = x^2 + y^2$	(r) 
(D) $V = \frac{x}{y}$	(s) 

19. Consider the imaginary surfaces S_1, S_2, S_3 and S_4 drawn near a point charge as shown in figure.



COLUMN-I gives different surfaces and **COLUMN-II** corresponding electric flux. Match the entries of **COLUMN-I** to **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) S_1	(p) $\frac{3q}{8\varepsilon_0}$
(B) S_2	(q) $\frac{q}{2\varepsilon_0}$
(C) S_3	(r) $\frac{q}{6\varepsilon_0}$
(D) S_4	(s) $\frac{q}{4\varepsilon_0}$

20. Two spherical shells shown in figure have uniformly distributed charge q_1 and q_2. If r is the distance of a point from common centre and

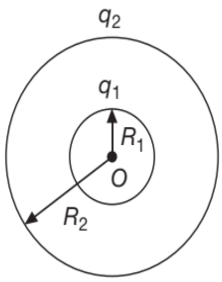
E_1 is electric field for $r < R_1$,

E_2 is electric field for $R_1 < r < R_2$,

V_1 is electric potential for $r < R_1$ and

V_2 is electric potential for $R_1 < r < R_2$,

then match the quantities in **COLUMN-I** with their respective property(ies) in **COLUMN-II**.

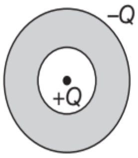
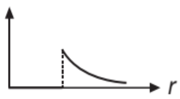
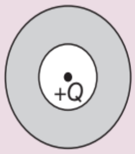
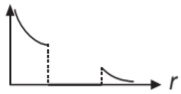
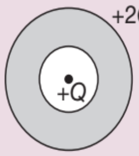
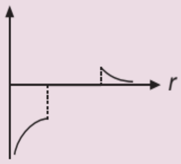


COLUMN-I	COLUMN-II
(A) E_1	(p) is constant for q_2 and varies for q_1.
(B) V_1	(q) is zero for q_2 and varies for q_1
(C) V_2	(r) is constant
(D) E_2	(s) is zero

21. n identical drops of a liquid each having charge q and radius r coalesce. Match the unfilled places in **COLUMN-I** with their respective fills given in **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) $E_{big} = ...E_{small}$	(p) $n^{1/3}$
(B) $V_{big} = ...V_{small}$	(q) n^3
(C) $C_{big} = ...C_{small}$	(r) $n^{2/3}$
(D) $\sigma_{big} = ...\sigma_{small}$	(s) $n^{-1/3}$

22. Entries in **COLUMN-I** show four hollow metal spheres each with internal radius a and external radius b. Match each charge distribution in **COLUMN-I** with the corresponding graph of electric field versus radial distance r from centre as shown in **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) 	(p) 
(B) 	(q) 
(C) 	(r) 
(D) 	(s) 

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INTEGER/NUMERICAL ANSWER TYPE QUESTIONS

In this section, the answer to each question is a numerical value obtained after doing series of calculations based on the data given in the question(s).

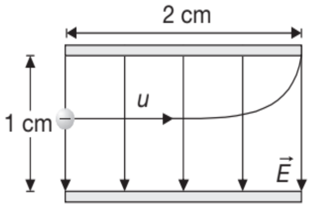
1. A ring of radius 0.1 m is made out of a thin metallic wire of area of cross-section 10^{-6} m^2. The ring has a uniform charge of π coulomb. The change in the radius of the ring, when a charge of 10^{-8} coulomb is placed at the centre of the ring is $x \times 10^{-5}$ m. Find x, if the young's modulus of the metal is 2×10^{11} Nm^{-2}.

2. Three identical small balls, each of mass 0.1 g, are suspended from one point by silk threads each having a length of $l = 20$ cm. What charge, in nC, must be imparted to each ball so as to make each thread form an angle $\alpha = 30°$ with the vertical?

3. In classical experiments performed to measure the charge of an electron, a charged drop of oil is placed between the horizontal plates of a plane capacitor. Under the action of an electrostatic field, the drop moves uniformly upward, covering a certain distance during the time $t_1 = 6$ ms, or downward, when the sign of the charge on the plates changes, covering the same distance during the time $t_2 = 3$ ms. Assuming the force of friction between the drop and the air to be proportional to the velocity of the drop, find the time t, in millisecond during which the drop travels the same distance after the field is switched off.

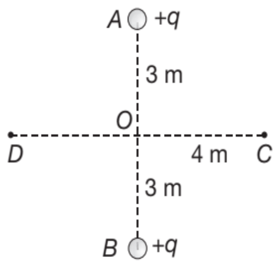
4. Four point charges each of magnitude 1 μC (each positive) are fixed at the vertices of a square $ABCD$. The diagonals of the square intersect at O. Length of each diagonal is 2 m. A particle of mass 2 g having a charge $+2\ \mu$C is released from a point 1 cm from O and 99 cm from A. The motion of the particle is SHM with period $\frac{\pi\sqrt{x}}{3}$ s. Find the value of x. (Neglect gravity).

5. An electron is projected with an initial speed $u = 4 \times 10^6$ ms^{-1} into the uniform field between the parallel plates in figure. The direction of the field is vertically downward, and the field is zero except in the space between the plates. The electron enters the field at a point midway between the plates. If the electron just misses the upper plate as it emerges from the field, find the magnitude of the electric field in NC^{-1}.



6. A uniform surface charge density 8σ exists over the entire x-y plane except for a circular hole of radius a centred at the origin. The electric field at a point $P(0, 0, \sqrt{3}a)$ on the z-axis is found to be $\sqrt{x}\frac{\sigma}{\varepsilon_0}$. Find the value of x.

7. Two fixed, equal, positive charges, each of magnitude 5×10^{-5} C are located at points A and B separated by a distance of 6 m. An equal and opposite charge moves towards them along the line COD, the perpendicular bisector of the line AB. The moving charge when it reaches the point C at a distance of 4 m from O, has a kinetic energy of 4 joules. The distance of the farthest point D, in metre, where the negative charge will reach before returning towards C is $\sqrt{x}$. Find x.



8. Positive charge Q is uniformly distributed throughout the volume of a dielectric sphere of radius R. A point mass having charge $+q$ and mass m is fired towards the centre of the sphere with velocity v from a point A at distance $\frac{5R}{2}$ from the centre of the sphere. The minimum velocity v so that it can penetrate $\frac{R}{2}$ distance of the sphere is $\sqrt{\frac{Qqx}{2\pi\varepsilon_0 m}}$. Neglect any resistance other than electric interaction. Charge on the small mass remains constant throughout the motion. Find the integral value of x to the nearest approximation.

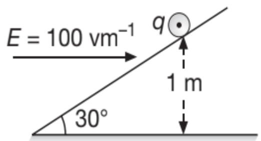
9. A particle A having a charge q is fixed on a vertical (insulated) wall. A second particle B of mass m, charge Q is suspended by a silk thread of length l from a point P on the wall that is at a distance l above the A. Calculate the angle in degree made by the thread with the vertical, when B stays in equilibrium for $Qq = 4\pi\varepsilon_0 mgl^2$.

10. Two positively charged particles each of mass 1.7×10^{-27} kg having charge of 1.6×10^{-19} C are placed at separation r. Calculate r, (in cm) to the nearest integer if each one experiences a repulsive force equal to its weight. $\left(\text{Take } g = 10\ \text{ms}^{-2}\right)$.

11. The bob of a simple pendulum has a mass of 40 g and a positive charge 4×10^{-6} C. It makes 20 oscillation in 45 s. A vertical electric field pointing upward and of magnitude 2.5×10^{4} NC^{-1} is switched on. How much time, in seconds will it now take to complete 20 oscillations.

12. A thin fixed ring of radius 1 meter has a positive charge 1×10^{-5} coulomb uniformly distributed over it. A particle of mass 0.9 g and having a negative charge of 1×10^{-6} coulomb is placed on the axis at a distance of 1 cm from the centre of the ring. Show that the motion of the negatively charged particle is approximately simple harmonic. The time period of oscillations is $\frac{\pi}{k}$. Find k.

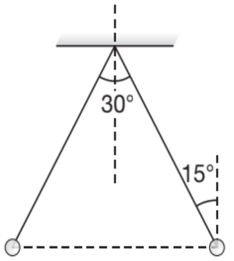
13. An inclined plane making an angle $30°$ with the horizontal is placed in a uniform horizontal electric field E of 100 Vm^{-1} as shown. A particle of mass 1 kg and charge 0.01 C is allowed to slide down from rest from a height of 1 m. If the coefficient of friction is 0.2, find the time, in millisecond it will take the particle to reach the bottom. (Take $g = 10$ ms^{-2})



14. A ball of mass m with a charge q can rotate in a vertical plane at the end of a string of length $l = 3.6$ m in a uniform electrostatic field whose lines of force are directed upwards. What horizontal velocity, in ms^{-1}, must be imparted to the ball in the upper position so that the tension in the string in the lower position of the ball is 15 times than the weight of the ball? Given $E = \frac{6mg}{5q}$ and $g = 10$ ms^{-2}.

15. Two equally charged identical metal spheres A and B repel each other with a force 2×10^{-5} N. Another identical uncharged sphere C is touched to B and then placed at the midpoint between A and B. What is the net electric force, in μN on C?

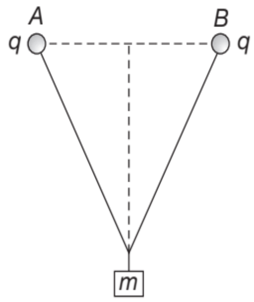
16. Two identically charged spheres are suspended by strings of equal length. The strings make an angle of $30°$ with each other. When suspended in a liquid of density 0.8 gmcc^{-1} the angle remains same. What is the dielectric constant of liquid. Density of sphere = 1.6 gcc^{-1}.



17. Two identical pith balls are charged by rubbing against each other. They are suspended from a horizontal rod through two strings of length 20 cm each. The separation between the suspension points being 5 cm. In equilibrium the separation between the balls is 3 cm. Find the mass m in gram, nearest to an integer, of each ball and the tension in millinewton, nearest to two digit integer, in the strings. The charge on each ball has magnitude 2×10^{-8} C.

18. A charge $Q_1=+11\left(\frac{11}{3}\right)^{\frac{3}{2}}\times10^{-9}$ C is located at the origin in free space and another charge Q at $(2,\ 0,\ 0)$. If the x-component of the electric field at $(3,\ 1,\ 1)$ is zero, calculate the value of Q in nC.

19. Two similar helium filled spherical balloons tied to a 5 g weight with strings each carrying an electric charge q float in equilibrium as shown in figure.



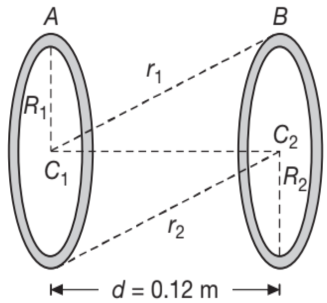
(a) Find the magnitude of q, in μC, assuming that the charge on each balloon as if it were concentrated at its centre.

(b) Find the volume of each balloon, in cc (neglect the weight of the unfilled balloons and assume that the density of air 1.29 kgm^{-3} and density of helium inside the balloon 0.2 kgm^{-3}).

20. A charge $Q=\frac{5}{100}$ nC is distributed over two concentric hollow spheres of radii $r=3$ cm and $R=6$ cm such that the surface densities are equal. Find the potential, in volt, at the common centre.

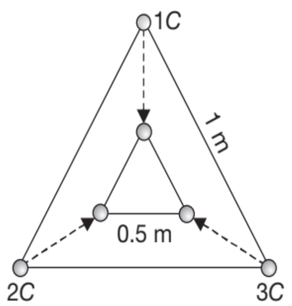
21. A charged dust particle of radius 5×10^{-7} m is located in a horizontal electric field having an intensity of 6.28×10^{5} Vm^{-1}. The surrounding medium is air with coefficient of voscosity $\eta=1.6\times10^{-5}$ Nsm^{-2}. If this particle moves with a uniform horizontal speed 0.02 ms^{-1}, find the number of electrons in it.

22. Two circular wire loops of radii 0.05 m and 0.09 m, respectively are put such that their axes coincide and their centres are 0.12 m apart. Charge of 10^{-6} C is spread uniformly on each loop. Find the potential difference, in volt between the centres of the loops.



23. The radii of internal and external spheres of concentric spherical air capacitor are 1 cm and 4 cm respectively. A potential difference of 3000 V is applied between the spheres. A velocity $x\times10^{5}$ ms^{-1} will be imparted to an electron when it approaches from a distance of $r_1=3$ cm to $r_2=3$ cm as measured from the centre of spheres. Then find x closest to three digit integer.

24. Three point charges of 1C, 2C and 3C are placed at the corners of an equilateral triangle of side 1 m. The work required to move these charges to the corners of a smaller equilateral triangle of sides 0.5 m as shown in Figure is $x\times10^{9}$ J. Find x



25. Three point charges of 0.1 C are placed at the corners of an equilateral triangle with side $L=1$ m. If this system is supplied energy at the rate of 1 kW, how much time, in hours will be required to move one of the charges on to the mid point of the line joining the two charges.

26. An electron enters a region between the plates of a parallel plate capacitor at a point equidistant from either plate. The capacitor plates are 2×10^{-2} m apart and 10^{-1} m long. A potential difference of 300 V is maintained across the plates. Assuming that the initial velocity of the electron is parallel to the capacitor plates, the largest value of the velocity of the electrons so that they do not fly out of the capacitor at the other end is $x \times 10^5$ ms^{-1}. Taking, $m_e = 9 \times 10^{-31}$ kg and $e = 1.6 \times 10^{-19}$ coulomb, find the value of x closest to three digit integer.

27. Two plane parallel conducting plates 1.5×10^{-2} m apart are held horizontal one above the other in air. The upper plate is maintained at positive potential of 1.5 kV while the other plate is earthed.

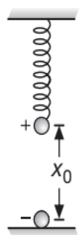
(a) Calculate the number of electrons which must be attached to a small oil drop of mass 4.9×10^{-15} kg between the plates to maintain it at rest, assuming that the density of air is negligible in comparison with that of oil.

(b) If the potential of above plate is suddenly changed to -1.5 kV and what is the initial acceleration, in ms^{-2}, of the charged drop?

(c) Also obtain the terminal velocity of the drop, in μms^{-1} if its radius is 5×10^{-6} m and the coefficient of viscosity of air is 1.8×10^{-5} Nsm^{-2}.

$\left(\text{Take } g = 10 \text{ ms}^{-2}\right)$

28. A positively charged sphere of mass $m = 5$ kg is attached by a spring of force constant $K = 10^4$ Nm^{-1}. The sphere is tied with a thread so that the spring is in its natural length. Another identical, negatively charged sphere is fixed to the floor, vertically below the positively charged sphere as shown in figure. Initial separation between sphere is $x_0 = 0.5$ m. Now thread is burnt and maximum elongation of the spring is 0.1 m, calculate the charge, in μC on each sphere. Take $g = 10$ ms^{-2}.



Initial position

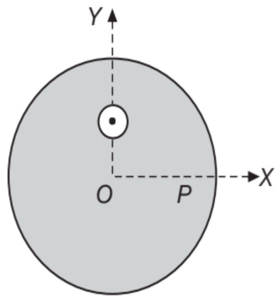
29. An infinite long straight conductor is uniformly charged, the charge per unit length being 6×10^4 Cm^{-1}.

(a) What is the force experienced by a proton, in μN, at a perpendicular distance 0.5 m from it?

(b) How much work in mJ will be required to bring the proton at a perpendicular distance from 0.5 m to 0.2 m from the conductor. Give your answer closest to the two digit integer, in this case.

30. Two concentric spherical shells have radii 0.15 m and 0.3 m. The inner sphere is given a charge -6×10^{-2} μC. An electron escapes from the inner sphere with negligible speed. Assuming that the region between the spheres is vacuum, the speed with which it will strike the outer sphere is $* \times 10^6$ ms^{-1}, where $*$ is not readable. Find the value of $*$. $\left(\frac{e}{m} \text{ for electron} = 1.76 \times 10^{11} \text{ Ckg}^{-1}\right)$.

31. A non-conducting sphere of radius $R = 5$ cm is centred at origin of coordinate system. It has a spherical cavity of radius 1 cm having centre at $(0, 3)$ cm. The material of sphere has a uniform charge density $\rho = \frac{10^{-6}}{\pi}$ Cm^{-3}. Calculate the electric potential at point $P(4 \text{ cm}, 0)$ to the nearest two digit integer.



32. Two small identical balls P and Q, each of mass 0.866 g, carry identical charges and are suspended by two threads of equal length of 50 cm each from the same point. At equilibrium, they are separated by a distance of 50 cm. Find the charge on each ball in nC. (Take $g = 10$ ms^{-2}).

33. A particle having a charge of $q = 8.85$ μC is placed on the axis of a circular ring of radius $R = 30$ cm at a point P at a distance of $a = 40$ cm from centre of ring. Calculate the electric flux passing through the ring in kNC^{-1}.

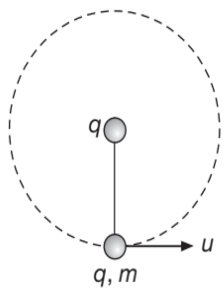
34. A particle of mass 2 μg and carrying a charge of 1×10^{-9} C is moving directly towards a fixed positive point charge of magnitude 10^{-8} C. When it is at a distance of 10 cm from the fixed point charge it has a velocity of 1 ms^{-1}. At what distance from the fixed point charge will the particle come momentarily to rest? (in mm)

35. A copper atom consists of copper nucleus surrounded by 29 electrons. The atomic weight of copper is $63.5\ \text{gmol}^{-1}$. Let us now take two pieces of copper each weighing 10 g. Let us transfer one electron from one piece to another for every 1000 atoms in that piece. The coulomb force between the two pieces after the transfer of electrons if they are 1 cm apart is $x \times 10^6$ N. Find x, close to the nearest integer. (Avogadro number $N_A = 6 \times 10^{23}$ gmole^{-1}, charge on an electron $= -1.6 \times 10^{-19}$ coulomb)

36. It is required to hold four equal point charges each having a charge $Q = \frac{8}{7}(1 - 2\sqrt{2})$ C in equilibrium at the corners of a square. Find the point charge, in coulomb, that will do this if placed at the centre of the square.

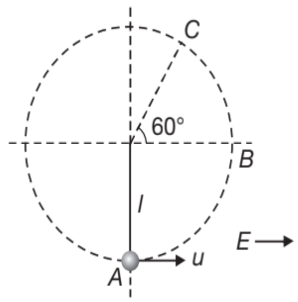
37. A radioactive source in the form of a metal sphere of radius 10^{-2} m, emits beta particles (electrons) at the rate of 5×10^{10} particles per second. The source is electrically insulated. How long, in μs will it take for its potential to be raised by 2 V assuming that 40% of the emitted beta particles escape the source.

38. A small ball of mass 2×10^{-3} kg having a charge of $1\ \mu$C is suspended by a string of length 0.8 m. Another identical ball having the same charge is kept at the point of suspension. Determine the minimum horizontal velocity in cms^{-1} which should be imparted to the lower ball so that it can make complete revolution.



39. The centres of two metal spheres of radius 10 cm are 50 cm apart on the x-axis. The spheres are initially neutral, but a charge Q is transferred from one sphere to the other, creating a potential difference 100 V. A proton is released from rest from the surface of the positively charged sphere and travels to the negatively charged sphere. At what speed, in kms^{-1} does it strike the negatively charged sphere?

40. A simple pendulum with a bob of mass $m = 1$ kg, charge $q = 5\ \mu$C and string length $l = 1$ m is given a horizontal velocity u in a uniform electric field $E = 2 \times 10^6$ Vm^{-1} at its bottommost point A, as shown in figure. It is given that the speed u is such that the particle leaves the circle at point C. Find the speed u to the nearest integer. (Take $g = 10$ ms^{-2})



41. Two insulating spheres have radii 0.3 cm and 0.5 cm, masses 0.1 kg and 0.7 kg, and uniformly distributed charges of $-2\ \mu$C and $3\ \mu$C. They are released from rest when their centers are separated by 1 m.

(a) How fast in cms^{-1} will each be moving when they collide?

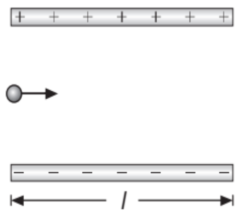
(b) If the spheres were conductors, would the speeds be greater or less than those as calculated in part (a)? Give reasonable explanation to your answer.

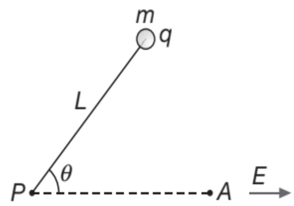
42. A particle having mass $m = 1$ kg and charge $q = 2\ \mu$C is thrown from a horizontal ground with a speed $u = 20$ ms^{-1} that makes an angle $\alpha = 45°$ with the horizontal. A horizontal electric field $E = 2 \times 10^7$ Vm^{-1} exist in this space. Find the range, in metre on the horizontal ground of the projectile thrown.

43. A ball of mass 2 kg, charge $1\ \mu$C is dropped from top of a high tower. In space electric field exist in horizontal direction away from tower which varies as $E = (5 - 2x) \times 10^6$ Vm^{-1}. Find maximum horizontal distance that the ball can go from the tower.

44. A particle having a charge of 1.6×10^{-19} C enters midway between the plates of a parallel plate condenser. The initial velocity of particle is parallel to the plates. A potential difference of 300 volts is applied to the capacitor plates. If the length of the capacitor plates is 10 cm and they are separated by 2 cm, calculate the greatest initial velocity, in kms^{-1} for which the particle will not be able to come out of the plates. The mass of the particle is 12×10^{-24} kg.

45. A uniform electric field E is created between two parallel charged plates as shown in figure. An electron enter the field symmetrically between the plates with a speed u. The length of each plate is l. Find the angle of deviation, in degree of the path of the electron as it comes out of the field for $u^2 = \frac{\sqrt{3}Ele}{m}$.





46. A particle having charge $q = +2\ \mu C$ and mass $m = 0.01$ kg is connected to a string that is $L = 1.5$ m long and is tied to the pivot point P in figure. The particle, string and pivot point all lie on a frictionless horizontal table. The particle is released from rest when the string makes an angle $\theta = 60°$ with a uniform electric field of magnitude $E = 300\ Vm^{-1}$. Determine the speed of the particle in cms^{-1} when the string becomes parallel to the electric field (point A in figure).

47. A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = kr^a$, where k and a are constants and r is the distance from its centre. If the electric field at $r = \frac{R}{2}$ is $\frac{1}{8}$ times that at $r = R$, find the value of a.

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1. [Online April 2019]
The bob of a simple pendulum has mass 2 g and a charge of $5.0\ \mu C$. It is at rest in a uniform horizontal electric field of intensity $2000\ Vm^{-1}$. At equilibrium, the angle that the pendulum makes with the vertical is (take $g = 10\ ms^{-2}$)

(A) $\tan^{-1}(0.2)$ (B) $\tan^{-1}(5.0)$
(C) $\tan^{-1}(2.0)$ (D) $\tan^{-1}(0.5)$

2. [Online April 2019]
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 $-4Q$, the new potential difference between the same two surfaces is

(A) $-2V$ (B) V
(C) $2V$ (D) $4V$

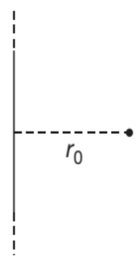
3. [Online April 2019]
The electric field in a region is given by $\vec{E} = (Ax + B)\hat{i}$, where E is in NC^{-1} and x is in metres. The values of constants are $A = 20$ SI unit and $B = 10$ SI unit. If the potential at $x = 1$ is V_1 and that at $x = -5$ is V_2, then $V_1 - V_2$ is

(A) 180 V (B) –520 V
(C) 320 V (D) –48 V

4. [Online April 2019]
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

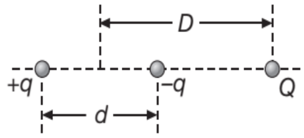
(A) $\sqrt{\frac{2qE}{md}}$ (B) $2\sqrt{\frac{qE}{md}}$
(C) $\sqrt{\frac{qE}{2md}}$ (D) $\sqrt{\frac{qE}{md}}$

5. [Online April 2019]
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



(A) $v \propto \sqrt{\ln\left(\frac{r}{r_0}\right)}$ (B) $v \propto e^{+\frac{r}{r_0}}$
(C) $v \propto \ln\left(\frac{r}{r_0}\right)$ (D) $v \propto \left(\frac{r}{r_0}\right)$

6. [Online April 2019]
A system of three charges are placed as shown in the figure



If $D \gg d$, the potential energy of the system is best given by

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

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

7. [Online April 2019]
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 $D \gg d$, will behave as

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

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

8. [Online April 2019]
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 v at $z=4a$. The minimum value of v such that it crosses the origin is

(A) $\sqrt{\frac{2}{m}}\left(\frac{1}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{\frac{1}{2}}$ (B) $\sqrt{\frac{2}{m}}\left(\frac{1}{5}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{\frac{1}{2}}$

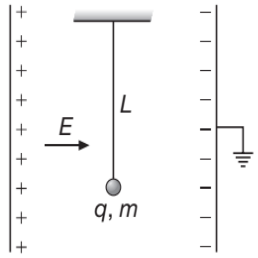
(C) $\sqrt{\frac{2}{m}}\left(\frac{4}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{\frac{1}{2}}$ (D) $\sqrt{\frac{2}{m}}\left(\frac{2}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{\frac{1}{2}}$

9. [Online April 2019]
In free space, a particle A of charge $1\ \mu\text{C}$ is held fixed at a point P. Another particle B of the same charge and mass $4\ \mu\text{g}$ 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 [Take $\frac{1}{4\pi\varepsilon_0}=9\times10^9\ \text{Nm}^2\text{C}^{-2}$]

(A) $2.0\times10^3\ \text{ms}^{-1}$ (B) $3.0\times10^4\ \text{ms}^{-1}$

(C) $1.5\times10^2\ \text{ms}^{-1}$ (D) $6.3\times10^4\ \text{ms}^{-1}$

10. [Online April 2019]
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



(A) $2\pi\sqrt{\frac{L}{\left(g-\frac{qE}{m}\right)}}$ (B) $2\pi\sqrt{\frac{L}{\left(g+\frac{qE}{m}\right)}}$

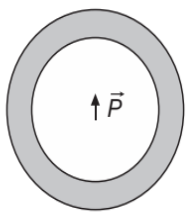
(C) $2\pi\sqrt{\frac{L}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$ (D) $2\pi\sqrt{\frac{L}{\sqrt{g^2-\frac{q^2E^2}{m^2}}}}$

11. [Online April 2019]
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)

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

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

12. [Online April 2019]
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



(A) Surface charge density on the outer surface depends on $|\vec{P}|$
(B) Surface charge density on the inner surface is uniform and equal to $\frac{\left(\frac{Q}{2}\right)}{4\pi a^2}$
(C) Electric field outside the shell is the same as that of point charge at the centre of the shell
(D) Surface charge density on the inner surface of the shell is zero everywhere

13. [Online April 2019]
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

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

(C) $a = 2^{-\frac{1}{4}}R$ (D) $a = 8^{-\frac{1}{4}}R$

14. [Online January 2019]
Three charges $+Q$, q, $+Q$ are placed respectively, at distance, 0, $\frac{d}{2}$ and d from the origin, on the x-axis. If the net force experienced by $+Q$, placed at $x = 0$, is zero then value of q is

(A) $+\frac{Q}{2}$ (B) $-\frac{Q}{2}$

(C) $-\frac{Q}{4}$ (D) $+\frac{Q}{4}$

15. [Online January 2019]
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

(A) $\frac{R}{\sqrt{2}}$ (B) $\frac{R}{\sqrt{5}}$

(C) R (D) $R\sqrt{2}$

16. [Online January 2019]
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 Vm^{-1}) at a point $y = 3$ m on y-axis is, $\left[\text{Take } \frac{1}{4\pi\varepsilon_0} = 9\times10^9\ Nm^2C^{-2}\right]$

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

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

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

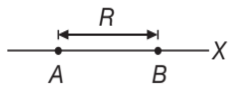
(D) $(-63\hat{i} + 27\hat{j})\times10^2$

17. [Online January 2019]
Charge is distributed within a sphere of radius R with volume charge density $\rho(r) = \frac{A}{r^2}e^{-\frac{2r}{a}}$, where A and a are constants. If Q is the total charge of this charge distribution, the radius R is

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

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

18. [Online January 2019]
Two electric dipoles, A, B with respective dipole moments $\vec{d}_A = -4qa\hat{i}$ and $\vec{d}_B = -2qa\hat{i}$ are 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

(A) $\frac{\sqrt{2}R}{\sqrt{2}-1}$ (B) $\frac{\sqrt{2}R}{\sqrt{2}+1}$

(C) $\frac{R}{\sqrt{2}-1}$ (D) $\frac{R}{\sqrt{2}+1}$

19. [Online January 2019]
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

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

(C) $\frac{Q(a^2+b^2+c^2)}{4\pi\varepsilon_0(a^3+b^3+c^3)}$ (D) $\frac{Q}{12\pi\varepsilon_0}\frac{ab+bc+ca}{abc}$

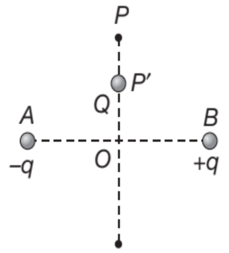
20. [Online January 2019]
Four equal point charges Q each are placed in the xy plane at (0, 2), (4, 2), $(4,\ -2)$ and $(0,\ -2)$. The work required to put a fifth charge Q at the origin of the coordinate system will be

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

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

21. [Online January 2019]
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

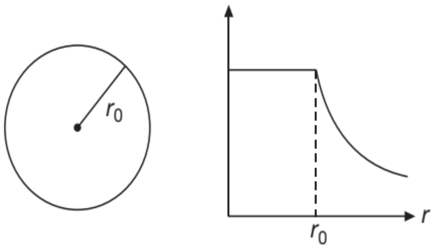
$y \gg 2a$. The charge Q experiences an electrostatic force F. If Q is now moved along the equatorial line to P' such that $OP' = \left(\frac{y}{3}\right)$, the force on Q will be close to $\left(\frac{y}{3} \gg 2a\right)$



(A) $\frac{F}{3}$ (B) $9F$

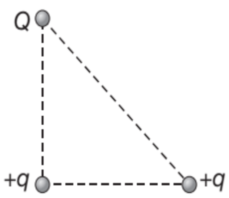
(C) $27F$ (D) $3F$

22. [Online January 2019]
The given graph shows variation (with distance r from centre) of



(A) Potential of a uniformly charged spherical shell
(B) Electric field of a uniformly charged sphere
(C) Electric field of uniformly charged spherical shell
(D) Potential of a uniformly charged sphere

23. [Online January 2019]
Three charges Q, $+q$ and $+q$ are placed at the vertices of a right-angle isosceles triangles as shown below. The net electrostatic energy of the configuration is zero, if the value of Q is



(A) $\frac{-\sqrt{2}q}{\sqrt{2}+1}$ (B) $+q$

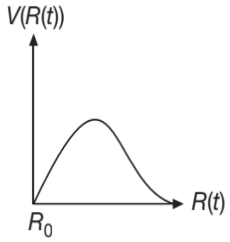
(C) $-2q$ (D) $\frac{-q}{1+\sqrt{2}}$

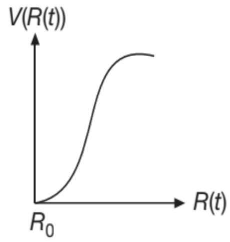
24. [Online January 2019]
An electric field of $1000\ \text{Vm}^{-1}$ is applied to an electric dipole at angle of $45°$. The value of electric dipole moment is $10^{-29}\ \text{Cm}$. What is the potential energy of the electric dipole?

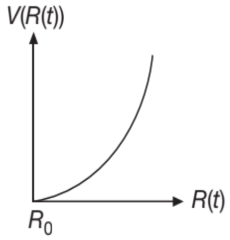
(A) -9×10^{-20} J (B) -10×10^{-29} J

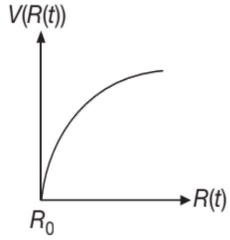
(C) -7×10^{-27} J (D) -20×10^{-18} J

25. [Online January 2019]
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

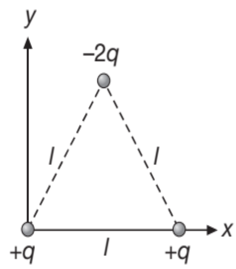
(A)


(B)


(C)


(D)


26. [Online January 2019]
Determine the electric dipole moment of the system of three charges, placed on the vertices of an equilateral triangle, as shown in the figure



(A) $2ql\hat{j}$ (B) $\sqrt{3}ql\left(\frac{\hat{j}-\hat{i}}{\sqrt{2}}\right)$

(C) $-\sqrt{3}ql\hat{j}$ (D) $ql\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

27. [Online January 2019]
A parallel plate capacitor with plates of area $1\ \text{m}^2$ each, are at a separation of $0.1\ \text{m}$. If the electric field between the plates is $100\ \text{NC}^{-1}$, the magnitude of charge on each plate is (Take $\varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2}$)

(A) 8.85×10^{-10} C (B) 9.85×10^{-10} C

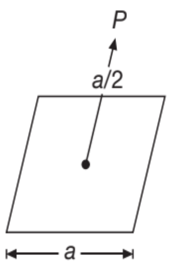
(C) 6.85×10^{-10} C (D) 7.85×10^{-10} C

28. [2018]
Three concentric metal shells A, B and C of respective radii, a, b and $c(a<b<c)$ have surface charge densities $+\sigma$, $-\sigma$ and $+\sigma$ respectively. The potential of shell B is

(A) $\frac{\sigma}{\varepsilon_0}\left(\frac{a^2-b^2}{a}+c\right)$ (B) $\frac{\sigma}{\varepsilon_0}\left(\frac{a^2-b^2}{b}+c\right)$

(C) $\frac{\sigma}{\varepsilon_0}\left(\frac{b^2-c^2}{b}+a\right)$ (D) $\frac{\sigma}{\varepsilon_0}\left(\frac{b^2-c^2}{c}+a\right)$

29. [Online 2018]
A charge Q is placed at a distance $\frac{a}{2}$ above the centre of the square surface of edge a as shown in the figure. The electric flux through the square surface is



(A) $\frac{Q}{3\varepsilon_0}$ (B) $\frac{Q}{6\varepsilon_0}$

(C) $\frac{Q}{\varepsilon_0}$ (D) $\frac{Q}{2\varepsilon_0}$

30. [Online 2018]
A solid ball of radius R has a charge density ρ given by $\rho=\rho_0\left(1-\frac{r}{R}\right)$ for $0\le r\le R$. The electric field outside the ball is

(A) $\frac{\rho_0R^3}{12\varepsilon_0r^2}$ (B) $\frac{4\rho_0R^3}{3\varepsilon_0r^2}$

(C) $\frac{3\rho_0R^3}{4\varepsilon_0r^2}$ (D) $\frac{\rho_0R^3}{\varepsilon_0r^2}$

31. [Online 2018]
Two identical conducting spheres A and B, carry equal charge. They are separated by a distance much larger than their diameters and the force between them is F. A third identical conducting sphere, C, is uncharged. Sphere C is first touched to A, then to B and then removed. As a result, the force between A and B would be equal to

(A) $\frac{3F}{8}$ (B) $\frac{F}{2}$

(C) $\frac{3F}{4}$ (D) F

32. [Online 2018]
A body of mass M and charge q is connected to a spring of spring constant k. It is oscillating along x-direction about its equilibrium position, taken to be at $x=0$, with an amplitude A. An electric field E is applied along the x-direction. Which of the following statements is correct?

(A) The total energy of the system is $\frac{1}{2}m\omega^2A^2-\frac{1}{2}\frac{q^2E^2}{k}$.

(B) The new equilibrium position is at a distance $\frac{2qE}{k}$ from $x=0$.

(C) The new equilibrium position is at a distance $\frac{qE}{2k}$ from $x=0$.

(D) The total energy of the system is $\frac{1}{2}m\omega^2A^2+\frac{1}{2}\frac{q^2E^2}{k}$.

33. [2017]
An electric dipole has a fixed dipole moment $\vec{p}$, which makes angle θ with respect to x-axis. When subjected to an electric field $\vec{E}_1=E\hat{i}$, it experiences a torque $\vec{T}_1=\tau\hat{k}$. When subjected to another electric field $\vec{E}_2=\sqrt{3}E_1\hat{j}$ it experiences a torque $\vec{T}_2=-\vec{T}_1$. The angle θ is

(A) 30° (B) 45°

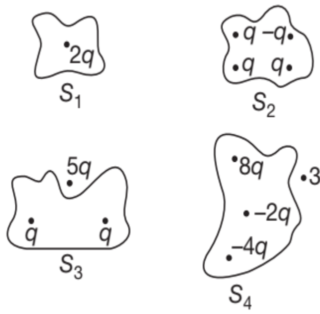
(C) 60° (D) 90°

34. [Online 2017]
There is a uniform electrostatic field in a region. The potential at various points on a small sphere centred at P, in the region, is found to vary between the limits 589 V to 589.8 V. What is the potential at a point on the sphere whose radius vector makes an angle of 60° with the direction of the field?

(A) 589.2 V (B) 589.6 V

(C) 589.5 V (D) 589.4 V

35. [Online 2017]
Four closed surfaces and corresponding charge distributions are shown below.



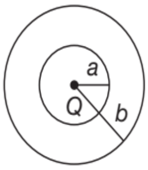
Let the respective electric fluxes through the surfaces be Φ_1, Φ_2, Φ_3 and Φ_4. Then

(A) $\Phi_1 = \Phi_2 = \Phi_3 = \Phi_4$ (B) $\Phi_1 > \Phi_3;\ \Phi_2 < \Phi_4$

(C) $\Phi_1 > \Phi_2 > \Phi_3 > \Phi_4$ (D) $\Phi_1 < \Phi_2 = \Phi_3 > \Phi_4$

36. [2016]

The region between two concentric spheres of radii 'a' and 'b', respectively (see figure), has volume charge density $\rho = \frac{A}{r}$, where A is a constant and r is the distance from the centre.



At the centre of the spheres is a point charge Q. The value of A such that the electric field in the region between the spheres will be constant, is

(A) $\frac{Q}{2\pi a^2}$ (B) $\frac{Q}{2\pi(b^2 - a^2)}$

(C) $\frac{2Q}{\pi(a^2 - b^2)}$ (D) $\frac{2Q}{\pi a^2}$

37. [Online 2016]

The potential (in volts) of a charge distribution is given by

$V(z) = 30 - 5z^2$ for $|z| \le 1$ m

$V(z) = 35 - 10|z|$ for $|z| \ge 1$ m

$V(z)$ does not depend on x and y. If this potential is generated by a constant charge per unit volume ρ_0 (in units of ε_0) which is spread over a certain region, then choose the correct statement

(A) $\rho_0 = 20\varepsilon_0$ in the entire region.

(B) $\rho_0 = 10\varepsilon_0$ for $|z| \le 1$ m and $\rho_0 = 0$ elsewhere

(C) $\rho_0 = 20\varepsilon_0$ for $|z| \le 1$ m and $\rho_0 = 0$ elsewhere

(D) $\rho_0 = 40\varepsilon_0$ in the entire region

38. [Online 2016]

Within a spherical charge distribution of charge density $\rho(r)$, N equipotential surfaces of potential V_0, $V_0 + \Delta V$, $V_0 + 2\Delta V$, ….. $V_0 + N\Delta V\ (\Delta V > 0)$, are drawn and have increasing radii $r_0, r_1, r_2, \ldots, r_N$, respectively. If the difference in the radii of the surfaces is constant for all values of V_0 and ΔV then

(A) $\rho(r) = \text{constant}$ (B) $\rho(r) \propto \frac{1}{r^2}$

(C) $\rho(r) \propto \frac{1}{r}$ (D) $\rho(r) \propto r$

39. [2015]

A uniformly charged solid sphere of radius R has potential V_0 (measured with respect to ∞) on its surface. For this sphere the equipotential surfaces with potentials $\frac{3V_0}{2}, \frac{5V_0}{4}, \frac{3V_0}{4}$ and $\frac{V_0}{4}$ have radius R_1, R_2, R_3 and R_4 respectively. Then

(A) $R_1 = 0$ and $R_2 > (R_4 - R_3)$

(B) $R_1 \ne 0$ and $(R_2 - R_1) > (R_4 - R_3)$

(C) $R_1 = 0$ and $R_2 < (R_4 - R_3)$

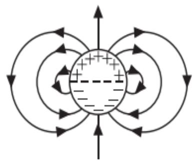
(D) $2R < R_4$

40. [2015]

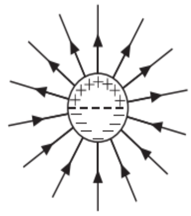
A long cylindrical shell carries positive surface charge σ in the upper half and negative surface charge $-\sigma$ in the lower half. The electric field lines around the cylinder will look like figure given in

(figures are schematic and not drawn to scale)

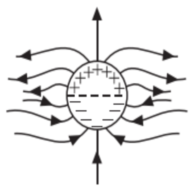
(A)



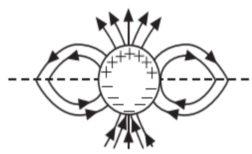
(B)



(C)

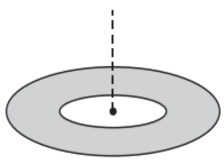


(D)



41. [Online 2015]

A thin disc of radius $b = 2a$ has a concentric hole of radius a in it (shown in figure). It carries uniform surface charge σ on it. If the electric field on its axis at height $h\ (h \ll a)$ from its centre is given as Ch then value of C is

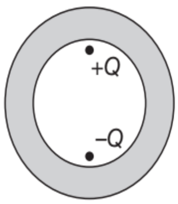


(A) $\frac{\sigma}{a\varepsilon_0}$ (B) $\frac{\sigma}{2a\varepsilon_0}$

(C) $\frac{\sigma}{4a\varepsilon_0}$ (D) $\frac{\sigma}{8a\varepsilon_0}$

42. [Online 2015]

Shown in the figure are two point charges $+Q$ and $-Q$ inside the cavity of a spherical shell. The charges are kept near the surface of the cavity on opposite sides of the centre of the shell. If σ_1 is the surface charge on the inner surface and Q_1 net charge on it and σ_2 the surface charge on the outer surface and Q_2 net charge on it then



(A) $\sigma_1 \neq 0,\ Q_1 \neq 0;\ \sigma_2 \neq 0,\ Q_2 \neq 0$

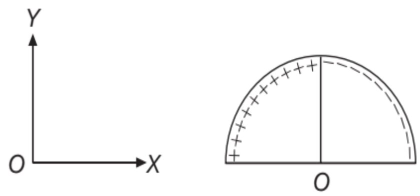
(B) $\sigma_1 \neq 0,\ Q_1 = 0;\ \sigma_2 \neq 0,\ Q_2 = 0$

(C) $\sigma_1 \neq 0,\ Q_1 = 0;\ \sigma_2 = 0,\ Q_2 = 0$

(D) $\sigma_1 = 0,\ Q_1 = 0;\ \sigma_2 = 0,\ Q_2 = 0$

43. [Online 2015]

A wire, of length $L(=20\text{ cm})$, is bent into a semi-circular arc. If the two equal halves of the arc, were each to be uniformly charged with charges $\pm Q$, $(|Q| = 10^3 \varepsilon_0$ Coulomb where ε_0 is the permittivity (in SI units) of free space) the net electric field at the centre O of the semi-circular arc would be



(A) $(50 \times 10^3\text{ NC}^{-1})\hat{j}$ (B) $(25 \times 10^3\text{ NC}^{-1})\hat{i}$

(C) $(25 \times 10^3\text{ NC}^{-1})\hat{j}$ (D) $(50 \times 10^3\text{ NC}^{-1})\hat{i}$

44. [Online 2015]

An electric field $\vec{E} = (30\hat{i} + 30\hat{j})\text{ NC}^{-1}$ exists in a region of space. If the potential at the origin is taken to be zero then the potential at $x = 2$ m, $y = 2$ m is

(A) -130 JC^{-1} (B) -120 JC^{-1}

(C) -140 JC^{-1} (D) -110 JC^{-1}

45. [2014]

Assume that an electric field $\vec{E} = 30x^2\hat{i}$ exists in space. Then the potential difference $V_A - V_O$, where V_O is the potential at the origin and V_A the potential at $x = 2$ m is

(A) 120 V (B) –120 V

(C) –80 V (D) 80 V

46. [2013]

Two charges, each equal to q, are kept at $x = -a$ and $x = a$ on the x-axis. A particle of mass m and charge $q_0 = \frac{q}{2}$ is placed at the origin. If charge q_0 is given a small displacement $(y \ll a)$ along the y-axis, the net force acting on the particle is proportional to

(A) y (B) $-y$

(C) $\frac{1}{y}$ (D) $-\frac{1}{y}$

47. [2013]

A charge Q is uniformly distributed over a long rod AB of length L as shown in the figure. The electric potential at the point O lying at a distance L from the end A is

(A) $\frac{Q\ln 2}{8\pi\varepsilon_0 L}$ (B) $\frac{3Q}{4\pi\varepsilon_0 L}$

(C) $\frac{Q}{4\pi\varepsilon_0 L\ln 2}$ (D) $\frac{Q\ln 2}{4\pi\varepsilon_0 L}$

48. [2012]

This question has Statement 1 and Statement 2. Of the four choices given after the statements, choose the one that best describes the two statements.

An insulating solid sphere of radius R has a uniformly positive charge density ρ. As a result of this uniform charge distribution there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point outside the sphere. The electric potential at infinity is zero.

Statement 1: When a charge q is taken from the centre to the surface of the sphere, its potential energy changes by $\frac{q\rho}{3\varepsilon_0}$.

Statement 2: The electric field at a distance $r\,(r < R)$ from the centre of the sphere is $\frac{\rho r}{3\varepsilon_0}$.

(A) Statement 1 is true, Statement 2 is false.

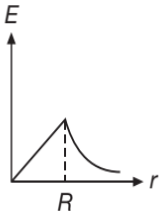
(B) Statement 1 is false, Statement 2 is true.

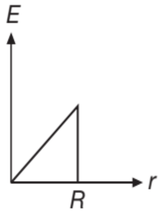
(C) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.

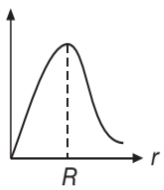
(D) Statement 1 is true, Statement 2 is true; Statement 2 is not the correct explanation of Statement 1.

49. [2012]
In a uniformly charged sphere of total charge Q and radius R, the electric field E is plotted as a function of distance from the centre. The graph which would correspond to the above will be

(A)


(B)


(C)


(D)


50. [2011]
Two identical charged spheres suspended from a common point by two massless strings of length l are initially a distance $d(d \ll l)$ apart because of their mutual repulsion. The charge begins to leak from both the spheres at a constant rate. As a result the charges approach each other with a velocity v. Then as a function of distance x between them

(A) $v \propto x^{-1/2}$ (B) $v \propto x^{-1}$
(C) $v \propto x^{1/2}$ (D) $v \propto x$

51. [2011]
The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre; a, b are constants. Then the charge density inside the ball is

(A) $-24\pi a\varepsilon_0 r$ (B) $-6a\varepsilon_0 r$
(C) $-24\pi a\varepsilon_0$ (D) $-6a\varepsilon_0$

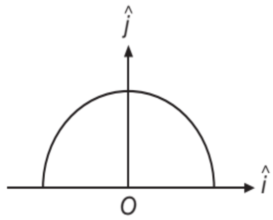
52. [2010]
Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle of $30°$ with each other. When suspended in a liquid of density 0.8 g cm^{-3}, the angle remains the same. If density of the material of the sphere is 1.6 g cm^{-3}, the dielectric constant of the liquid is
(A) 1 (B) 4
(C) 3 (D) 2

53. [2010]
Let there be a spherically symmetric charge distribution with charge density varying as $\rho(r) = \rho_0\left(\frac{5}{4} - \frac{r}{R}\right)$ upto $r = R$ and $\rho(r) = 0$ for $r > R$, where r is the distance from the origin. The electric field at a distance $r(r < R)$ from the origin is given by

(A) $\frac{\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$ (B) $\frac{4\pi\rho_0 r}{3\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$

(C) $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$ (D) $\frac{4\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$

54. [2010]
A thin semi-circular ring of radius r has a positive charge q distributed uniformly over it. The net field $\vec{E}$ at the centre O is



(A) $\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$ (B) $\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$

(C) $-\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$ (D) $-\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$

55. [2009]
A charge Q is placed at each of the opposite corners of a square. A charge q is placed at each of the other two corners. If the net electrical force on Q is zero, then the $\frac{Q}{q}$ equals

(A) $-2\sqrt{2}$ (B) -1

(C) 1 (D) $-\frac{1}{\sqrt{2}}$

56. [2009]
Two points P and Q are maintained at the potentials of 10 V and -4 V respectively. The work done in moving 100 electrons from P to Q is

(A) $-9.60 \times 10^{-17} \text{ J}$

(B) $9.60 \times 10^{-17} \text{ J}$

(C) $-2.24 \times 10^{-16} \text{ J}$

(D) $2.24 \times 10^{-16} \text{ J}$

57. [2009]

Let $\rho(r) = \frac{Q}{\pi R^4} r$ be the charge density distribution for a solid sphere of radius R and total charge Q. For a point 'p' inside the sphere at distance r_1 from the centre of the sphere, the magnitude of electric field is

(A) 0 (B) $\frac{Q}{4\pi\varepsilon_0 r_1^2}$

(C) $\frac{Qr_1^2}{4\pi\varepsilon_0 R^4}$ (D) $\frac{Qr_1^2}{3\pi\varepsilon_0 R^4}$

58. **[2009]**

This question contains Statement 1 and Statement 2. Of the four choices given after the statements, choose the one that best describes the two statements.

Statement 1: For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q

Statement 2: The network done by a conservative force on an object moving along a closed loop is zero.

(A) Statement 1 is true, Statement 2 is false.
(B) Statement 1 is true, Statement 2 is true; Statement 2 is the correct explanation of Statement 1.
(C) Statement 1 is true, Statement 2 is true; Statement 2 is not the correct explanation of Statement 1.
(D) Statement 1 is false, Statement 2 is true.

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Single Correct Choice Type Problems

This section contains Single Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONLY ONE is correct.

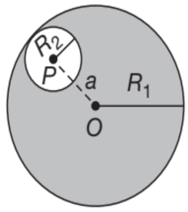
1. **[JEE (Advanced) 2019]**

A thin spherical insulating shell of radius R carries a uniformly distributed charge such that the potential at its surface is V_0. A hole with a small area $\alpha 4\pi R^2 (\alpha \ll 1)$ is made on the shell without affecting the rest of the shell. Which one of the following statements is correct?

(A) The potential at the centre of the shell is reduced by $2\alpha V_0$.
(B) The magnitude of electric field at the centre of the shell is reduced by $\frac{\alpha V_0}{2R}$.
(C) The magnitude of electric field at a point, located on a line passing through the hole and shell's centre, on a distance $2R$ from the centre of the spherical shell will be reduced by $\frac{\alpha V_0}{2R}$.
(D) The ratio of the potential at the centre of the shell to that of the point at $\frac{1}{2}R$ from centre towards the hole will be $\frac{1-\alpha}{1-2\alpha}$.

2. **[JEE (Advanced) 2015]**

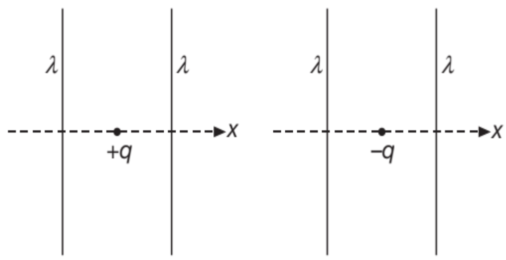
Consider a uniform spherical charge distribution of radius R_1 centred at the origin O. In this distribution, a spherical cavity of radius R_2, centred at P with distance $OP = a = R_1 - R_2$ (see figure) is made. If the electric field inside the cavity at position $\vec{r}$ is $\vec{E}(\vec{r})$, then the correct statements is/are



(A) $\vec{E}$ is uniform, its magnitude is independent of R_2 but its direction depends on $\vec{r}$
(B) $\vec{E}$ is uniform, its magnitude depends on R_2 and its direction depends on $\vec{r}$
(C) $\vec{E}$ is uniform, its magnitude is independent of a but its direction depends on $\vec{a}$
(D) $\vec{E}$ is uniform and both its magnitude and direction depend on $\vec{a}$

3. **[JEE (Advanced) 2015]**

The figures below depict two situations in which two infinitely long static line charges of constant positive line charge density λ are kept parallel to each other. In their resulting electric field, point charges q and $-q$ are kept in equilibrium between them. The point charges are confined to move in the x direction only. If they are given a small displacement about their equilibrium positions, then the correct statements is/are



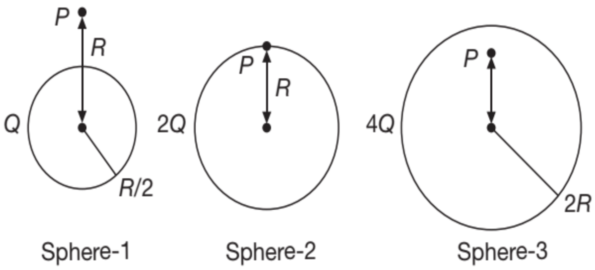
(A) both charges execute simple harmonic motion
(B) both charges will continue moving in the direction of their displacement

(C) charge $+q$ executes simple harmonic motion while charge $-q$ continues moving in the direction of its displacement

(D) charge $-q$ executes simple harmonic motion while charge $+q$ continues moving in the direction of its displacement

4. [JEE (Advanced) 2014]

Charges Q, $2Q$ and $4Q$ are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii $\frac{R}{2}$, R and $2R$ respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1, E_2 and E_3 respectively, then

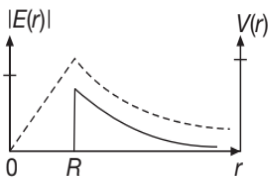


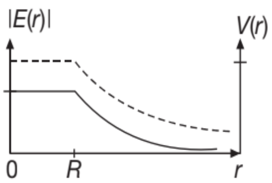
(A) $E_1 > E_2 > E_3$ (B) $E_3 > E_1 > E_2$

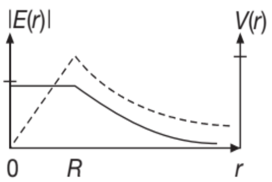
(C) $E_2 > E_1 > E_3$ (D) $E_3 > E_2 > E_1$

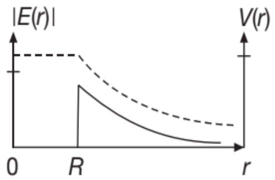
5. [IIT-JEE 2012]

Consider a thin spherical shell of radius R with its centre at the origin, carrying uniform positive surface charge density. The variation of the magnitude of the electric field $|E(r)|$ and the electric potential $V(r)$ with the distance r from the centre, is best represented by which graph?

(A)


(B)


(C)


(D)


6. [IIT-JEE 2012]

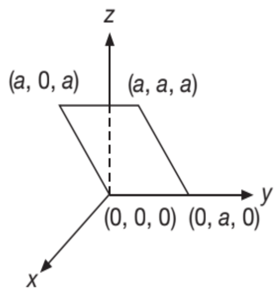
Two large vertical and parallel metal plates having a separation of 1 cm are connected to a DC voltage source of potential difference X. A proton is released at rest midway between the two plates. It is found to move at 45° to the vertical just after release. Then X is nearly

(A) 1×10^{-5} V (B) 1×10^{-7} V

(C) 1×10^{-9} V (D) 1×10^{-10} V

7. [IIT-JEE 2011]

Consider an electric field $\vec{E} = E_0\hat{x}$, where E_0 is a constant. The flux through the shaded area (as shown in the figure) due to this field is

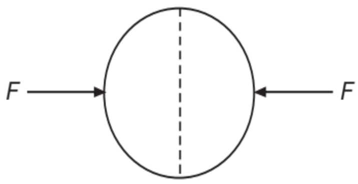


(A) $2E_0a^2$ (B) $\sqrt{2}E_0a^2$

(C) E_0a^2 (D) $\frac{E_0a^2}{\sqrt{2}}$

8. [IIT-JEE 2010]

A uniformly charged thin spherical shell of radius R carries uniform surface charge density of σ per unit area. It is made of two hemispherical shells, held together by pressing them with force F (see figure). F is proportional to



(A) $\frac{1}{\varepsilon_0}\sigma^2R^2$ (B) $\frac{1}{\varepsilon_0}\sigma^2R$

(C) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R}$ (D) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R^2}$

9. [IIT-JEE 2010]

A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7}\times 10^5\ \text{Vm}^{-1}$. When the field is switched off, the drop is observed to fall with terminal velocity $2\times10^{-3}\ \text{ms}^{-1}$. Given $g = 9.8\ \text{ms}^{-2}$, viscosity of the air $= 1.8\times10^{-5}\ \text{Nsm}^{-2}$ and the density of oil $= 900\ \text{kgm}^{-3}$, the magnitude of q is

(A) 1.6×10^{-19} C (B) 3.2×10^{-19} C

(C) 4.8×10^{-19} C (D) 8×10^{-19} C

10. [IIT-JEE 2009]

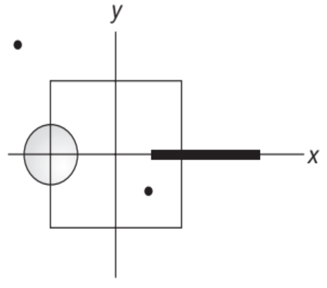
Three concentric metallic spherical shells of radii R, $2R$ and $3R$ are given charges Q_1, Q_2 and Q_3, respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then, the ratio of the charges given to the shells, $Q_1 : Q_2 : Q_3$, is

(A) $1:2:3$ (B) $1:3:5$

(C) $1:4:9$ (D) $1:8:18$

11. [IIT-JEE 2009]

A disk of radius $\frac{a}{4}$ having a uniformly distributed charge $6C$ is placed in the x-y plane with its centre at $\left(-\frac{a}{2}, 0, 0\right)$. A rod of length a carrying a uniformly distributed charge $8C$ is placed on the x-axis from $x = \frac{a}{4}$ to $x = \frac{5a}{4}$. Two point charges $-7C$ and $3C$ are placed at $\left(\frac{a}{4}, -\frac{a}{4}, 0\right)$ and $\left(-\frac{3a}{4}, \frac{3a}{4}, 0\right)$, respectively. Consider a cubical surface formed by six surfaces $x = \pm\frac{a}{2}$, $y = \pm\frac{a}{2}$, $z = \pm\frac{a}{2}$. The electric flux through this cubical surface is

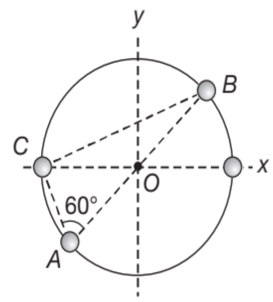


(A) $-\frac{2C}{\varepsilon_0}$ (B) $\frac{2C}{\varepsilon_0}$

(C) $\frac{10C}{\varepsilon_0}$ (D) $\frac{12C}{\varepsilon_0}$

12. [IIT-JEE 2008]

Consider a system of three charges $\frac{q}{3}$, $\frac{q}{3}$ and $-\frac{2q}{3}$ placed at points A, B and C, respectively, as shown in the figure. Take O to be the centre of the circle of radius R and angle $CAB = 60°$.



(A) The electric field at point O is $\frac{q}{8\pi\varepsilon_0 R^2}$ directed along the negative x-axis

(B) The potential energy of the system is zero

(C) The magnitude of the force between the charges at C and B is $\frac{q^2}{54\pi\varepsilon_0 R^2}$

(D) The potential at point O is $\frac{q}{12\pi\varepsilon_0 R}$

13. [IIT-JEE 2007]

Positive and negative point charges of equal magnitude are kept at $\left(0, 0, \frac{a}{2}\right)$ and $\left(0, 0, -\frac{a}{2}\right)$, respectively, The work done by the electric field when another positive point charge in moved from $(-a, 0, 0)$ to $(0, a, 0)$ is

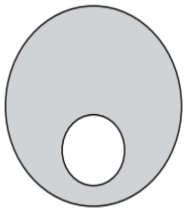
(A) positive
(B) negative
(C) zero
(D) depends on the path connecting the initial and final positions

14. [IIT-JEE 2007]

Consider a neutral conducting sphere. A positive point charge is placed outside the sphere. The net charge on the sphere is then

(A) negative and distributed uniformly over the surface of the sphere
(B) negative and appears only at the point on the sphere closest to the point charge
(C) negative and distributed non-uniformly over the entire surface of the sphere
(D) zero

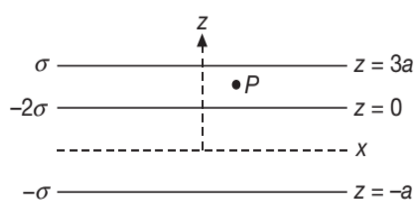
15. [IIT-JEE 2007]
A spherical portion has been removed from a solid sphere having a charge distributed uniformly in its volume as shown in the figure. The electric field inside the emptied space is



(A) zero everywhere
(B) non-zero and uniform
(C) non-uniform
(D) zero only at its centre

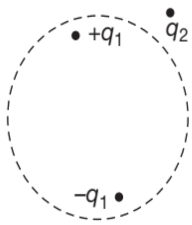
16. [IIT-JEE 2007]
A long, hollow conducting cylinder is kept coaxially inside another long, hollow conducting cylinder of larger radius. Both the cylinders are initially electrically neutral.
(A) A potential difference appears between the two cylinders when a charge density is given to the inner cylinder
(B) A potential difference appears between the two cylinders when a charge density is given to the outer cylinder
(C) No potential difference appears between the two cylinders when a uniform line charge is kept along the axis of the cylinders
(D) No potential difference appears between the two cylinders when same charge density is given to both the cylinders

17. [IIT-JEE 2005]
Three infinitely long charge sheets are placed as shown in figure. The electric field at point P is



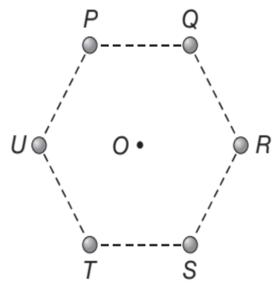
(A) $\frac{2\sigma}{\varepsilon_0}\hat{k}$ (B) $-\frac{2\sigma}{\varepsilon_0}\hat{k}$
(C) $\frac{4\sigma}{\varepsilon_0}\hat{k}$ (D) $-\frac{4\sigma}{\varepsilon_0}\hat{k}$

18. [IIT-JEE 2004]
Consider the charge configuration and a spherical Gaussian surface as shown in the figure. When calculating the flux of the electric field over the spherical surface, the electric field will be due to



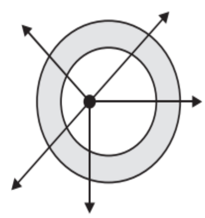
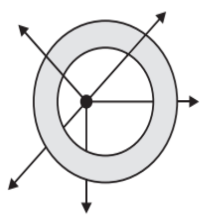
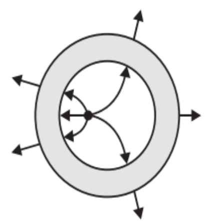
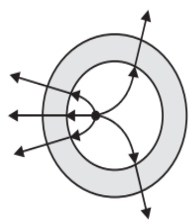
(A) q_2
(B) only the positive charges
(C) all the charges
(D) $+q_1$ and $-q_1$

19. [IIT-JEE 2004]
Six charges, three positive and three negative of equal magnitude are to be placed at the vertices of a regular hexagon such that the electric field at O is double the electric field when only one positive charge of same magnitude is placed at R. Which of the following arrangements of charge is possible for, P, Q, R, S, T and U respectively?



(A) +, −, +, −, −, + (B) +, −, +, −, +, −
(C) +, +, −, +, −, − (D) −, +, +, −, +, −

20. [IIT-JEE 2003]
A metallic shell has a point charge q kept inside its cavity. Which one of the following diagrams correctly represents the electric lines of forces?

(A)

(B)

(C)

(D)


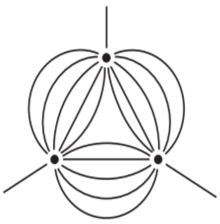
21. [IIT-JEE 2002]
Two equal point charges are fixed at $x = -a$ and $x = +a$ on the x-axis. Another point charge Q is placed at the origin. The change in the electrical potential energy of Q, when it is displaced by a small distance x along the x-axis, is approximately proportional to

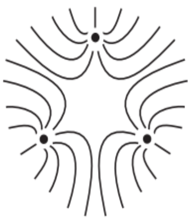
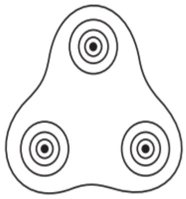
(A) x (B) x^2
(C) x^3 (D) $\frac{1}{x}$

22. [IIT-JEE 2002]
Two equal point charges are fixed at $x = -a$ and $x = +a$ on the x-axis. Another point charge Q is placed at the origin. The change in the electrical potential energy of Q, when it is displaced by a small distance x along the x-axis, is approximately proportional to

(A) x (B) x^2
(C) x^3 (D) $\frac{1}{x}$

23. [IIT-JEE 2001]
Three positive charges of equal value q are placed at the vertices of an equilateral triangle. The resulting lines of force should be sketched as in

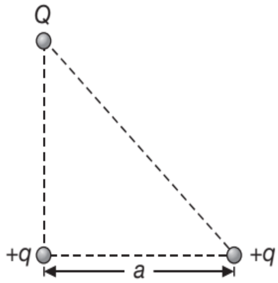
(A)

(B)

(C)

(D)


24. [IIT-JEE 2001]
A uniform electric field pointing in positive x-direction exists in a region. Let A be the origin, B be the point on the x-axis at $x = +1$ cm and C be the point on the y-axis at $y = +1$ cm. Then the potentials at the points A, B and C satisfy

(A) $V_A < V_B$ (B) $V_A > V_B$
(C) $V_A < V_C$ (D) $V_A > V_C$

25. [IIT-JEE 2000]
Three charges Q, $+q$ and $+q$ are placed at the vertices of a right angle triangle (isosceles triangle) as shown. The net electrostatic energy of the configuration is zero, if Q is equal to



(A) $\frac{-q}{1+\sqrt{2}}$ (B) $\frac{-2q}{2+\sqrt{2}}$
(C) $-2q$ (D) $+q$

26. [IIT-JEE 1998]
A charge $+q$ is fixed at each of the points $x = x_0$, $x = 3x_0$, $x = 5x_0$,.... ad infinitum on the x-axis and a charge $-q$ is fixed at each of points $x = 2x_0$, $x = 4x_0$, $x = 6x_0$.... ad infinitum. Here x_0 is a positive constant. The potential at the origin due to the above system of charges is

(A) zero (B) $\frac{q}{8\pi\varepsilon_0 x_0 \log_e 2}$
(C) ∞ (D) $\frac{q \log_e 2}{4\pi\varepsilon_0 x_0}$

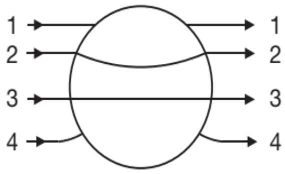
27. [IIT-JEE 1997]
An electron of mass m_e, initially at rest, moves through a certain distance in a uniform electric field in time t_1. A proton of mass m_p, also, initially at rest takes time t_2 to move through an equal distance in this uniform electric field. Neglecting the effect of gravity, the ratio $\frac{t_2}{t_1}$ is nearly equal to

(A) 1 (B) $\left(\frac{m_p}{m_e}\right)^{\frac{1}{2}}$
(C) $\left(\frac{m_e}{m_p}\right)^{\frac{1}{2}}$ (D) 1836

28. [IIT-JEE 1997]
A non-conducting ring of radius 0.5 m carries a total charge of 1.11×10^{-10} C distributed non-uniformly on its circumference producing an electric field $\vec{E}$ everywhere in space. The value of the line integral $\int_{l=\infty}^{l=0} -\vec{E} \cdot d\vec{l}$, ($l = 0$ being the centre of the ring) in volt is

(A) +2 (B) –1
(C) –2 (D) 0

29. [IIT-JEE 1996]
A metallic sphere is placed in a uniform electric field. The lines of force follow the path(s) shown in the figure as



(A) 1 (B) 2
(C) 3 (D) 4

30. [IIT-JEE 1995]
Two point charges $+q$ and $-q$ are held fixed at $(-d, 0)$ and $(d, 0)$ respectively of a x-y co-ordinate system. Then:
(A) the electric field E at all points on the x-axis has the same direction
(B) work has to be done in bringing at a test charge from ∞ to the origin
(C) electric field at all point on y-axis is along x-axis
(D) the dipole moment is $2qd$ along the x-axis

31. [IIT-JEE 1992]
Two identical thin rings, each of radius a metre are coaxial and placed a metre apart. If Q_1 and Q_2 are respectively the charges uniformly spread on the two rings, the work done in moving a charge q coulomb from the centre of one ring to that of the other is

(A) zero (B) $\dfrac{q(Q_1-Q_2)(\sqrt{2}-1)}{4\sqrt{2}\pi\varepsilon_0 a}$

(C) $\dfrac{q\sqrt{2}(Q_1+Q_2)}{4\pi\varepsilon_0 a}$ (D) $\dfrac{q(Q_1+Q_2)(\sqrt{2}+1)}{4\sqrt{2}\pi\varepsilon_0 a}$

32. [IIT-JEE 1989]
A solid conducting sphere having a charge Q is surrounded by an uncharged concentric 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 $-3Q$, the new potential difference between the same two surfaces is
(A) V (B) $2V$
(C) $4V$ (D) $-2V$

33. [IIT-JEE 1987]
A charge q is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium if q is equal to

(A) $-\dfrac{Q}{2}$ (B) $-\dfrac{Q}{4}$

(C) $+\dfrac{Q}{4}$ (D) $+\dfrac{Q}{2}$

34. [IIT-JEE 1984]
Two equal negative charges $-q$ are fixed at points $(0, a)$ and $(0, -a)$ on the y-axis. A positive charge Q is released from rest at the point $(2a, 0)$ on the x-axis. The charge Q will
(A) Execute simple harmonic motion about the origin
(B) Move to the origin and remains at rest
(C) Move to infinity
(D) Execute oscillatory but not simple harmonic motion.

35. [IIT-JEE 1983]
A hollow metal sphere of radius 5 cm is charged so that the potential on its surface is 10 V. The potential at the centre of the sphere is
(A) ZERO
(B) 10 V
(C) same as at a point 5 cm away from the surface
(D) same as at a point 25 cm away from the surface

36. [IIT-JEE 1981]
An alpha particle of energy 5 MeV is scattered through $180°$ by a fixed uranium nucleus. The distance of closest approach is of the order of
(A) 1 Å (B) 10^{-10} cm
(C) 10^{-12} cm (D) 10^{-15} cm

Multiple Correct Choice Type Problems

This section contains Multiple Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONE OR MORE is/are correct.

1. [JEE (Advanced) 2019]
A charged shell of radius R carries a total charge Q. Given ϕ as the flux of electric field through a closed cylindrical surface of height h, radius r and with its centre same as that of the shell. Here, centre of the cylinder is a point on the axis of the cylinder which is equidistant from its top and bottom surfaces. Which of the following option(s) is/are correct?
(ε_0 is the permittivity of free space)

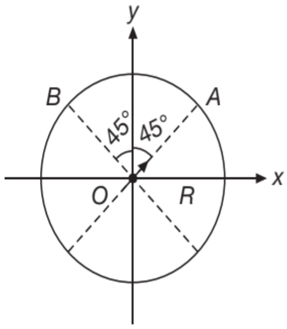
(A) If $h > 2R$ and $r = \dfrac{3R}{5}$ then $\phi = \dfrac{Q}{5\varepsilon_0}$

(B) If $h < \dfrac{8R}{5}$ and $r = \dfrac{3R}{5}$ then $\phi = 0$

(C) If $h > 2R$ and $r > R$ then $\phi = \frac{Q}{\varepsilon_0}$

(D) If $h > 2R$ and $r = \frac{4R}{5}$ then $\phi = \frac{Q}{5\varepsilon_0}$

2. [JEE (Advanced) 2019]
An electric dipole with dipole moment $\frac{p_0}{\sqrt{2}}(\hat{i}+\hat{j})$ is held fixed at the origin O in the presence of an uniform electric field of magnitude E_0. If the potential is constant on a circle of radius R centered at the origin as shown in figure, then the correct statement(s) is/are (ε_0 is permittivity of free space. $R \gg$ dipole size)



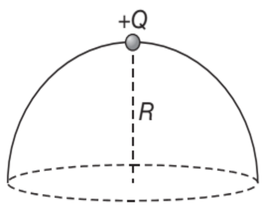
(A) Total electric field at point B is $\vec{E}_B = 0$

(B) Total electric field at point A is $\vec{E}_A = \sqrt{2}E_0(\hat{i}+\hat{j})$

(C) $R = \left(\frac{p_0}{4\pi\varepsilon_0 E_0}\right)^{\frac{1}{3}}$

(D) The magnitude of total electric field on any two points of the circle will be same

3. [JEE (Advanced) 2017]
A point charge $+Q$ is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct?



(A) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$.

(B) The component of the electric field normal to the flat surface is constant over the surface

(C) Total flux through the curved and the flat surfaces is $\frac{Q}{\varepsilon_0}$

(D) The circumference of the flat surface is an equipotential

4. [JEE (Advanced) 2014]
Let $E_1(r)$, $E_2(r)$ and $E_3(r)$ be the respective electric fields at a distance r from a point charge Q, and infinitely long wire with constant linear charge density λ, and an infinite plane with uniform surface charge density σ. If $E_1(r_0) = E_2(r_0) = E_3(r_0)$ at a given distance r_0, then

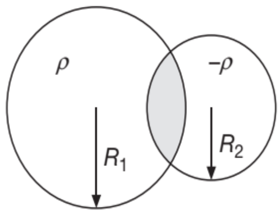
(A) $Q = 4\sigma\pi r_0^2$

(B) $r_0 = \frac{\lambda}{2\pi\sigma}$

(C) $E_1\left(\frac{r_0}{2}\right) = 2E_2\left(\frac{r_0}{2}\right)$

(D) $E_2\left(\frac{r_0}{2}\right) = 4E_3\left(\frac{r_0}{2}\right)$

5. [JEE (Advanced) 2013]
Two non-conducting spheres of radii R_1 and R_2 and carrying uniform volume charge densities $+\rho$ and $-\rho$, respectively, are placed such that they partially overlap, as shown in the figure. At all points in the overlapping region

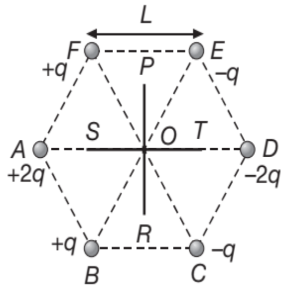


(A) the electrostatic field is zero
(B) the electrostatic potential is constant
(C) the electrostatic field is constant in magnitude
(D) the electrostatic field has same direction

6. [JEE (Advanced) 2013]
Two non-conducting solid spheres of radii R and $2R$, having uniform volume charge densities ρ_1 and ρ_2 respectively, touch each other. The net electric field at a distance $2R$ from the centre of the smaller sphere, along the line joining the centre of the spheres, is zero. The ratio $\frac{\rho_1}{\rho_2}$ can be

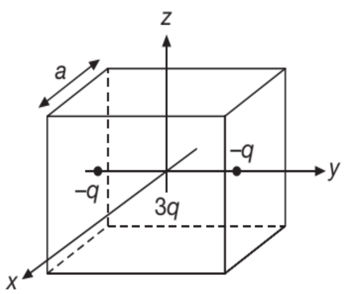
(A) –4 (B) $-\frac{32}{25}$
(C) $\frac{32}{25}$ (D) 4

7. [IIT-JEE 2012]
Six point charges are kept at the vertices of a regular hexagon of side L and centre O as shown in the figure. Given that $K = \frac{1}{4\pi\varepsilon_0}\frac{q}{L^2}$, which of the following statements(s) is(are) correct.



(A) The electric field at O is $6K$ along OD
(B) The potential at O is zero
(C) The potential at all points on the line PR is same
(D) The potential at all points on the line ST is same

8. [IIT-JEE 2012]
A cubical region of side a has its centre at the origin. It encloses three fixed point charges, $-q$ at $\left(0,\ -\frac{a}{4},\ 0\right)$, $+3q$ at $(0, 0, 0)$ and $-q$ at $\left(0,\ +\frac{a}{4},\ 0\right)$. Choose the correct option(s).



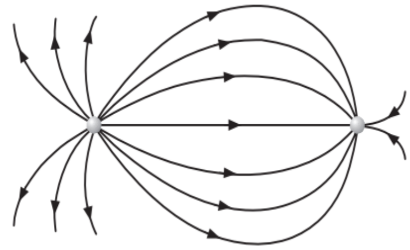
(A) The net electric flux crossing the plane $x=+\frac{a}{2}$ is equal to the net electric flux crossing the plane $x=-\frac{a}{2}$
(B) The net electric flux crossing the plane $y=+\frac{a}{2}$ is more than the net electric flux crossing the plane $y=-\frac{a}{2}$
(C) The net electric flux crossing the entire region is $\frac{q}{\varepsilon_0}$
(D) The net electric flux crossing the plane $z=+\frac{a}{2}$ is equal to the net electric flux crossing the plane $x=+\frac{a}{2}$

9. [IIT-JEE 2011]
Which of the following statement(s) is/are correct?
(A) If the electric field due to a point charge varies as $r^{-2.5}$ instead of r^{-2}, then the Gauss's law will still be valid
(B) The Gauss's law can be used to calculate the field distribution around an electric dipole
(C) If the electric field between two point charges is zero somewhere, then the sign of the two charges is the same
(D) The work done by the external force in moving a unit positive charge from point A at potential V_A to point B at potential V_B is $(V_B - V_A)$

10. [IIT-JEE 2011]
A spherical metal shell A of radius R_A and a solid metal sphere B of radius $R_B (< R_A)$ are kept far apart and each is given charge $+Q$. Now they are connected by a thin metal wire. Then

(A) $E_A^{\text{inside}} = 0$
(B) $Q_A > Q_B$
(C) $\frac{\sigma_A}{\sigma_B} = \frac{R_B}{R_A}$
(D) $E_A^{\text{on surface}} < E_B^{\text{on surface}}$

11. [IIT-JEE 2010]
A few electric field lines for a system of two charges Q_1 and Q_2 fixed at two different points on the x-axis are shown in the figure. These lines suggest that

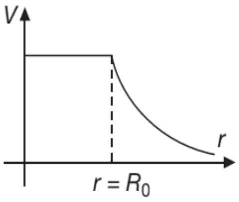


(A) $|Q_1| > |Q_2|$
(B) $|Q_1| < |Q_2|$
(C) at a finite distance to the left of Q_1 the electric field is zero
(D) at a finite distance to the right of Q_2 the electric field is zero

12. [IIT-JEE 2009]
Under the influence of the coulomb field of charge $+Q$, a charge $-q$ is moving around it in an elliptical orbit. Find out the correct statement(s).
(A) The angular momentum of the charge $-q$ is constant
(B) The linear momentum of the charge $-q$ is constant
(C) The angular velocity of the charge $-q$ is constant
(D) The linear speed of the charge $-q$ is constant

13. [IIT-JEE 2006]

For spherical symmetrical charge distribution, variation of electric potential with distance from centre is given in diagram. Given that $V = \frac{q}{4\pi\varepsilon_0 R_0}$ for $r \le R_0$ and $V = \frac{q}{4\pi\varepsilon_0 r}$ for $r \ge R_0$



Then which option(s) is/are correct

(A) Total charge within $2R_0$ is q.

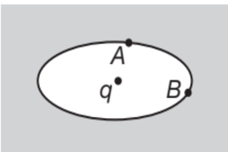
(B) Total electrostatic energy for $r \le R_0$ is zero.

(C) At $r = R_0$ electric field is discontinuous.

(D) There will be no charge anywhere except at $r = R_0$.

14. [IIT-JEE 1999]

An ellipsoidal cavity is carved within a perfect conductor (see figure). A positive charge q is placed at the centre of the cavity. The points A and B are on the cavity surface as shown in figure. Then,



(A) electric field near A in the cavity = electric field near B in the cavity.

(B) charge density at A = charge density at B.

(C) potential at A = potential at B.

(D) total electric flux through the surface of the cavity is $\frac{q}{\varepsilon_0}$.

15. [IIT-JEE 1998]

A non-conducting solid sphere of radius R is uniformly charged. The magnitude of the electric field due to the sphere at a distance r from its centre

(A) increases as r increases for $r < R$

(B) decreases as r increases for $0 < r < \infty$

(C) decreases as r increases for $R < r < \infty$

(D) is discontinuous at $r = R$

16. [IIT-JEE 1998]

A positively charged thin metal ring of radius R is fixed in the x-y plane with its centre at the origin O. A negatively charged particle P is released from rest at the point $(0, 0, z_0)$ where $z_0 > 0$. Then the motion of P is

(A) periodic for all values of z_0 satisfying $0 < z_0 < \infty$

(B) simple harmonic for all values of z_0 satisfying $0 < z_0 \le R$

(C) approximately simple harmonic provided $z_0 \ll R$

(D) such that P crosses O and continues to move along the negative z-axis towards $z = -\infty$

Reasoning Based Problems

This section contains Reasoning type questions, each having four choices (A), (B), (C) and (D) out of which ONLY ONE is correct. Each question contains STATEMENT 1 and STATEMENT 2. You have to mark your answer as

Bubble (A) If both statements are TRUE and STATEMENT 2 is the correct explanation of STATEMENT 1.

Bubble (B) If both statements are TRUE but STATEMENT 2 is not the correct explanation of STATEMENT 1.

Bubble (C) If STATEMENT 1 is TRUE and STATEMENT 2 is FALSE.

Bubble (D) If STATEMENT 1 is FALSE but STATEMENT 2 is TRUE.

1. [IIT-JEE 2008]

Statement-1: For practical purposes, the earth is used as a reference at zero potential in electrical circuits.

Statement-2: The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$.

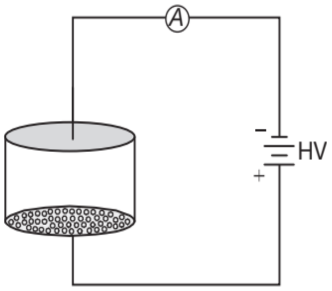
Linked Comprehension Type Problems

This section contains Linked Comprehension Type Questions or Paragraph based Questions. Each set consists of a Paragraph followed by questions. Each question has four choices (A), (B), (C) and (D), out of which only one is correct. (For the sake of competitiveness there may be a few questions that may have more than one correct options)

Comprehension 1

Consider an evacuated cylindrical chamber of height h having rigid conducting plates at the ends and an insulating curved surface as shown in the figure. A number of spherical balls made of a light weight and soft material and coated with a conducting material are placed on the bottom plate. The balls have a radius $r << h$. Now a high voltage source (HV) is connected across the conducting plates such that the bottom plate is at $+V_0$ and the top plate at $-V_0$.

Due to their conducting surface, the balls will get charged, will become equipotential with the plate and are repelled by it. The balls will eventually collide with the top plate, where the coefficient of restitution can be taken to be zero due to the soft nature of the material of the balls. The electric field in the chamber can be considered to be that of a parallel plate capacitor. Assume that there are no collisions between the balls and the interaction between them is negligible. (Ignore gravity)

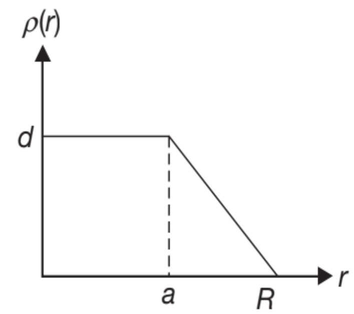


1. **[JEE (Advanced) 2016]**
   Which one of the following statements is correct?
   (A) The balls will bounce back to the bottom plate carrying the opposite charge they went up with
   (B) The balls will execute simple harmonic motion between the two plates
   (C) The balls will bounce back to the bottom plate carrying the same charge they went up with
   (D) The balls will stick to the top plate and remain there

2. **[JEE (Advanced) 2016]**
   The average current in the steady state registered by the ammeter in the circuit will be
   (A) proportional to $V_0^{1/2}$
   (B) proportional to V_0^2
   (C) proportional to the potential V_0
   (D) zero

Comprehension 2

The nuclear charge (Ze) is non-uniformly distributed within a nucleus of radius R. The charge density $\rho(r)$ (charge per unit volume) is depended only on the radial distance r from the centre of the nucleus as shown in figure. The electric field is only along the radial direction.



3. **[IIT-JEE 2008]**
   The electric field at $r = R$ is
   (A) independent of a
   (B) directly proportional to a
   (C) directly proportional to a^2
   (D) inversely proportional to a

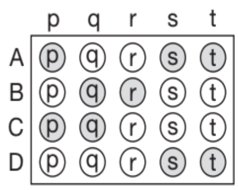
4. **[IIT-JEE 2008]**
   For $a = 0$, the value d (maximum value of ρ as shown in the figure) is
   (A) $\dfrac{3Ze^2}{4\pi R^3}$ (B) $\dfrac{3Ze}{\pi R^3}$
   (C) $\dfrac{4Ze}{3\pi R^3}$ (D) $\dfrac{Ze}{3\pi R^3}$

5. **[IIT-JEE 2008]**
   The electric field within the nucleus is generally observed to be linearly dependent on r. This implies
   (A) $a = 0$ (B) $a = \dfrac{R}{2}$
   (C) $a = R$ (D) $a = \dfrac{2R}{3}$

Matrix Match/Column Match Type Questions

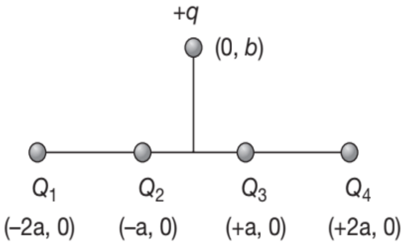
Each question in this section contains statements given in two columns, which have to be matched. The statements in **COLUMN-I** are labelled A, B, C and D, while the statements in **COLUMN-II** are labelled p, q, r, s (and t). Any given statement in **COLUMN-I** can have correct matching with **ONE OR MORE** statement(s) in **COLUMN-II**. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following examples:

If the correct matches are A → p, s and t; B → q and r; C → p and q; and D → s and t; then the correct darkening of bubbles will look like the following:



1. **[JEE (Advanced) 2014]**
   Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x-axis at $x = -2a$, $-a$, $+a$ and $+2a$ respectively. A positive charge q is placed on the positive y-axis at a distance $b > 0$. Four options of the signs of these charges are given in List I. The direction of the forces on the charge q is given in List II. Match

List I with List II and select the correct answer using the code given below the lists.



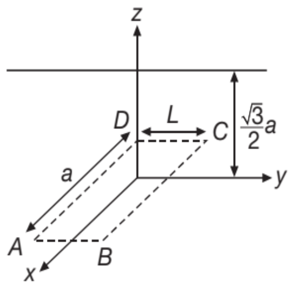
List I	List II
P. Q_1, Q_2, Q_3, Q_4 all positive	1. $+x$
Q. Q_1, Q_2 positive; Q_3, Q_4 negative	2. $-x$
R. Q_1, Q_4 positive; Q_2, Q_3 negative	3. $+y$
S. Q_1, Q_3 positive; Q_2, Q_4 negative	4. $-y$

Codes
(A) P-3, Q-1, R-4, S-2
(B) P-4, Q-2, R-3, S-1
(C) P-3, Q-1, R-2, S-4
(D) P-4, Q-2, R-1, S-3

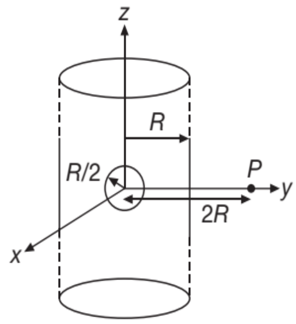
Integer/Numerical Answer Type Questions

In this section, the answer to each question is a numerical value obtained after doing series of calculations based on the data given in the question(s).

1. [JEE (Advanced) 2015]
An infinitely long uniform line charge distribution of charge per unit length λ lies parallel to the y-axis in the y-z plane at $z=\frac{\sqrt{3}}{2}a$ (see figure). If the magnitude of the flux of the electric field through the rectangular surface $ABCD$ lying in the x-y plane with its centre at the origin is $\frac{\lambda L}{n\varepsilon_0}$ ($\varepsilon_0 =$ permittivity of free space), then the value of n is



2. [IIT-JEE 2012]
An infinitely long solid cylinder of radius R has a uniform volume charge density ρ. It has a spherical cavity of radius $\frac{R}{2}$ with its centre on the axis of the cylinder, as shown in the figure. The magnitude of the electric field at the point P, which is at a distance $2R$ from the axis of the cylinder, is given by the expression $\frac{23\rho R}{16k\varepsilon_0}$. The value of k is



3. [IIT-JEE 2011]
Four point charges, each of $+q$, are rigidly fixed at the four corners of a square planar soap film of side a. The surface tension of the soap film is γ. The system of charges and planar film are in equilibrium, and $a=k\left(\frac{q^2}{\gamma}\right)^{\frac{1}{N}}$, where k is a constant. Then N is.

4. [IIT-JEE 2009]
A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = kr^a$, where k and a are constants and r is the distance from its centre. If the electric field at $r=\frac{R}{2}$ is $\frac{1}{8}$ times that at $r=R$, find the value of a.

ANSWER KEYS–TEST YOUR CONCEPTS AND PRACTICE EXERCISES

Test Your Concepts-I (Based on Coulomb's Law)

1. $K = 4$
2. 2×10^{16} N
3. $\dfrac{\lambda_0 L^2}{3}$
4. $\dfrac{\rho}{\rho-\sigma}$
5. 4×10^{42}, 10^{36}, 8.6×10^{-11} Ckg^{-1}
6. $9\times10^{-4}\left(6\hat{i}-8\hat{j}\right)$ N, 9×10^{-3} N
7. $\left(-21\hat{i}-28\hat{j}+84\hat{k}\right)\times10^{-5}$ N
8. 2.25 mm
9. 33×10^{-9} C
11. $2\pi\sqrt{\dfrac{4\pi\varepsilon_0 mL^3}{Qq}}$
12. $Q = 2L\sqrt{4\pi\varepsilon_0 k\left(L-L_0\right)}$
13. 3 μC and –1 μC
14. 38 μC or 12 μC
15. 4.1×10^{16} rads^{-1}, 1.5×10^{-16} s
17. $\left(\dfrac{4\pi\varepsilon_0 mgR^2}{\sqrt{3}}\right)^{\frac{1}{2}}$
18. $\mu = 0.18$
19. 1

Test Your Concepts-II (Based on Principle of Superposition)

1. $\dfrac{Q^2}{4\pi\varepsilon_0 a^2}\left[1+\dfrac{1}{\sqrt{2}}+\dfrac{1}{3\sqrt{3}}\right]\left(\hat{i}+\hat{j}+\hat{k}\right)$

   $\dfrac{\sqrt{3}Q^2}{4\pi\varepsilon_0 a^2}\left(1+\dfrac{1}{\sqrt{2}}+\dfrac{1}{3\sqrt{3}}\right)$ MAGNITUDE
2. $\dfrac{mg\pi\varepsilon_0}{h}\left(h^2+\dfrac{\ell^2}{2}\right)^{3/2}$
3. Radially outwards $\pm\dfrac{a}{\sqrt{2}}$, $\dfrac{Qq_0}{3\sqrt{3}\pi\varepsilon_0 a^2}$
4. $\dfrac{\sqrt{3}q^2}{4\pi\varepsilon_0 R^2}$
5. $\dfrac{q^2}{4\pi\varepsilon_0 a^2}$
6. (a) zero

   (b) $F = \dfrac{qQ}{4\pi\varepsilon_0 a^2}$
7. $2\pi\sqrt{2\sqrt{2}\left(\dfrac{Qq}{\pi\varepsilon_0 ma^3}\right)}$
8. $\dfrac{qQ}{4\pi\varepsilon_0 a^2}$
9. 10 N (parallel to AB)

Test Your Concepts-III (Based on Electric Field)

1. $\dfrac{q}{4\pi\varepsilon_0 a^2}$
2. $\dfrac{Qx}{8\pi^2\varepsilon_0 R^3}$
3. 0.2 N (due North), 0.5 N (due South)
4. $\dfrac{\sqrt{6}q}{4\pi\varepsilon_0 \ell^2}$
5. $E = \dfrac{mg}{q}$
7. (a) Q_2 is negative and Q_1 is positive.

   (b) $\left|\dfrac{Q_1}{Q_2}\right| = \left(\dfrac{\ell+a}{a}\right)^2$

   (c) $\dfrac{1}{\left(\dfrac{Q_1}{Q_2}\right)^{1/3}-1}$
8. $f = \lambda RE_0$ along positive x-axis.
9. (a) $\dfrac{2Qqx_0}{4\pi\varepsilon_0\left(R^2+x_0^2\right)^{3/2}}$ {towards the centre}

   (b) The motion of the bead is periodic between $\pm x_0$

(c) $m\frac{d^2x}{dt^2} = -\frac{2Qqx_0}{4\pi\varepsilon_0\left(R^2+x_0^2\right)^{3/2}}$ with $\frac{dx}{dt}=0$ at $x=\pm x_0$

and $x = x_0$ at $t=0$

(d) $x = x_0\cos(\omega t)$ and $v = -x_0\omega\sin(\omega t)$, where

$\omega = \sqrt{\frac{2Qq}{4\pi\varepsilon_0 mR^3}}$

(e) $\sqrt{\frac{4\pi^3\varepsilon_0 mR^3}{2Qq}}$

10. $2\pi\sqrt{\frac{mR\pi}{4qE}}$

11. $\frac{\lambda}{2\sqrt{2}\pi\varepsilon_0 R}$

12. $\frac{mgd}{q\sqrt{\ell^2-d^2}}$

13. $T = 2\pi\sqrt{\frac{\ell}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2-2g\left(\frac{qE}{m}\right)\cos\beta}}}$

14. $2\sqrt{\frac{2md}{qE}}$ not a simple harmonic motion but periodic in nature.

15. $\frac{\lambda\sqrt{2}}{4\pi\varepsilon_0\ell}\left(-2\hat{i}+14\hat{j}\right)$

16. $-\left(\frac{3\lambda}{\pi\varepsilon_0\ell}\right)\hat{j}$

17. (a) $q = \frac{mg}{(A\cot\theta+B)}$

(b) $T = \frac{mgA}{(A\cos\theta+B\sin\theta)}$

18. (a) $\frac{mv^2}{qR}$

(b) $\frac{mv^2}{\sqrt{2qR}}$

19. 5.25 μC

20. $\frac{1}{4\pi\varepsilon_0}\frac{Qx}{\left(R^2+x^2\right)^{\frac{3}{2}}}\hat{i}$

21. $\frac{\lambda_0}{8\pi\varepsilon_0 x_0}$

22. $E_x = \frac{\lambda}{4\pi\varepsilon_0 b}$ and $E_y = \frac{\lambda}{4\pi\varepsilon_0 b}$ with $E_{net} = \frac{\sqrt{2}\lambda}{4\pi\varepsilon_0 b}$

Test Your Concepts-IV (Based on Dipoles and Dipole Moment)

1. $2p\cos\frac{\theta}{2}$

2. $|\vec{p}| = \sqrt{17}qa$

at an angle $\tan^{-1}\left(\frac{1}{4}\right)$ with the z axis.

3. $T = 2\pi\sqrt{\frac{4\pi\varepsilon_0 I}{\sigma}}$

4. (a) $2\pi\sqrt{\frac{md}{2\lambda LE}}$

(b) (i) λLdE

(ii) $2\lambda LdE$

5. (a) $\pi\sqrt{\frac{m}{\lambda\sin^2\theta_0 E}}$

(b) $8\lambda R^2E\sin^2\theta_0$

6. (a) zero

(b) $-\frac{\lambda\vec{p}}{2\pi\varepsilon_0 r^2}$

(c) $\frac{\lambda\vec{p}}{2\pi\varepsilon_0 r^2}$

7. $\pi R^2\lambda_0$

8. (a) $\frac{qp}{4\pi\varepsilon_0 d^2}$

(b) $\frac{pq}{2\pi\varepsilon_0 d^3}\hat{i}$

Test Your Concepts-V (Based on Flux)

1. $\frac{q}{\varepsilon_0}\left(1-\frac{\ell}{\sqrt{R^2+\ell^2}}\right)$

2. $\frac{q}{\varepsilon_0}\left(\frac{L}{\sqrt{L^2+4R^2}}\right)$

3. $\dfrac{\lambda R}{2\varepsilon_0}$

4. $\left(1+\dfrac{\sqrt{3}}{2}\right)\dfrac{q}{2\varepsilon_0}$

5. $2HRE$

6. $E\left(2RH\cos\theta+\pi R^2\sin\theta\right)$

7. $\dfrac{ch\ell^2}{2}$

8. (a) 858 Nm^2C^{-1}
   (b) 0
   (c) 428.75 Nm^2C^{-1}

9. 180 kN m^2C^{-1}

10. 1 MNC^{-1}

11. (a) -2.34 kNm^2C^{-1}
    (b) $+2.34$ kNm^2C^{-1}
    (c) 0

12. $+1.87$ kNm^2C^{-1}

13. ERh

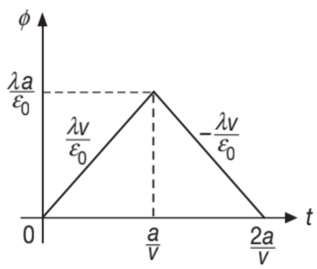
14. (a) $+\dfrac{Q}{2\varepsilon_0}$
    (b) $-\dfrac{Q}{2\varepsilon_0}$

Test Your Concepts-VI (Based on Gauss's Law)

1. zero

2. (a) $\dfrac{q}{\varepsilon_0}$
   (b) $\dfrac{q}{6\varepsilon_0}$

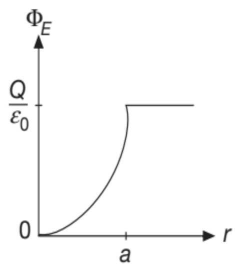
3. $4\pi\varepsilon_0\alpha R$

4.


5. $\dfrac{1}{3\varepsilon_0}kx^2$

6. (a) $\dfrac{q}{2\varepsilon_0}$
   (b) $\dfrac{q}{2\varepsilon_0}$

7. $\dfrac{Q-6q}{6\varepsilon_0}$, $q=\dfrac{Q}{6}$

8. (a) $\dfrac{Qr^3}{\varepsilon_0 a^3}$
   (b) $\dfrac{Q}{\varepsilon_0}$
   (c)


9. When $R\le d$, $\Phi_E=\dfrac{q_{enc}}{\varepsilon_0}=0$

   When $R>d$, $\Phi_E=\dfrac{2\lambda\sqrt{R^2-d^2}}{\varepsilon_0}$

10. (a) $\dfrac{\rho_0 R^5}{5\varepsilon_0 r^2}$
    (b) $\dfrac{\rho_0 r^3}{5\varepsilon_0}$

11. (a) $\begin{cases}\dfrac{\rho_0 d^3}{24\varepsilon_0}\hat{i} & \text{for } x>\dfrac{d}{2}\\ -\dfrac{\rho_0 d^3}{24\varepsilon_0}\hat{i} & \text{for } x<-\dfrac{d}{2}\end{cases}$

    (b) $\begin{cases}\dfrac{\rho_0 x^3}{3\varepsilon_0}\hat{i} & \text{for } x>0\\ -\dfrac{\rho_0 x^3}{3\varepsilon_0}\hat{i} & \text{for } x<0\end{cases}$

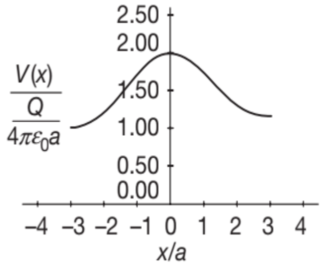
12. $\dfrac{\rho_0}{2\,\varepsilon_0}$

13. (b) $g=\left(\dfrac{GM_E}{R_E^3}\right)r$

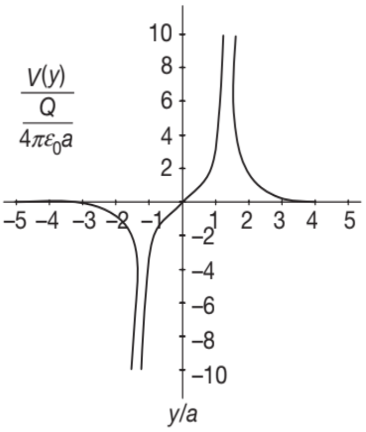
15. $\dfrac{\rho\vec{a}}{2\varepsilon_0}$

Test Your Concepts-VII
(Based on Electrostatic Potential and Energy)

1. (a)



(b)



2. -7.62×10^{-2} J

3. 1.35 MJ

4. 9×10^{3} V

5. (a) $\dfrac{2QE}{k}$

(b) $\dfrac{QE}{k}$

(c) $2\pi\sqrt{\dfrac{m}{k}}$

(d) $\dfrac{2(QE-\mu_k mg)}{k}$

6. 1.8×10^{4} V

7. 40 kV

8. $\dfrac{1}{4\pi\varepsilon_0}\dfrac{2Qqx^2}{a^3}$

9. 0.4 ms^{-1}

10. (a) 4.5×10^{-3} J

(b) -4.5×10^{-3} J

11. $-Q\left(\dfrac{a}{b}\right)$

12. (a) 6 m

(b) $-2\ \mu$C

13. $r = 0.5$ m

$r = 0.25$ m

14. $\dfrac{5}{9}\left(\dfrac{q^2}{4\pi\varepsilon_0 d}\right)$

15. $-0.553\dfrac{Q}{4\pi\varepsilon_0 R}$

16. $-q_0E_0a$

17. $\dfrac{\lambda}{4\pi\varepsilon_0}(\pi+2\log_e 3)$

18. $\left(\dfrac{\pi\sigma_0}{4\pi\varepsilon_0}\right)\left[R\sqrt{R^2+x^2}+x^2\log_e\left(\dfrac{x}{R+\sqrt{R^2+x^2}}\right)\right]$

19. (i) $\dfrac{2q}{4\pi\varepsilon_0}, \dfrac{q}{3\pi\varepsilon_0}$

(ii) $\dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{2q}{3}\right), \dfrac{q}{4\pi\varepsilon_0}\left[\dfrac{4q}{5}\right]$

20. 1 m

21. $\sqrt{\dfrac{7Qq}{4\pi\varepsilon_0 m\ell}}$

22. $5.824\left(\dfrac{1}{4\pi\varepsilon_o}\cdot\dfrac{q^2}{a}\right)$

23. $V\left(\dfrac{a}{3t}\right)^{1/3}$

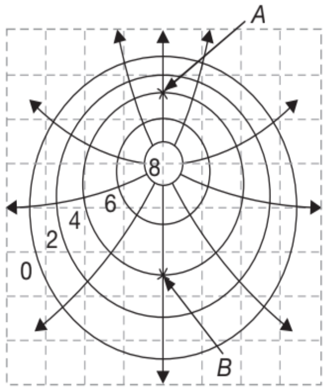
Test Your Concepts-VIII
(Based on Equipotential Surfaces)

1. $+260V$

2. (a) $E_A > E_B$

(b) 200 NC^{-1} downwards

(c)



Test Your Concepts-IX (Based on Relation Between Electrostatic Field and Potential)

1. $5\sqrt{2}\ \text{NC}^{-1}$

2. $E_x = 3E_0 a^3 xz\left(x^2+y^2+z^2\right)^{-\frac{5}{2}}$

   $E_y = 3E_0 a^3 yz\left(x^2+y^2+z^2\right)^{-\frac{5}{2}}$

   $E_z = E_0 + E_0 a^3\left(2z^2-x^2-y^2\right)\left(x^2+y^2+z^2\right)^{-\frac{5}{2}}$

3. $-2\hat{i}-3\hat{j}+\hat{k}$

4. 3 V

5. (a) 1 V (b) 1 V

6. (a) $-2a\left(x\hat{i}-y\hat{j}\right)$

   (b) $-ay\hat{i}-ax\hat{j}$

7. $\vec{E} = -\left(2ax\hat{i}+2ay\hat{j}+2bz\hat{k}\right)$

   $|\vec{E}| = 2\sqrt{a^2\left(x^2+y^2\right)+b^2z^2}$

   An ellipsoid of revolution with semi-axis

   $\sqrt{\frac{V}{a}}, \sqrt{\frac{V}{a}}, \sqrt{\frac{V}{b}}$.

8. $-\left(axy+byz\right)+C$

Test Your Concepts-X (Based on Motion of Charged Particles in Electric Field)

1. (a) 60 V

   (b) $4.6\times10^{6}\ \text{ms}^{-1}$

2. (a) $1.52\times10^{5}\ \text{ms}^{-1}$

   (b) $6.5\times10^{6}\ \text{ms}^{-1}$

3. (a) -4.5×10^{-5} J

   (b) $3.46\times10^{4}\ \text{ms}^{-1}$

4. 27.3 fm

5. $\sqrt{\left(1+\frac{1}{\sqrt{8}}\right)\frac{1}{4\pi\varepsilon_0}\frac{q^2}{mL}}$

6. $1.45\times10^{7}\ \text{ms}^{-1}$

7. $\sqrt{\frac{1}{4\pi\varepsilon_0}\frac{q^2}{3m\ell}}$

8. $\sqrt{\frac{Q^2}{2\pi\varepsilon_0 MR}}$

9. $mg\ell-\frac{1}{2}mu^2+\frac{q^2}{4\pi\varepsilon_0}\frac{1}{\sqrt{2}\ell}\left(1-\sqrt{2}\right)$

10. $\frac{Qq}{4\pi\varepsilon_0 mv_0^2}+\sqrt{\left(\frac{Qq}{4\pi\varepsilon_0 mv_0^2}\right)^2+\ell^2}$

11. $\left(\frac{ae}{2m\ell}\right)\left(\frac{6m\ell^2}{ae}\right)^{\frac{2}{3}}$

12. $v_1=\sqrt{\frac{Qqr_2}{2\pi\varepsilon_0 mr_1\left(r_1+r_2\right)}}$, $v_2=\sqrt{\frac{Qqr_1}{2\pi\varepsilon_0 mr_2\left(r_1+r_2\right)}}$

13. $\frac{e^2}{\pi\varepsilon_0 mv_0^2}$

Test Your Concepts-XI (Based on Conductors)

1. 2 N

2. $-\frac{1}{2\varepsilon_0}\left(\sigma_A+\sigma_B\right)$, $\frac{1}{2\varepsilon_0}\left(\sigma_A-\sigma_B\right)$, $\frac{1}{2\varepsilon_0}\left(\sigma_A+\sigma_B\right)$

   $E_I = E_{III} = 0$, $E_{II} = \frac{\sigma}{\varepsilon_0}$

3. $1.77\ \text{pCm}^{-3}$

4. (a) $496\ \text{nCm}^{-2}$

   (b) $992\ \text{nCm}^{-2}$

5. (a) $\dfrac{-q}{4\pi a^2}$

(b) $\dfrac{Q+q}{4\pi b^2}$

6. Charge on the outer surface of the sphere is $-Q$

Charge on the inner surface of the shell is $+Q$

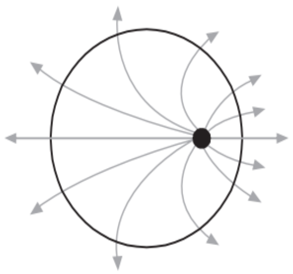
Charge on the outer surface of the shell is $+2Q$

Inside the sphere within the material of the shell, $E = 0$

Between the sphere and shell $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$

Outside the shell $E = \dfrac{2Q}{4\pi\varepsilon_0 r^2}$

7.



8. (a) For $r < a$, $E = \dfrac{\rho r}{3\varepsilon_0}$

For $a < r < b$ and $c < r$, $E = \dfrac{Q}{4\pi r^2 \varepsilon_0}$

For $b \le r \le c$, $E = 0$

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

9. (a) $+2Q$

(b) $\dfrac{2Q}{4\pi\varepsilon_0 r^2}$

(c) $E = 0$

(d) 0

(e) $+3Q$

(f) $\dfrac{3Q}{4\pi\varepsilon_0 r^2}$

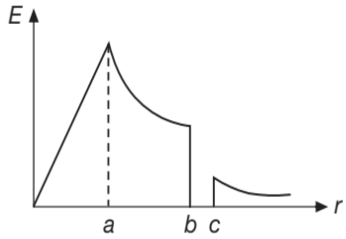
(g) $+3Q\left(\dfrac{r^3}{a^3}\right)$

(h) $\left(\dfrac{3Q}{4\pi\varepsilon_0 a^3}\right)r$

(i) $-3Q$

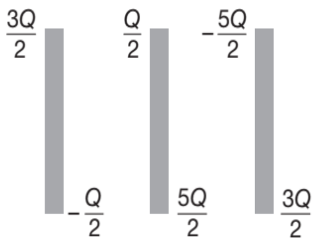
(j) $+2Q$

(k)



Test Your Concepts-XII (Based on Charge Distribution)

1.



3. $\left(\dfrac{Q}{2} - \varepsilon_0 AE\right), \left(\dfrac{Q}{2} + \varepsilon_0 AE\right)$

$-\varepsilon_0 AE$, $+\varepsilon_0 AE$

4. $E_{\text{left}} = E - \dfrac{Q}{2A\varepsilon_0}$, $E_{\text{right}} = E + \dfrac{Q}{2A\varepsilon_0}$

5. $AE\varepsilon_0$, $-AE\varepsilon_0$

6. $\dfrac{(\sigma_1 - \sigma_2)qa}{\sqrt{2}\,\varepsilon_0}$

Test Your Concepts-XIII (Based on Concept of Self and Interaction Energy)

1. $\dfrac{q^2}{8\pi\varepsilon_0}\left[\dfrac{1}{R_1} - \dfrac{1}{R_2}\right]$

2. $\dfrac{q\left(q_0 + \dfrac{q}{2}\right)}{4\pi\varepsilon_0}\left[\dfrac{1}{R_1} - \dfrac{1}{R_2}\right]$

3. $\dfrac{\sigma^2}{2\varepsilon_0}$

4. $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q^2}{2R}$

Single Correct Choice Type Questions

1. D	2. D	3. D	4. C	5. C	6. C	7. D	8. A	9. A	10. B
11. B	12. D	13. B	14. B	15. A	16. A	17. D	18. A	19. D	20. D
21. B	22. D	23. C	24. C	25. C	26. D	27. A	28. B	29. B	30. B
31. D	32. A	33. D	34. C	35. B	36. A	37. B	38. A	39. A	40. A
41. D	42. B	43. A	44. D	45. B	46. C	47. D	48. C	49. C	50. D
51. C	52. D	53. D	54. C	55. B	56. C	57. B	58. A	59. A	60. C
61. B	62. C	63. C	64. A	65. C	66. A	67. C	68. B	69. D	70. A
71. D	72. A	73. D	74. D	75. A	76. D	77. B	78. C	79. C	80. C
81. A	82. B	83. C	84. D	85. B	86. C	87. C	88. C	89. D	90. B
91. B	92. A	93. B	94. A	95. C	96. B	97. D	98. B	99. A	100. C
101. D	102. C	103. B	104. A	105. A	106. B	107. A	108. A	109. C	110. B
111. B	112. D	113. C	114. A	115. B	116. B	117. D	118. D	119. D	120. C
121. D	122. A	123. C	124. C	125. D	126. C	127. D	128. C	129. D	130. B
131. A	132. C	133. C	134. D	135. B	136. B	137. B	138. A	139. C	140. A
141. C	142. A	143. A	144. C	145. C	146. B	147. B	148. C	149. D	150. A
151. A	152. D	153. B	154. C	155. A	156. B	157. C	158. C	159. C	160. D
161. A	162. D	163. D	164. A	165. C	166. B	167. D	168. D	169. A	170. B
171. A	172. B	173. B	174. C	175. D	176. A	177. C	178. D	179. A	180. B
181. C	182. A	183. A	184. D	185. B	186. B	187. C			

Multiple Correct Choice Type Questions

1. A, C	2. A, C	3. A, B, C, D	4. A, C, D	5. C, D
6. A, C	7. D	8. D	9. C, D	10. A, B, C
11. A, C	12. A, B	13. A, B, C	14. B, D	15. D
16. B, D	17. A, B, C, D	18. A, B, C, D	19. B, D	20. A, D
21. D	22. A, B, C	23. A, C, D	24. A, B, C, D	25. A, C
26. B, C	27. A, B, D	28. B, C, D	29. A, C, D	30. A, B
31. A, B, C, D	32. C, D	33. A, B, C, D	34. A, B, C, D	35. A, B, C, D
36. A	37. D	38. A, D	39. A, D	40. B, D
41. A, D	42. A, C	43. B, D	44. A, B	45. A, C
46. A, C	47. A, B, C	48. B, D	49. A, C, D	50. A, B, C
51. A, D	52. A, B, D	53. A, C, D	54. B, C	55. A, B, C
56. B, C	57. B, C, D	58. A, B, C	59. B, C, D	60. A, D
61. A, C, D				

Reasoning Based Questions

1. C	2. B	3. D	4. C	5. A	6. D	7. D	8. A	9. B	10. A
11. D	12. C	13. B	14. B	15. B	16. D	17. D	18. A	19. A	20. A

Linked Comprehension Type Questions

1. C	2. B	3. C	4. A	5. D	6. D	7. B	8. C	9. C	10. C
11. B	12. D	13. B	14. C	15. A	16. A	17. B	18. D	19. C	20. A
21. B	22. C	23. D	24. C	25. D	26. B	27. A	28. C	29. B	30. A
31. D	32. D	33. C	34. B	35. A	36. D	37. A	38. B	39. C	40. A
41. B	42. D	43. D	44. C	45. C	46. B	47. C	48. C	49. B	50. C
51. A	52. D	53. B	54. C	55. B	56. A	57. C	58. B	59. D	60. A

Matrix Match/Column Match Type Questions

1. A → (p, q, r, s)	B → (p, q, s)	C → (p, q, s)	D → (p, q, r, s, t)
2. A → (p, r, s, t)	B → (p, q)	C → (p, q)	D → (p, r, s, t)
3. A → (p, r, s)	B → (p, q)	C → (p, q, r, s)	D → (p, r, s, t)
4. A → (q, r, s)	B → (p)	C → (p, q, r, s)	D → (p, q, r, s)
5. A → (q, r)	B → (s)	C → (t)	D → (p)
6. A → (s, t)	B → (p, q, r)	C → (q, r)	D → (p)
7. A → (r, s)	B → (p, r, s)	C → (q)	D → (t)
8. A → (q, s)	B → (p)	C → (t)	D → (r)
9. A → (s, t)	B → (q)	C → (p)	D → (r, s)
10. A → (q, t)	B → (s)	C → (p)	D → (r)
11. A → (r)	B → (s)	C → (p)	D → (p)
12. A → (s)	B → (r)	C → (q, t)	D → (p)
13. A → (p)	B → (q, s)	C → (p)	D → (q, r)
14. A → (r, s)	B → (r, s)	C → (p, s)	D → (p, s)
15. A → (p, s)	B → (q, s)	C → (q, s)	D → (s)
16. A → (p, r, s, t)	B → (p, r, s, t)	C → (p, q, r, s)	D → (q)
17. A → (q)	B → (r)	C → (s)	D → (p)
18. A → (s)	B → (r)	C → (p)	D → (q)
19. A → (r)	B → (q)	C → (p)	D → (s)
20. A → (s)	B → (r)	C → (p)	D → (q)
21. A → (p)	B → (r)	C → (p)	D → (p)
22. A → (q)	B → (r)	C → (p)	D → (s)

Integer/Numerical Answer Type Questions

1. 225	2. 33	3. 12	4. 2	5. 2275
6. 12	7. 72	8. 1	9. 60	10. 12

11. 52	**12.** 5	**13.** 1320	**14.** 24	**15.** 20
16. 2	**17.** 8	**18.** 33	**19.** (a) 55, (b) 2293	**20.** 9
21. 30	**22.** 7080	**23.** 154	**24.** 99	**25.** 50
26. 365	**27.** (a) 3, (b) 20, (c) 58	**28.** 100	**29.** 345, 16	**30.** 8
31. 35	**32.** 373	**33.** 100	**34.** 47	**35.** 2
36. 2	**37.** 700	**38.** 586	**39.** 758	**40.** 6
41. 1080, 155	**42.** 200	**43.** 5	**44.** 10	**45.** 30
46. 30	**47.** 2			

ARCHIVE: JEE MAIN

1. D	**2.** B	**3.** A	**4.** A	**5.** A	**6.** A	**7.** C	**8.** D	**9.** D	**10.** C
11. C	**12.** C	**13.** D	**14.** C	**15.** A	**16.** A	**17.** A	**18.** B	**19.** A	**20.** D
21. C	**22.** A	**23.** A	**24.** C	**25.** D	**26.** C	**27.** A	**28.** B	**29.** B	**30.** A
31. A	**32.** D	**33.** C	**34.** A	**35.** A	**36.** B	**37.** B	**38.** C	**39.** C, D	**40.** A
41. C	**42.** C	**43.** B	**44.** D	**45.** C	**46.** A	**47.** D	**48.** B	**49.** B	**50.** A
51. D	**52.** D	**53.** C	**54.** D	**55.** A	**56.** D	**57.** C	**58.** D		

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Single Correct Choice Type Problems

1. D	**2.** D	**3.** C	**4.** C	**5.** D	**6.** C	**7.** C	**8.** A	**9.** D	**10.** B
11. A	**12.** C	**13.** C	**14.** D	**15.** B	**16.** A	**17.** B	**18.** C	**19.** D	**20.** C
21. B	**22.** B	**23.** C	**24.** B	**25.** B	**26.** D	**27.** B	**28.** A	**29.** D	**30.** C
31. B	**32.** A	**33.** B	**34.** D	**35.** B	**36.** C				

Multiple Correct Choice Type Problems

1. A, B, C	**2.** A, C	**3.** A, D	**4.** C	**5.** C, D
6. B, D	**7.** A, B, C	**8.** A, C	**9.** C, D	**10.** A, B, C, D
11. A, D	**12.** A	**13.** A, B, C, D	**14.** C, D	**15.** A, C
16. A, C				

Reasoning Based Problems

1. B

Linked Comprehension Type Problems

1. A	**2.** B	**3.** A	**4.** B	**5.** C

Matrix Match/Column Match Type Questions

1. A

Integer/Numerical Answer Type Questions

1. 6	**2.** 6	**3.** 3	**4.** 2