CHAPTER 11

Electrostatics

1. 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) $\frac{\sigma}{\varepsilon_0}\left[\frac{b^2-c^2}{c}+a\right]$ *(2018)*

2. A parallel plate capacitor of capacitance 90 pF is connected to a battery of emf 20 V. If a dielectric material of dielectric constant $K = \frac{5}{3}$ is inserted between the plates, the magnitude of the induced charge will be

(a) 1.2 nC (b) 0.3 nC (c) 2.4 nC (d) 0.9 nC

(2018)

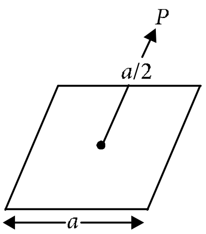
3. A charge Q is placed at a distance $a/2$ above the centre of the square surface of edge a as shown in the figure. The electric flux through the square surface is

(a) $\frac{Q}{3\varepsilon_0}$

(b) $\frac{Q}{6\varepsilon_0}$

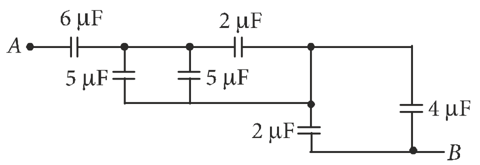
(c) $\frac{Q}{\varepsilon_0}$

(d) $\frac{Q}{2\varepsilon_0}$



(Online 2018)

4. The equivalent capacitance between A and B in the circuit given below, is



(a) 5.4 μF (b) 4.9 μF (c) 3.6 μF (d) 2.4 μF

(Online 2018)

5. 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) $\frac{\rho_0 R^3}{12\varepsilon_0 r^2}$ (b) $\frac{4\rho_0 R^3}{3\varepsilon_0 r^2}$ (c) $\frac{3\rho_0 R^3}{4\varepsilon_0 r^2}$ (d) $\frac{\rho_0 R^3}{\varepsilon_0 r^2}$

(Online 2018)

6. A parallel plate capacitor with area 200 cm^2 and separation between the plates 1.5 cm, is connected across a battery of emf V. If the force of attraction between the plates is 25×10^{-6} N, the value of V is approximately

$\left(\varepsilon_0 = 8.85\times10^{-12}\,\frac{C^2}{N\,m^2}\right)$

(a) 150 V (b) 100 V (c) 250 V (d) 300 V

(Online 2018)

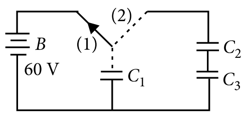
7. A capacitor C_1 = 1.0 μF is charged up to a voltage V = 60 V by connecting it to battery B through switch (1). Now C_1 is disconnected from battery and connected to a circuit consisting of two uncharged capacitors C_2 = 3.0 F and C_3 = 6.0 F through switch (2), as shown in the figure. The sum of final charges on C_2 and C_3 is

(a) 20 C

(b) 40 C

(c) 36 C

(d) 54 C



(Online 2018)

8. 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

(Online 2018)

9. 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 $\frac{6}{7}\ \omega^7 W^7 - \frac{6}{7}\frac{{}^7b^7}{\quad}3$

(b) The new equilibrium position is at a distance $\frac{7\ b}{\quad}$ from $x = 0$.

(c) The new equilibrium position is at a distance $\frac{b}{7}$ from $x = 0$.

(d) The total energy of the system is $\frac{6}{7}\ \omega^7 W^7 + \frac{6}{7}\frac{{}^7b^7}{7}3$

(Online 2018)

10. 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° *(2017)*

11. A capacitance of 2 μF is required in an electrical circuit across a potential difference of 1.0 kV. A large number of 1 μF capacitors are available which can withstand a potential difference of not more than 300 V. The minimum number of capacitors required to achieve this is

(a) 2 (b) 16 (c) 24 (d) 32 *(2017)*

12. The energy stored in the electric field produced by a metal sphere is 4.5 J. If the sphere contains 4 μC charge, its radius will be

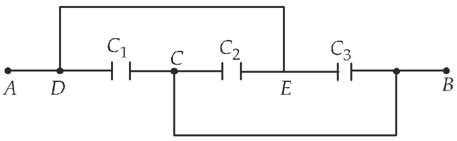
[Take : $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N – m^2/C^2]

(a) 32 mm (b) 20 mm
(c) 16 mm (d) 28 mm *(Online 2017)*

13. 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 589.0 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 *(Online 2017)*

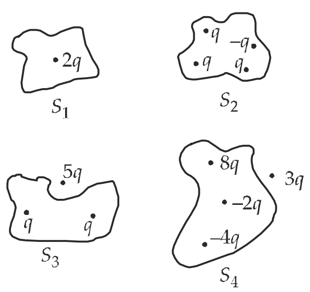
14. A combination of parallel plate capacitors is maintained at a certain potential difference.



When a 3 mm thick slab is introduced between all the plates, in order to maintain the same potential difference, the distance between the plates is increased by 2.4 mm. Find the dielectric constant of the slab.

(a) 6 (b) 5 (c) 4 (d) 3 *(Online 2017)*

15. Four closed surfaces and corresponding charge distributions are shown below.

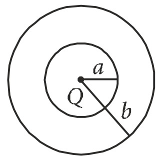


Let the respective electric fluxes through the surfaces be Φ_1, Φ_2, Φ_3 and Φ_4. Then

(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) $\Phi_1 < \Phi_2 = \Phi_3 > \Phi_4$ *(Online 2017)*

16. The region between two concentric spheres of radii 'a' and 'b', respectively (see figure), has volume charge density $\rho = \frac{W}{}1$ where A is a constant and r is the distance from the centre.

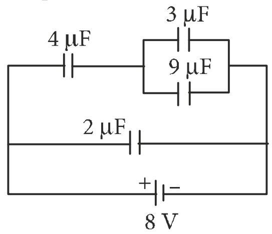
At the centre of the spheres is a point charge Q. The value of A such that the electric field in the region between the spheres will be constant, is



(a) $\frac{n}{7\pi\ \ 7}$ (b) $\frac{Q}{2\pi(b^2 - a^2)}$

(c) $\frac{2Q}{\pi(a^2 - b^2)}$ (d) $\frac{7n}{\pi\ \ 7}$ *(2016)*

17. A combination of capacitors is set up as shown in the figure. The magnitude of the electric field due to a point charge Q (having a charge equal to the sum of the charges on the 4 μF and 9 μF capacitors), at a point distant 30 m from it, would equal



(a) 240 N/C (b) 360 N/C
(c) 420 N/C (d) 480 N/C *(2016)*

18. Three capacitors each of 4 μF are to be connected in such a way that the effective capacitance is 6 μF. This can be done by connecting them

(a) all in series (b) all in parallel
(c) two in parallel and one in series
(d) two in series and one in parallel *(Online 2016)*

19. The potential (in volts) of a charge distribution is given by

$V(z) = 30 - 5z^2$ for $|z| \leq 1$ m
$V(z) = 35 - 10|z|$for $|z| \geq 1$ 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 $|z| \leq 1$ m and $\rho_0 = 0$ elsewhere
(c) $\rho_0 = 20\ \varepsilon_0$ for $|z| \leq 1$ m and $\rho_0 = 0$ elsewhere
(d) $\rho_0 = 40\ \varepsilon_0$ in the entire region *(Online 2016)*

20. Within a spherical charge distribution of charge density $\rho(r)$, N equipotential surfaces of potential V_0, $V_0 + \Delta V$, V_0

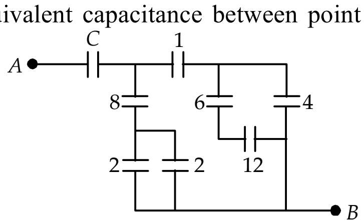
$+ 2\Delta V, ...V_0 + N\Delta V\,(\Delta V > 0)$, are drawn and have increasing radii r_0, r_1, r_2, ...r_N, respectively. If the difference in the radii of the surfaces is constant for all values of V_0 and ΔV then

(a) $\rho(r)$ = constant (b) $\rho(r) \propto \frac{1}{r^2}$

(c) $\rho(r) \propto \frac{1}{r}$ (d) $\rho(r) \propto r$

(Online 2016)

21. Figure shows a network of capacitors where the numbers indicates capacitances in micro Farad. The value of capacitance C if the equivalent capacitance between point A and B is to be 1 μF is

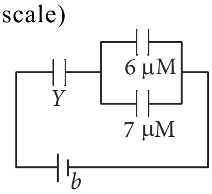


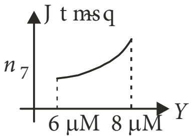
(a) $\frac{32}{23}$ μF

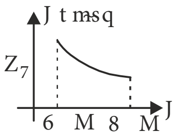
(b) $\frac{31}{23}$ μF

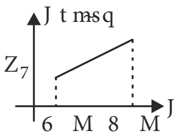
(c) $\frac{33}{23}$ μF (d) $\frac{34}{23}$ μF *(Online 2016)*

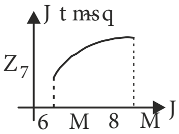
22. In the given circuit, charge Q_2 on the 2 μF capacitor changes as C is varied from 1 μF to 3 μF. Q_2 as a function of 'C' is given properly by (figures are drawn schematically and are not to scale)



(a) 

(b) 

(c) 

(d) 

(2015)

23. 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 $\frac{8s\,5}{7}1\frac{:s\,5}{9}1\frac{3s\,5}{9}1$ mzp $\frac{s\,5}{9}$ have radius R_1, R_2, R_3 and R_4 respectively. Then

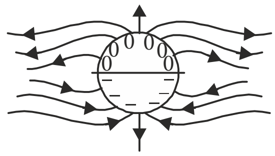
(a) $R_1 = 0$ and $R_2 < (R_4 - R_3)$

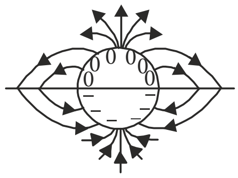
(b) $2R < R_4$

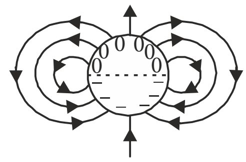
(c) $R_1 = 0$ and $R_2 > (R_4 - R_3)$

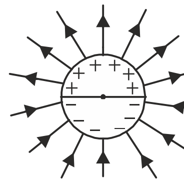
(d) $R_1 \neq 0$ and $(R_2 - R_1) > (R_4 - R_3)$ *(2015)*

24. A long cylindrical shell carries positive surface charge σ in the upper half and negative surface charge –σ 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) 

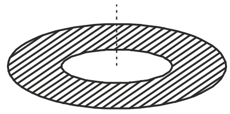
(b) 

(c) 

(d) 

(2015)

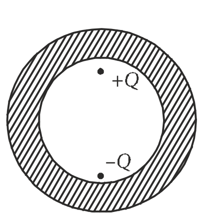
25. A thin disc of radius $b = 2a$ has a concentric hole of radius a in it (see figure). It carries uniform surface charge σ on it. If the electric field on its axis at height h ($h << a$) from its centre is given as Ch then value of C is



(a) $\frac{\sigma}{\varepsilon_5}$ (b) $\frac{\sigma}{7\ \varepsilon_5}$ (c) $\frac{\sigma}{9\ \varepsilon_5}$ (d) $\frac{\sigma}{=\ \varepsilon_5}$

(Online 2015)

26. 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) $\sigma_1 \neq 0, Q_1 \neq 0\ ;\ \sigma_2 \neq 0, Q_2 \neq 0$

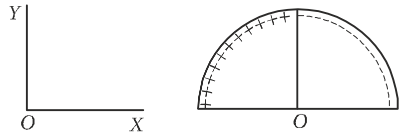
(b) $\sigma_1 \neq 0, Q_1 = 0\ ;\ \sigma_2 \neq 0, Q_2 = 0$

(c) $\sigma_1 \neq 0, Q_1 = 0\ ;\ \sigma_2 = 0, Q_2 = 0$

(d) $\sigma_1 = 0, Q_1 = 0\ ;\ \sigma_2 = 0, Q_2 = 0$

(Online 2015)

27. A wire, of length L(= 20 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) $-:5\times 65^{8}$ V4J $.^{j}$ (b) $-7:\times 65^{8}$ V4J $.^{j}$

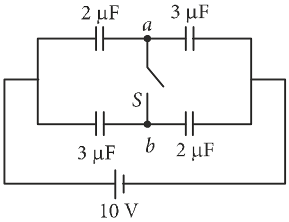
(c) $-7:\times 65^{8}$ V4J $.^{j}$ (d) $-:5\times 65^{8}$ V4J $.^{j}$

(Online 2015)

28. An electric field $\vec{E} = (30\hat{i} + 30\hat{j})\,\mathrm{NC}^{-1}$ 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 J (b) –120 J
(c) –140 J (d) –110 J *(Online 2015)*

29. In figure is shown a system of four capacitors connected across a 10 V battery. Charge that will flow from switch S when it is closed is



(a) 5 μC from b to a (b) 20 μC from a to b
(c) 5 μC from a to b (d) zero *(Online 2015)*

30. A parallel plate capacitor is made of two circular plates separated by a distance of 5 mm and with a dielectric of dielectric constant 2.2 between them. When the electric field in the dielectric is 3×10^4 V/m, the charge density of the positive plate will be close to
(a) 6×10^4 C/m^2 (b) 6×10^{-7} C/m^2
(c) 3×10^{-7} C/m^2 (d) 3×10^4 C/m^2
(2014)

31. 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) 80 J (b) 120 J (c) –120 J (d) – 80 J
(2014)

32. Two capacitors C_1 and C_2 are charged to 120 V and 200 V respectively. It is found that by connecting them together the potential on each one can be made zero. Then
(a) $9C_1 = 4C_2$ (b) $5C_1 = 3C_2$
(c) $3C_1 = 5C_2$ (d) $3C_1 + 5C_2 = 0$ *(2013)*

33. 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 $(y << a)$ along the y-axis, the net force acting on the particle is proportional to
(a) $-\frac{1}{y}$ (b) y (c) $-y$ (d) $\frac{1}{y}$
(2013)

34. 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) $\frac{Q\ln 2}{4\pi\epsilon_0 L}$ (b) $\frac{Q\ln 2}{8\pi\epsilon_0 L}$
(c) $\frac{3Q}{4\pi\epsilon_0 L}$ (d) $\frac{Q}{4\pi\epsilon_0 L\ln 2}$ *(2013)*

35. 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.

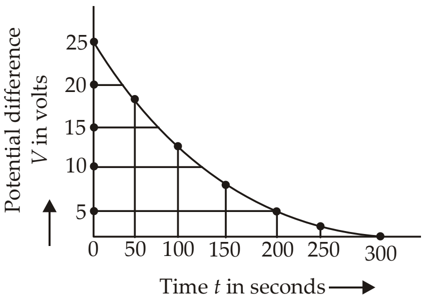
An insulating solid sphere of radius R has a uniformly positive charge density ρ. As a result of this uniform charge distribution there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point outside the sphere. The electric potential at infinity 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 $\frac{\rho r}{3\varepsilon_0}$.

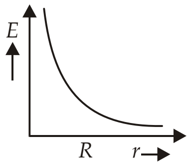
(a) Statement 1 is true, Statement 2 is false.
(b) Statement 1 is false, Statement 2 is true.
(c) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.
(d) Statement 1 is true, Statement 2 is true; Statement 2 is not the correct explanation of Statement 1.
(2012)

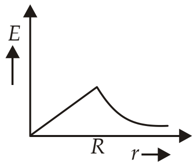
36.

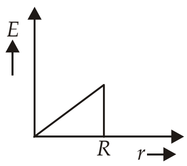


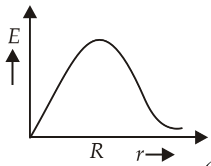
The figure shows an experimental plot for discharging of a capacitor in an R-C circuit. The time constant t of this circuit lies between
(a) 0 and 50 sec (b) 50 sec and 100 sec
(c) 100 sec and 150 sec (d) 150 sec and 200 sec
(2012)

37. 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)


(2012)

38. Two identical charged spheres suspended from a common point by two massless strings of length l are initially a distance $d(d << l)$ 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) $v \propto x$ *(2011)*

39. 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) $-6a\varepsilon_0$ *(2011)*

40. 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

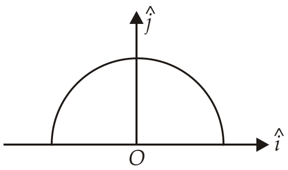
(a) 1 (b) 4 (c) 3 (d) 2 *(2010)*

41. 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) $\frac{4\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$ *(2010)*

42. 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) $-\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$ *(2010)*

43. 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 Q/q equals

(a) $-2\sqrt{2}$ (b) -1 (c) 1 (d) $-\frac{1}{\sqrt{2}}$ *(2009)*

44. 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) -9.60×10^{-17} J (b) 9.60×10^{-17} J
(c) -2.24×10^{-16} J (d) 2.24×10^{-16} J *(2009)*

45. 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) $\frac{Qr_1^2}{3\pi\varepsilon_0 R^4}$ *(2009)*

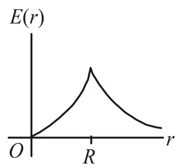
46. This question contains Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.

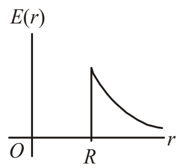
Statement-1: For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.

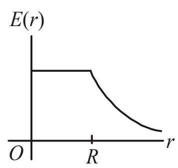
Statement-2: The net work done by a conservative force on an object moving along a closed loop is zero.

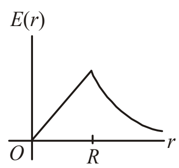
(a) Statement-1 is true, Statement-2 is false
(b) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
(c) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.
(d) Statement-1 is false, Statement-2 is true. *(2009)*

47. A thin spherical shell of radius R has charge Q spread uniformly over its surface. Which of the following graphs most closely represents the electric field $E(r)$ produced by the shell in the range $0 \le r < \infty$, where r is the distance from the centre of the shell?

(a) 

(b) 

(c) 

(d) 

(2008)

48. A parallel plate capacitor with air between the plates has a capacitance of 9 pF. The separation between its plates is d. The space between the plates is now filled with two dielectrics. One of the dielectrics has dielectric constant $k_1 = 3$ and thickness $d/3$ while the other one has dielectric constant $k_2 = 6$ and thickness $2d/3$. Capacitance of the capacitor is now

(a) 20.25 pF (b) 1.8 pF
(c) 45 pF (d) 40.5 pF *(2008)*

49. A parallel plate condenser with a dielectric of dielectric constant K between the plates has a capacity C and is charged to a potential V volt. The dielectric slab is slowly removed from between the plates and then reinserted. The net work done by the system in this process is

(a) zero (b) $\frac{1}{2}(K-1)\,CV^2$

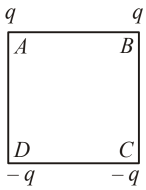
(c) $\frac{CV^2(K-1)}{K}$ (d) $(K-1)\,CV^2$ *(2007)*

50. The potential at a point x (measured in μm) due to some charges situated on the x-axis is given by

$$V(x) = 20/(x^2 - 4) \text{ volt}$$

The electric field E at $x = 4$ μm is given by
(a) (10/9) volt/μm and in the +ve x direction
(b) (5/3) volt/μm and in the –ve x direction
(c) (5/3) volt/μm and in the +ve x direction
(d) (10/9) volt/μm in the –ve x direction *(2007)*

51. Charges are placed on the vertices of a square as shown. Let $\vec{E}$ be the electric field and V the potential at the centre. If the charges on A and B are interchanged with those on D and C respectively, then



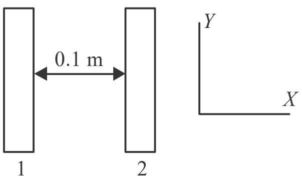
(a) $\vec{E}$ changes, V remains unchanged
(b) $\vec{E}$ remains unchanged, V changes
(c) both $\vec{E}$ and V change
(d) $\vec{E}$ and V remain unchanged *(2007)*

52. A battery is used to charge a parallel plate capacitor till the potential difference between the plates becomes equal to the electromotive force of the battery. The ratio of the energy stored in the capacitor and the work done by the battery will be
(a) 1/2 (b) 1 (c) 2 (d) 1/4 *(2007)*

53. An electric charge 10^{-3} μC is placed at the origin (0, 0) of $X - Y$ co-ordinate system. Two points A and B are situated at $(\sqrt{2}, \sqrt{2})$ and (2,0) respectively. The potential difference between the points A and B will be
(a) 4.5 volt (b) 9 volt (c) zero (d) 2 volt *(2007)*

54. Two spherical conductors A and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surface of spheres A and B is
(a) 1 : 4 (b) 4 : 1 (c) 1 : 2 (d) 2 : 1 *(2006)*

55. Two insulating plates are both uniformaly charged in such a way that the potential difference between them is $V_2 - V_1 = 20$ V. (*i.e.* plate 2 is at a higher potential).



The plates are separated by $d = 0.1$ m and can be treated as infinitely large. An electron is released from rest on the inner surface of plate 1. What is its speed when it hits plate 2?
($e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg)
(a) 32×10^{-19} m/s (b) 2.65×10^{6} m/s
(c) 7.02×10^{12} m/s (d) 1.87×10^{6} m/s *(2006)*

56. A electric dipole is placed at an angle of 30º to a non-uniform electric field. The dipole will experience
(a) a torque only
(b) a translational force only in the direction of the field
(c) a translational force only in a direction normal to the direction of the field
(d) a torque as well as a translational force. *(2006)*

57. A fully charged capacitor has a capacitance C. It is discharged through a small coil of resistance wire embedded in a thermally insulated block of specific heat capacity s and mass m. If the temperature of the block is raised by ΔT, the potential difference V across the capacitance is

(a) $\frac{ms\Delta T}{C}$ (b) $\sqrt{\frac{2ms\Delta T}{C}}$

(c) $\sqrt{\frac{2mC\Delta T}{s}}$ (d) $\frac{mC\Delta T}{s}$ *(2005)*

58. A parallel plate capacitor is made by stacking n equally spaced plates connected alternatively. If the capacitance between any two adjacent plates is C then the resultant capacitance is
(a) C (b) nC
(c) $(n-1)C$ (d) $(n+1)C$ *(2005)*

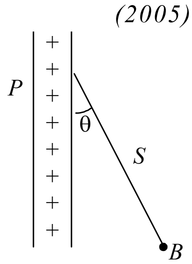
59. Two thin wire rings each having a radius R are placed at a distance d apart with their axes coinciding. The charges on the two rings are $+Q$ and $-Q$. The potential difference between the centers of the two rings is

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

(c) $\frac{QR}{4\pi\varepsilon_0 d^2}$ (d) $\frac{Q}{2\pi\varepsilon_0}\left[\frac{1}{R} - \frac{1}{\sqrt{R^2 + d^2}}\right]$ *(2005)*

60. Two point charges $+8q$ and $-2q$ are located at $x = 0$ and $x = L$ respectively. The location of a point on the x axis at which the net electric field due to these two point charges is zero is
(a) $8L$ (b) $4L$ (c) $2L$ (d) $L/4$ *(2005)*

61. A charged ball B hangs from a silk thread S, which makes an angle θ with a large charged conducting sheet P, as shown in the figure. The surface charge density σ of the sheet is proportional to



(a) sinθ (b) tanθ
(c) cosθ (d) cotθ *(2005)*

62. Four charges equal to $-Q$ are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium the value of q is

(a) $-\frac{Q}{4}(1+2\sqrt{2})$ (b) $\frac{Q}{4}(1+2\sqrt{2})$

(c) $-\frac{Q}{2}(1+2\sqrt{2})$ (d) $\frac{Q}{2}(1+2\sqrt{2})$ *(2004)*

63. A charged particle q is shot towards another charged particle Q which is fixed, with a speed v. It approaches Q upto a closest distance r and then returns. If q were given a speed $2v$, the closest distances of approach would be

(a) r (b) $2r$

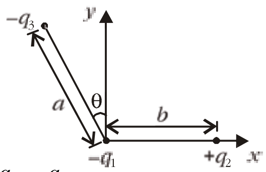
(c) $r/2$ (d) $r/4$ *(2004)*

64. Two spherical conductors B and C having equal radii and carrying equal charges in them repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that of B but uncharged is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is

(a) $F/4$ (b) $3F/4$

(c) $F/8$ (d) $3F/8$ *(2004)*

65. Three charges $-q_1$, $+q_2$ and $-q_3$ are placed as shown in the figure. The x-component of the force on $-q_1$ is proportional to



(a) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\cos\theta$

(b) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\sin\theta$

(c) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\cos\theta$ (d) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\sin\theta$ *(2003)*

66. The work done in placing a charge of 8×10^{-18} coulomb on a condenser of capacity 100 micro-farad is

(a) 16×10^{-32} joule (b) 3.1×10^{-26} joule

(c) 4×10^{-10} joule (d) 32×10^{-32} joule *(2003)*

67. A thin spherical conducting shell of radius R has a charge q. Another charge Q is placed at the centre of the shell. The electrostatic potential at a point P at a distance $R/2$ from the centre of the shell is

(a) $\frac{2Q}{4\pi\varepsilon_0 R}$ (b) $\frac{2Q}{4\pi\varepsilon_0 R}-\frac{2q}{4\pi\varepsilon_0 R}$

(c) $\frac{2Q}{4\pi\varepsilon_0 R}+\frac{q}{4\pi\varepsilon_0 R}$ (d) $\frac{(q+Q)}{4\pi\varepsilon_0}\frac{2}{R}$ *(2003)*

68. A sheet of aluminium foil of negligible thickness is introduced between the plates of a capacitor. The capacitance of the capacitor

(a) decreases (b) remains unchanged

(c) becomes infinite (d) increases *(2003)*

69. If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2, the electric charge inside the surface will be

(a) $(\phi_2 - \phi_1)\varepsilon_0$ (b) $(\phi_1 + \phi_2)/\varepsilon_0$

(c) $(\phi_2 - \phi_1)/\varepsilon_0$ (d) $(\phi_1 + \phi_2)\varepsilon_0$ *(2003)*

70. Capacitance (in F) of a spherical conductor with radius 1 m is

(a) 1.1×10^{-10} (b) 10^{-6}

(c) 9×10^{-9} (d) 10^{-3} *(2002)*

71. If a charge q is placed at the centre of the line joining two equal charges Q such that the system is in equilibrium then the value of q is

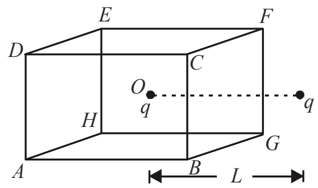
(a) $Q/2$ (b) $-Q/2$ (c) $Q/4$ (d) $-Q/4$ *(2002)*

72. If there are n capacitors in parallel connected to V volt source, then the energy stored is equal to

(a) CV (b) $\frac{1}{2}nCV^2$

(c) CV^2 (d) $\frac{1}{2n}CV^2$ *(2002)*

73. A charged particle q is placed at the centre O of cube of length L ($ABCDEFGH$). Another same charge q is placed at a distance L from O. Then the electric flux through $ABCD$ is



(a) $q/4\pi\varepsilon_0 L$ (b) zero

(c) $q/2\pi\varepsilon_0 L$ (d) $q/3\pi\varepsilon_0 L$ *(2002)*

74. On moving a charge of 20 coulomb by 2 cm, 2 J of work is done, then the potential difference between the points is

(a) 0.1 V (b) 8 V

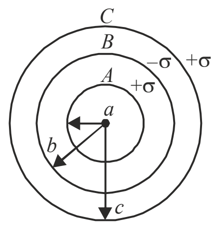
(c) 2 V (d) 0.5 V *(2002)*

ANSWER KEY

1. (b)	**2.** (a)	**3.** (b)	**4.** (d)	**5.** (a)	**6.** (c)	**7.** (b)	**8.** (a)	**9.** (d)	**10.** (c)	**11.** (d)	**12.** (c)
13. (a)	**14.** (b)	**15.** (a)	**16.** (a)	**17.** (c)	**18.** (d)	**19.** (b)	**20.** (c)	**21.** (a)	**22.** (d)	**23.** (a,b)	**24.** (c)
25. (c)	**26.** (c)	**27.** (b)	**28.** (d*)	**29.** (a)	**30.** (b)	**31.** (d*)	**32.** (c)	**33.** (b)	**34.** (a)	**35.** (b)	**36.** (c)
37. (b)	**38.** (a)	**39.** (d)	**40.** (d)	**41.** (c)	**42.** (d)	**43.** (a)	**44.** (d)	**45.** (c)	**46.** (c)	**47.** (b)	**48.** (d)
49. (a)	**50.** (a)	**51.** (a)	**52.** (a)	**53.** (c)	**54.** (d)	**55.** (b)	**56.** (d)	**57.** (b)	**58.** (c)	**59.** (d)	**60.** (c)
61. (b)	**62.** (b)	**63.** (d)	**64.** (d)	**65.** (b)	**66.** (d)	**67.** (c)	**68.** (b)	**69.** (a)	**70.** (a)	**71.** (d)	**72.** (b)
73. (*)	**74.** (a)										

Explanations

1. **(b):** The potential of the shell B,



$$V_B = \frac{kq_A}{r_b} + \frac{kq_B}{r_b} + \frac{kq_C}{r_c}$$

$$= \frac{4\pi}{4\pi\varepsilon_0}\left[\frac{\sigma \times a^2}{b} - \frac{\sigma \times b^2}{b} + \frac{\sigma \times c^2}{c}\right]$$

$$= \frac{\sigma}{\varepsilon_0}\left[\frac{a^2 - b^2}{b} + c\right]$$

2. **(a):** Induced charge on dielectric, $Q_{\text{ind}} = Q\left(1 - \frac{1}{K}\right)$

Final charge on capacitor, $Q = K\,C_0V$

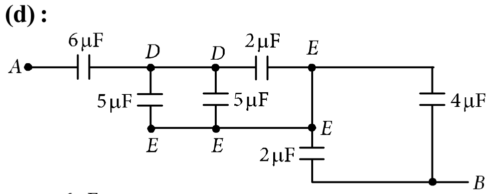
$$= \frac{5}{3} \times 90 \times 10^{-12} \times 20 = 3 \times 10^{-9}\text{C} = 3\text{ nC}$$

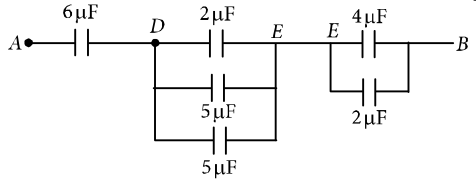
$$\therefore\ Q_{\text{ind}} = 3\left(1 - \frac{3}{5}\right) = 3 \times \frac{2}{5} = 1.2\text{ nC}$$

3. **(b):** Charged particle can be considered at the centre of a cube of side a, and given surface represents its one side.

So, flux through each face $\phi = \dfrac{Q}{6\varepsilon_0}$

4. **(d):**





$$\frac{1}{C_{\text{eq}}} = \frac{1}{6} + \frac{1}{12} + \frac{1}{6} = \frac{5}{12} \Rightarrow C_{\text{eq}} = \frac{12}{5} = 2.4\,\mu\text{F}$$

5. **(a):** Charge density on given solid ball varies as

$$\rho = \rho_0\left(1 - \frac{r}{R}\right);\ 0 \le r \le R$$

Electric field outside the ball is given by

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \qquad \text{...(i)}$$

Now, $dq = \rho dV = \rho(4\pi r^2)dr$ $\therefore$ $q = \int dq = \int_0^R \rho_0\left(1 - \frac{r}{R}\right)(4\pi r^2)\,dr$

$$= (4\pi\rho_0)\left[\frac{r^3}{3} - \frac{1}{R} \times \frac{r^4}{4}\right]_0^R = 4\pi\rho_0\left(\frac{R^3}{3} - \frac{R^3}{4}\right)$$

$$q = 4\pi\rho_0\left(\frac{R^3}{12}\right) \qquad \text{... (ii)}$$

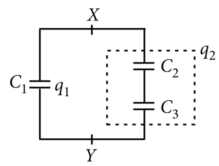
From eqns. (i) and (ii), $E = \dfrac{\rho_0 R^3}{12\varepsilon_0 r^2}$

6. **(c):** Here, $A = 200\text{ cm}^2 = 2 \times 10^{-2}\text{ m}^2$
$d = 1.5\text{ cm} = 1.5 \times 10^{-2}\text{ m}$, $F = 25 \times 10^{-6}\text{ N}$, $V = ?$

$$F = \frac{1}{2}(\varepsilon_0 A)\frac{V^2}{d^2} \quad \text{or} \quad V = d\sqrt{\frac{2F}{\varepsilon_0 A}}$$

$$V = 1.5 \times 10^{-2}\sqrt{\frac{2 \times 25 \times 10^{-6}}{8.85 \times 10^{-12} \times 2 \times 10^{-2}}} = 1.5 \times 10^2\sqrt{\frac{25}{8.85}} \approx 250\text{ V}$$

7. **(b):** Initially, potential on C_1, $V_0 = 60$ V
$q_0 = C_1V_0 = 1(\mu\text{F})\ (60\text{ V}) = 60\ \mu\text{C}$
Finally circuit can be modify as shown here.
Charge starts flowing from C_1 till the potential difference across C_1 is equal to potential difference across series combination of C_2 and C_3.



i.e., $\dfrac{q_1}{C_1} = \dfrac{q_2}{\dfrac{C_2C_3}{C_2 + C_3}}$

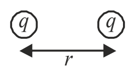
$C_1 = 1\ \mu\text{F}$, $C_2 = 3\ \mu\text{F}$, $C_3 = 6\ \mu\text{F}$

$$\therefore\ q_1 = \frac{q_2}{2} \quad \text{or} \quad q_2 = 2q_1 \qquad \text{...(i)}$$

Also, $q_1 + q_2 = 60$ ...(ii)
From equations (i) and (ii),
$q_1 = 20\ \mu\text{C}$ and $q_2 = 40\ \mu\text{C}$

8. **(a):** Initially force between spheres A and B, $F = \dfrac{kq^2}{r^2}$

When A and C are touched, charge on both will be $\dfrac{q}{2}$. Again C is touched with B the charge on B is given by



$$q_B = \frac{\frac{q}{2} + q}{2} = \frac{3q}{4}$$

Required force between spheres A and B is given by

$$F' = \frac{kq_Aq_B}{r^2} = \frac{k \times \frac{q}{2} \times \frac{3q}{4}}{r^2} = \frac{3}{8}\frac{kq^2}{r^2} = \frac{3}{8}F$$

9. **(d):** Equilibrium position will shift to a point where resultant force is zero.

$$kx_{\text{eq}} = qE \Rightarrow x_{\text{eq}} = \frac{qE}{k}$$

Total energy of the system,

$$E = \frac{1}{2}m\omega^2A^2 + \frac{1}{2}\frac{q^2E^2}{k}$$

10. **(c):** Dipole moment of fixed dipole can be written as

$$\vec{p} = p\cos\theta\,\hat{i} + p\sin\theta\,\hat{j}$$

For electric field $\vec{E}_1 = E\,\hat{i}$
Torque on the dipole

$$\vec{T}_1 = (\vec{p}\times\vec{E}_1)\ \vec{T}_1 = (p\cos\theta\,\hat{i} + p\sin\theta\,\hat{j})\times(E\,\hat{i})$$

$$\vec{T}_1 = pE\sin\theta\,(-\hat{k}) \qquad \ldots\text{(i)}$$

Now for $\vec{E}_2 = \sqrt{3}E_1\hat{j} = \sqrt{3}E\,\hat{j}$
In this case, torque on the dipole

$$\vec{T}_2 = (p\cos\theta\,\hat{i} + p\sin\theta\,\hat{j})\times(\sqrt{3}E\,\hat{j})$$

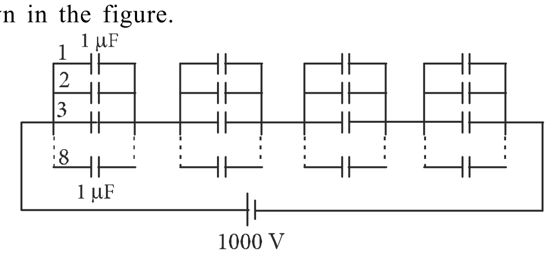
$$\vec{T}_2 = \sqrt{3}pE\cos\theta\,(\hat{k}) \qquad \ldots\text{(ii)}$$

Now given, $\vec{T}_2 = -\vec{T}_1$

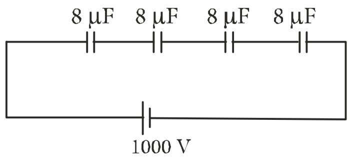
$$\sqrt{3}pE\cos\theta\,(\hat{k}) = -pE\sin\theta\,(-\hat{k})\quad \sqrt{3}\cos\theta = \sin\theta$$

or $\dfrac{\sin\theta}{\cos\theta} = \sqrt{3}\,;\ \tan\theta = \sqrt{3} \ \Rightarrow\ \theta = 60°$

11. (d): We have to get equivalent capacitance of 2 μF across 1000 V using 1 μF capacitor.
To obtain the desired capacitance, 8 capacitors of 1 μF should be connected in parallel with four such branches in series as shown in the figure.



|||



$$\frac{1}{C_{eq}} = \frac{1}{8}+\frac{1}{8}+\frac{1}{8}+\frac{1}{8} = \frac{4}{8} = \frac{1}{2}\quad \therefore\ C_{eq} = 2\ \mu\text{F}$$

$\therefore$ Total number of capacitor used = 8 × 4 = 32

12. (c): The energy stored in the electric field produced by a metal sphere = 4.5 J

$$\Rightarrow\ \frac{Q^2}{2C} = 4.5 \text{ or } C = \frac{Q^2}{2\times 4.5} \qquad \ldots\text{(i)}$$

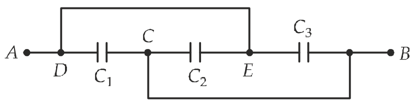
Capacitance of spherical conductor = $4\pi\varepsilon_0 R$

$$C = 4\pi\varepsilon_0 R = \frac{Q^2}{2\times 4.5} \qquad \text{[from eqn. (i)]}$$

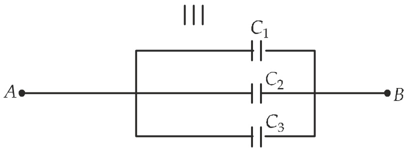
$$R = \frac{1}{4\pi\varepsilon_0}\times\frac{(4\times10^{-6})^2}{2\times4.5} = 9\times10^9\times\frac{16}{9}\times10^{-12} = 16\times10^{-3}\text{ m} = 16\text{ mm}$$

13. (a)

14. (b):



|||



As the capacitors are in parallel combination so they have equal potential differences.

$$C_{\text{before}} = \frac{\varepsilon_0 A}{3} \qquad \ldots\text{(i)}$$

$$C_{\text{after}} = \frac{\dfrac{k\varepsilon_0 A}{3}\cdot\dfrac{\varepsilon_0 A}{2.4}}{\dfrac{k\varepsilon_0 A}{3}+\dfrac{\varepsilon_0 A}{2.4}} \qquad \ldots\text{(ii)}$$

From (i) and (ii), $\dfrac{\varepsilon_0 A}{3} = \dfrac{\dfrac{k\varepsilon_0 A}{3}\cdot\dfrac{\varepsilon_0 A}{2.4}}{k\dfrac{\varepsilon_0 A}{3}+\dfrac{\varepsilon_0 A}{2.4}}$

or 3 k = 2.4 k + 3 or 0.6 k = 3 $\Rightarrow k = \dfrac{3}{0.6}$ or k = 5

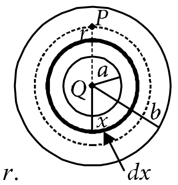
15. (a): $\phi = \dfrac{q_{\text{enclosed}}}{\varepsilon_0}$

For $S_1, \phi_1 = \dfrac{2q}{\varepsilon_0}$; for $S_2, \phi_2 = \dfrac{3q-q}{\varepsilon_0} = \dfrac{2q}{\varepsilon_0}$

For $S_3, \phi_3 = \dfrac{q+q}{\varepsilon_0} = \dfrac{2q}{\varepsilon_0}$; for $S_4, \phi_4 = \dfrac{8q-6q}{\varepsilon_0} = \dfrac{2q}{\varepsilon_0}$

Hence, $\phi_1 = \phi_2 = \phi_3 = \phi_4 = \dfrac{2q}{\varepsilon_0}$

16. (a): Using Gauss's theorem for radius r



$$\int \vec{b}\cdot \vec{\ } = \frac{6}{\varepsilon_5}\text{-}n + \ .$$

$$\Rightarrow\ b\times 9\pi\ ^7 = \frac{6}{\varepsilon_5}\text{-}n + \ . \qquad \ldots\text{(i)}$$

q = charge enclosed between $x = a$ and $x = r$.

$$= \int \frac{W}{\ }9\pi\ ^7 \quad = 9\pi W\!\int \quad = 9\pi W\left[\frac{\ ^7}{7}\right] \quad = 7\pi W\ ^7 - \ ^7.$$

Putting the value of q in equation (i), we get

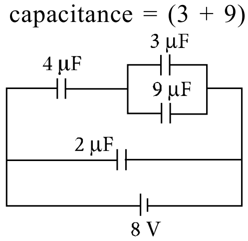
$$b\times 9\pi\ ^7 = \frac{6}{\varepsilon_5}\left[n + 7\pi W\ ^7 - \ ^7.\right]$$

$$b = \frac{6}{9\pi\varepsilon_5}\left[\frac{n}{\ ^7} + 7\pi W - \frac{7\pi W\ ^7}{\ ^7}\right]$$

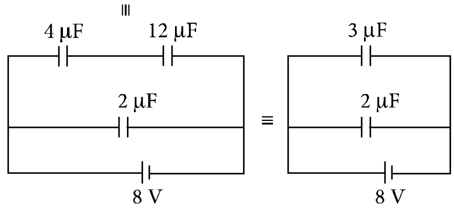
E will be constant if it is independent of r

$$\therefore\ \frac{n}{\ ^7} = \frac{7\pi W\ ^7}{\ ^7}\quad \{\sim\ W = \frac{n}{7\pi\ ^7}$$

17. (c): 3 μF and 9 μF are in parallel combination so their equivalent capacitance = (3 + 9) = 12 μF



|||



Now, 4 μF and 12 μF are in series so their equivalent capacitance $= \dfrac{9\times67}{6;} = 8\ \mu\text{M}$

Charge on 3 μF = (3 μF) × (8 V) = 24 μC

∴ charge on 4 μF and 12 μF are same (24 μC) as they are in series.

Charge on $> \mu\text{M} = \left(\dfrac{>}{>+8}\right)\times 79\ \mu\text{J} = 6 = \mu\text{J}$

Required charge Q = Charge on 4 μF + Charge on 9 μF

Q = (24 + 18) μC = 42 μC

Required electric field, $b = \dfrac{6}{9\pi\varepsilon_5}\times\dfrac{n}{7}$

$$b = >\times65^{>}\times\frac{97\times65^{-;}}{\text{-}85.^{7}} = 975\ \text{V J}^{-6}$$

18. (d): $\text{a}: \dfrac{1}{C_a} = \dfrac{1}{4}+\dfrac{1}{4}+\dfrac{1}{4} = \dfrac{3}{4} \Rightarrow C_a = \dfrac{4}{3}\mu\text{F}$

b : C_b = 4 + 4 + 4 = 12 μF

$\text{c}: C_c = \dfrac{(4+4)\times4}{(4+4)+4} = \dfrac{8}{3}\mu\text{F}$

$\text{d}: C_d = \dfrac{4\times4}{4+4}+4 = 6\ \mu\text{F}$

19. (b): Given : $V(z) = \begin{cases} 30-5z^2 \text{ for } |z| \le 1\text{ m} \\ 35-10|z| \text{ for } |z| \ge 1\text{ m}\end{cases}$

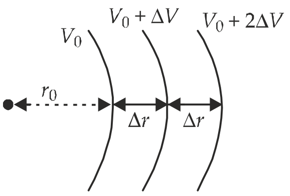
Now, $E(z) = -\dfrac{dV}{dz} = 10z$ for $|z| \le 1\text{m}$ = 10 for $|z| \ge 1$ m

∴ The source is an infinite non-conducting thick plate of thickness 2 m.

$\therefore\ E = \dfrac{q}{2A\varepsilon_0} \Rightarrow \dfrac{q}{At} = \rho_0 = \dfrac{2E}{t}\varepsilon_0 = \dfrac{2\times10}{2}\varepsilon_0 = 10\,\varepsilon_0$

20. (c): We know

$E = -\dfrac{dV}{dr}$



Here, ΔV and Δr are same for any pair of surfaces.

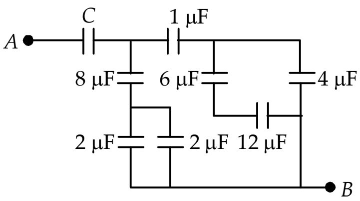
So, E = constant

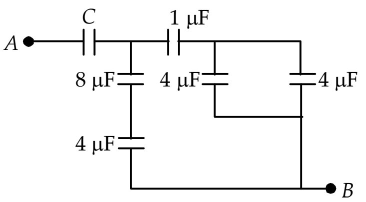
Now, electric field inside the spherical charge distribution,

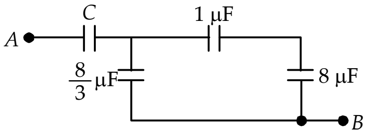
$E = \dfrac{\rho}{3\varepsilon_0}r$

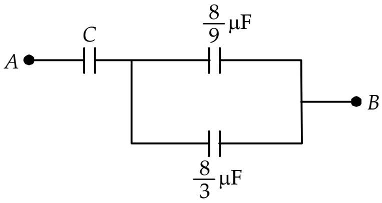
E would be constant if ρr = constant ⇒ $\rho(r) \propto \dfrac{1}{r}$

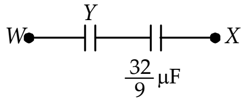
21. (a):











Here C_{AB} = 1 μF = $\dfrac{C\times\frac{32}{9}}{C+\frac{32}{9}}$ ⇒ $C+\dfrac{32}{9} = \dfrac{32C}{9}$

⇒ $\dfrac{23}{9}C = \dfrac{32}{9}$ ∴ $C = \dfrac{32}{23}\mu\text{F}$

22. (d): Equivalent capacitance of the circuit

$\dfrac{6}{Y} = \dfrac{6}{Y}+\dfrac{6}{\text{-}6+7.} = \dfrac{6}{Y}+\dfrac{6}{8}\ \{\sim Y\ = \dfrac{8Y}{Y+8}$

Total charge in the circuit, $Q = C_{eq}E = \dfrac{8Yb}{Y+8}$

Charge on the 2 μF capacitor,

$n_7 = \dfrac{7}{8}n = \dfrac{7}{8}\times\dfrac{8Yb}{\text{-}Y+8.} = \dfrac{7Yb}{Y+8}\ \{\sim n_7 = \dfrac{7b}{6+\frac{8}{Y}}$

mz p $\dfrac{n_7}{Y} = \dfrac{;b}{\text{-}Y+8.^7}$

As C increases, Q_2 increases and slope of $Q_2 - C$ curve decreases. Hence, graph (d) represents the correct variation.

23. (a, b) : Potential on the surface of charged solid sphere

$$s_5 = \frac{h}{o}$$

Spherical surface of radius r inside this sphere will be equipotential surface with potential $V(> V_0)$

$V = \dfrac{h}{7o^8}(3R^2-r^2) = \dfrac{s_5}{7o^7}(3R^2-r^2)$

∴ For $V = \dfrac{8s_5}{7}1\ \dfrac{8s_5}{7} = \dfrac{s_5}{7o^7}(3R^2-R_1^2) \Rightarrow R_1 = 0$

For $V = \dfrac{:s_5}{9}1\ \dfrac{:s_5}{9} = \dfrac{s_5}{7o^7}(3R^2-R_2^2) \Rightarrow R_2 = \dfrac{o}{\sqrt{7}}$

Spherical surface of radius r' outside this sphere will be equipotential surface with potential $V'(< V_0)$

$V' = \dfrac{h}{,} = \dfrac{s_5 o}{,}$ ∴ For $V' = \dfrac{8s_5}{9}\text{B}\ \dfrac{8s_5}{9} = \dfrac{s_5 o}{o_8} \Rightarrow R_3 = \dfrac{9o}{8}$

For $V' = \frac{s\ 5}{9} B \frac{s\ 5}{9} = \frac{s\ 5 o}{o_9} \Rightarrow R_4 = 4R$

Here $R_1 = 0$, $R_2 < (R_4 - R_3)$, $2R < R_4$ and $(R_2 - R_1) < (R_4 - R_3)$

So, options (a) and (b) are correct.

24. (c): The electric field lines around the cylinder must resemble that due to a dipole.

25. (c): Electric field due to complete disc ($R = 2a$),

$$E_1 = \frac{\sigma}{7\varepsilon_5}\left[6 - \frac{}{\sqrt{o^7 + \ ^7}}\right] = \frac{\sigma}{7\varepsilon_5}\left[6 - \frac{}{\sqrt{9\ ^7 + \ ^7}}\right]$$

$$= \frac{\sigma}{7\varepsilon_5}\left[6 - \frac{}{7}\right] \qquad \because \quad << \ .$$

Electric field due to disc ($R = a$),

$$E_2 = \frac{\sigma}{7\varepsilon_5}\left[6 - -\right]$$

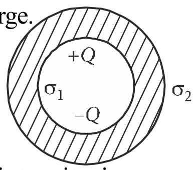
Hence, electric field due to given disc,

$$E = E_1 - E_2 = \frac{\sigma}{9\varepsilon_5} \quad \therefore\ Y = \frac{\sigma}{9\ \varepsilon_5}$$

26. (c) : On outer surface there will be no charge.

So $Q_2 = \sigma_2 = 0$

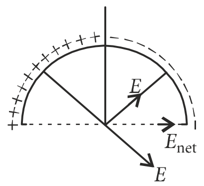
On inner surface total charge will be zero but charge distribution will be there so $Q_1 = 0$ and $\sigma_1 \neq 0$



27. (b): Due to quarter ring electric field intensity is

$$b = \frac{7\ \lambda}{o} \text{-ɪz} \frac{\theta}{7}$$

So, due to each quarter section, field intensity is



$$b = \frac{2\ \lambda}{o} \times \text{-ɪz} \frac{\pi}{9} = \frac{\sqrt{7}\ \lambda}{o} \qquad \left(\because\ \theta = \frac{\pi}{7}\right)$$

$$]\{\ \vec{b}_{\text{Vqµ}} = \sqrt{7}b\ ^{j} = \frac{\sqrt{7}\sqrt{7}\ \lambda}{o}^{j} = \frac{7\ \lambda}{o}^{j} = \frac{7\ \text{-}7n\,.}{\pi o^7}^{j} = \frac{9n}{9\pi^7\varepsilon_5 o^7}^{j}$$

$Q = 10^3\varepsilon_0$ C

$\pi R = L = 20$ cm

$$\text{-}\{1\vec{b}_{\text{Vqµ}} = \frac{9 \times 65^8 \varepsilon_5}{9\pi^7\varepsilon_5 o^7}^{j} = \frac{9 \times 65^8}{9 i^7}^{j}$$

$$= \frac{9 \times 65^8}{9 \times \text{-}53\!7.^7}^{j} = \frac{9 \times 65^8}{9 \times 53\!59}^{j} = 7\!: \times 65^8 \text{ V J}^{-6j}$$

28. (d*) : Change in potential in an electric field is given by, $dV = -\vec{b} \cdot \vec{\ }$

$$\int s = -\int \vec{b} \cdot \vec{\ } \qquad \text{Here, } \vec{\ } = \ ^{j} + \ ^{j}$$

$$\vec{b} = (7\!:\ \hat{\ } + 85\ \hat{\ }.\ \text{VJ}^{-6} \quad \therefore \int s = -\int \text{-}7\!:^{j} + 85^{j}.\cdot\text{-}\ \ ^{j} + \ ^{j}.$$

$$\int_5^s s = -\left\{\int_5^7 7\!: \ + \int_5^7 85\ \right\}$$

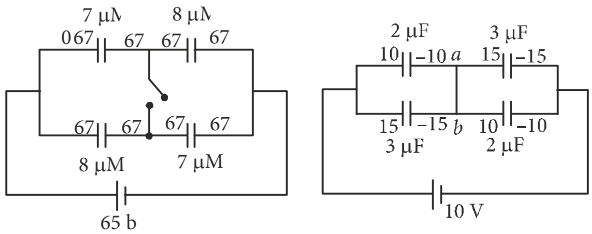
$$s\ -5 = -\left\{7\!:\text{g } i_5^7 + 85\text{g } i_5^7\right\}$$

$V = -[25 \times 2 + 30 \times 2]$ V = −110 V = −110 J/C

(*) Unit given in the options is incorrect.

29. (a): For upper and lower links, $Y = \frac{;}{:}$ µM

$\therefore Q_{\text{upper}} = Q_{\text{lower}} = 12$ µC



On closing switch, charge on 2 µF is 10 µC and that on 3 µF is 15 µC

At a, $q_i = -12 + 12 = 0$

$q_f = 15 - 10 = 5$ µC $\therefore$ Charge 5 µC flows from b to a.

30. (b): Here, $K = 2.2$. $E = 3 \times 10^4$ V m^{-1}

Electric field between the parallel plate capacitor with dielectric,

$$E = \frac{\sigma}{K\varepsilon_0} \Rightarrow \sigma = K\varepsilon_0 E = 2.2 \times 8.85 \times 10^{-12} \times 3 \times 10^4$$

$$\approx 6 \times 10^{-7} \text{ C m}^{-2}$$

31. (d*) : Here, $\vec{E} = 30x^2\,\hat{i}$,

V_O is at $x = 0$ and V_A is at $x = 2$ m. As, $dV = -\vec{E} \cdot d\vec{x}$

$$\text{or} \int_{V_O}^{V_A} dV = -\int_0^2 30x^2 dx \qquad \Rightarrow [V]_{V_O}^{V_A} = -\left[30 \times \frac{x^3}{3}\right]_0^2$$

$$\Rightarrow \quad (V_A - V_O) = -30 \times \frac{8}{3} = -80 \text{ J C}^{-1}$$

* Given unit in options is wrong.

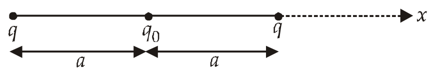
32. (c): For potential to be made zero, after connection

$120C_1 = 200C_2$

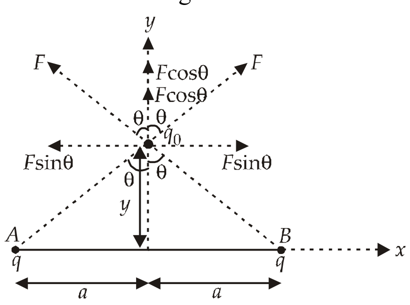
$6C_1 = 10C_2$

$3C_1 = 5C_2$

33. (b): The situation is as shown in the figure.



When a particle of mass m and charge $q_0\left(=\frac{q}{2}\right)$ placed at the origin is given a small displacement along the y-axis, then the situation is shown in the figure.



By symmetry, the components of forces on the particle of charge q_0 due to charges at A and B along x-axis will cancel each other where along y-axis will add up.

$\therefore$ The net force acting on the particle is

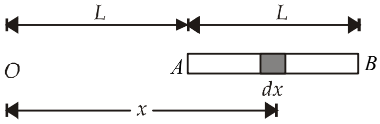
$$F_{\text{net}} = 2F\cos\theta = 2\frac{1}{4\pi\epsilon_0}\frac{qq_0}{(\sqrt{y^2+a^2})^2}\frac{y}{\sqrt{(y^2+a^2)}}$$

$$= \frac{2}{4\pi\epsilon_0}\frac{q\left(\frac{q}{2}\right)}{(y^2+a^2)}\frac{y}{\sqrt{(y^2+a^2)}} \quad \left(\because q_0 = \frac{q}{2}\text{ (Given)}\right)$$

$$= \frac{1}{4\pi\epsilon_0}\frac{q^2 y}{(y^2+a^2)^{3/2}}$$

As $y << a$ $\therefore$ $F_{\text{net}} = \frac{1}{4\pi\epsilon_0}\frac{q^2 y}{a^3}$ or $F_{\text{net}} \propto y$

34. (a) :



Consider a small element of length dx at a distance x from O.

Charge on the element, $dQ = \frac{Q}{L}dx$

Potential at O due to the element is

$$dV = \frac{1}{4\pi\epsilon_0}\frac{dQ}{x} = \frac{1}{4\pi\epsilon_0}\frac{Q}{Lx}dx$$

Potential at O due to the rod is

$$V = \int dV = \int_L^{2L}\frac{1}{4\pi\epsilon_0}\frac{Q}{Lx}dx = \frac{1}{4\pi\epsilon_0}\frac{Q}{L}[\ln x]_L^{2L} = \frac{Q\ln 2}{4\pi\epsilon_0 L}$$

35. (b) : Potential at the centre of the sphere, $V_C = \frac{R^2\rho}{2\varepsilon_0}$

Potential at the surface of the sphere, $V_S = \frac{1}{3}\frac{R^2\rho}{\varepsilon_0}$

When a charge q is taken from the centre to the surface, the change in potential energy is

$$\Delta U = (V_C - V_S)q = \left(\frac{R^2\rho}{2\varepsilon_0} - \frac{1}{3}\frac{R^2\rho}{\varepsilon_0}\right)q = \frac{1}{6}\frac{R^2\rho q}{\varepsilon_0}$$

Statement 1 is false. Statement 2 is true.

36. (c) : During discharging of a capacitor $V = V_0 e^{-t/\tau}$ where τ is the time constant of RC circuit. At $t = \tau$,

$$V = \frac{V_0}{e} = 0.37\,V_0$$

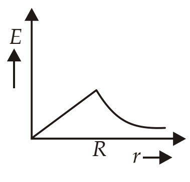
From the graph, $t = 0$, $V_0 = 25$ V $\therefore$ $V = 0.37 \times 25$ V $= 9.25$ V This voltage occurs at time lies between 100 sec and 500 sec. Hence, time constant τ of this circuit lies between 100 sec and 150 sec.

37. (b) : For uniformly charged sphere

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3} \quad (\text{For } r < R)$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2} \quad (\text{For } r = R)$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \quad (\text{For } r > R)$$

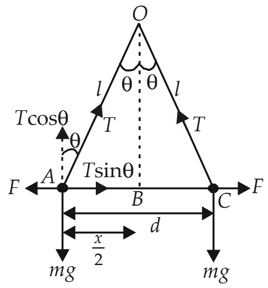


The variation of E with distance r from the centre is as shown in figure.

38. (a) : Figure shows equilibrium positions of the two sphere.

$\therefore$ $T\cos\theta = mg$

and $T\sin\theta = F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2}$



$\therefore$ $\tan\theta = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2 mg}$

When charge begins to leak from both the spheres at a constant rate, then

$$\tan\theta = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{x^2 mg}$$

$$\frac{x}{2l} = \frac{q^2}{4\pi\varepsilon_0 x^2 mg} \quad \left(\because \tan\theta = \frac{x}{2l}\right)$$

or $\frac{x}{2l} \propto \frac{q^2}{x^2}$ or $q^2 \propto x^3 \Rightarrow q \propto x^{3/2}$

$$\frac{dq}{dt} \propto \frac{3}{2}x^{1/2}\frac{dx}{dt} \text{ or } v \propto x^{-1/2} \quad \left(\because \frac{dq}{dt} = \text{constant}\right)$$

39. (d) : $\phi = ar^2 + b$

Electric field, $E = \frac{-d\phi}{dr} = -2ar$ ...(i)

According to Gauss's theorem, $\oint \vec{E}\cdot d\vec{S} = \frac{q_{\text{inside}}}{\varepsilon_0}$

or $-2ar4\pi r^2 = \frac{q_{\text{inside}}}{\varepsilon_0}$ (Using (i))

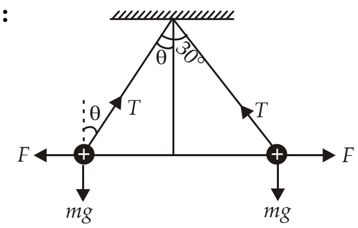
$$q_{\text{inside}} = -8\varepsilon_0 a\pi r^3$$

Charge density inside the ball is

$$\rho_{\text{inside}} = \frac{q_{\text{inside}}}{\frac{4}{3}\pi r^3} \quad \therefore \rho_{\text{inside}} = \frac{-8\varepsilon_0 a\pi r^3}{\frac{4}{3}\pi r^3}$$

$$\rho_{\text{inside}} = -6a\varepsilon_0$$

40. (d) :



Initially, the forces acting on each ball are

(i) Tension T (ii) Weight mg

(iii) Electrostatic force of repulsion F

For its equilibrium along vertical, $T\cos\theta = mg$ ...(i)

and along horizontal, $T\sin\theta = F$ ...(ii)

Dividing equation (ii) by (i), we get $\tan\theta = \frac{F}{mg}$ ...(iii)

When the balls are suspended in a liquid of density σ and dielectric constant K, the electrostatic force will become $(1/K)$ times, *i.e.* $F' = (F/K)$ while weight

$mg' = mg$ – upthrust

$= mg - V\sigma g$ [As upthrust $= V\sigma g$]

$$mg' = mg\left[1 - \frac{\sigma}{\rho}\right] \quad \left[\text{As } V = \frac{m}{\rho}\right]$$

For equilibrium of balls,

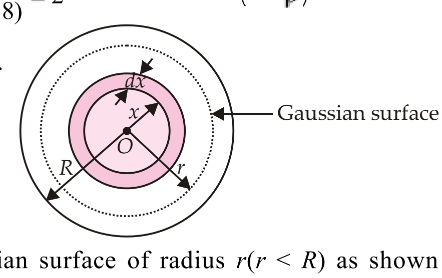
$$\tan\theta' = \frac{F'}{mg'} = \frac{F}{Kmg[1-(\sigma/\rho)]} \quad \text{...(iv)}$$

According to given problem, $\theta' = \theta$

From equations (iii) and (iv), we get $K = \dfrac{1}{\left(1-\dfrac{\sigma}{\rho}\right)}$

$$K = \frac{\rho}{(\rho-\sigma)} = \frac{1.6}{(1.6-0.8)} = 2$$

41. (c) : Consider a thin spherical shell of radius x and thickness dx as shown in the figure.



Volume of the shell, $dV = 4\pi x^2 dx$

Let us draw a Gaussian surface of radius $r(r < R)$ as shown in the figure above.

Total charge enclosed inside the Gaussian surface is

$$Q_{\text{in}} = \int_0^r \rho dV = \int_0^r \rho_0\left(\frac{5}{4}-\frac{x}{R}\right)4\pi x^2 dx = 4\pi\rho_0 \int_0^r \left(\frac{5}{4}x^2 - \frac{x^3}{R}\right)dx$$

$$= 4\pi\rho_0\left[\frac{5}{12}x^3 - \frac{x^4}{4R}\right]_0^r = 4\pi\rho_0\left[\frac{5}{12}r^3 - \frac{r^4}{4R}\right]$$

$$= \frac{4\pi\rho_0}{4}\left[\frac{5}{3}r^3 - \frac{r^4}{R}\right] = \pi\rho_0\left[\frac{5}{3}r^3 - \frac{r^4}{R}\right]$$

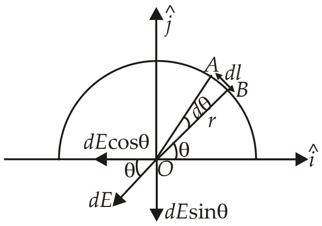
According to Gauss's law $E4\pi r^2 = \dfrac{Q_{\text{in}}}{\varepsilon_0}$

$$E4\pi r^2 = \frac{\pi\rho_0}{\varepsilon_0}\left[\frac{5}{3}r^3 - \frac{r^4}{R}\right]$$

$$E = \frac{\pi\rho_0 r^3}{4\pi r^2\varepsilon_0}\left[\frac{5}{3} - \frac{r}{R}\right] = \frac{\rho_0 r}{4\varepsilon_0}\left[\frac{5}{3} - \frac{r}{R}\right]$$

42. (d) : Linear charge density, $\lambda = \dfrac{q}{\pi r}$

Consider a small element AB of length dl subtending an angle $d\theta$ at the centre O as shown in the figure.



$\therefore$ Charge on the element, $dq = \lambda dl$

$$= \lambda r d\theta \left(\because \ d\theta = \frac{dl}{r}\right)$$

The electric field at the centre O due to the charge element is

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2} = \frac{\lambda r d\theta}{4\pi\varepsilon_0 r^2}$$

Resolve dE into two rectangular components

By symmetry, $\int dE\cos\theta = 0$

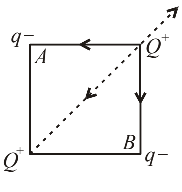
The net electric field at O is

$$\vec{E} = \int_0^\pi dE\sin\theta(-\hat{j}) = \int_0^\pi \frac{\lambda r d\theta}{4\pi\varepsilon_0 r^2}\sin\theta(-\hat{j})$$

$$= -\int_0^\pi \frac{qr\sin\theta d\theta}{4\pi^2\varepsilon_0 r^3}\hat{j} \qquad \left(\because \ \lambda = \frac{q}{\pi r}\right)$$

$$= -\int_0^\pi \frac{q\sin\theta d\theta}{4\pi^2\varepsilon_0 r^2}\hat{j} = -\frac{q}{4\pi^2\varepsilon_0 r^2}[-\cos\theta]_0^\pi \hat{j} = -\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$$

43. (a) : The force of repulsion by Q is cancelled by the resultant attracting force due to q^- and q^- at A and B.



Force of repulsion,

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{(a^2+a^2)} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q^2}{2a^2}$$

Total force of attraction along the diagonal

(taking $\cos\theta$ components)

$$= \frac{1}{4\pi\varepsilon_0}\left\{\frac{Qq}{a^2}\cdot\frac{1}{\sqrt{2}} + \frac{Qq}{a^2\sqrt{2}}\right\} = \frac{1}{4\pi\varepsilon_0}\left\{\frac{Qq\sqrt{2}}{a^2}\right\}$$

$$\Rightarrow \frac{Q^2}{2a^2} = \frac{Qq\sqrt{2}}{a^2} \quad \Rightarrow \frac{Q^2}{Qq^-} = -2\sqrt{2}$$

44. (d) : $+10$ V $\bullet\cdots\cdots\cdots\bullet$ -4 V

$P \qquad\qquad Q$

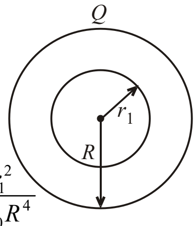
Work done in moving $100e^-$ from P to Q,

(Work done in moving 100 negative charges from the positive to the negative potential).

$W = (100e^-)(V_Q - V_P) = (-100 \times 1.6 \times 10^{-19})(-14 \text{ V}) = 2.24 \times 10^{-16}$ J

45. (c) : If the charge density, $\rho = \dfrac{Q}{\pi R^4}r$,

The electric field at the point p distant r_1 from the centre, according to Gauss's theorem is



$E\cdot 4\pi r_1^2$ = charge enclosed/ε_0

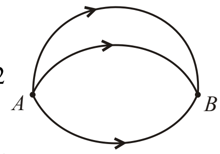
$$E\cdot 4\pi r_1^2 = \frac{1}{\varepsilon_0}\int \rho dV$$

$$\Rightarrow E\cdot 4\pi r_1^2 = \frac{1}{\varepsilon_0}\int_0^{r_1}\frac{Qr}{\pi R^4}\cdot 4\pi r^2 dr \Rightarrow E = \frac{Qr_1^2}{4\pi\varepsilon_0 R^4}$$

46. (c) : Work done = Potential difference × charge

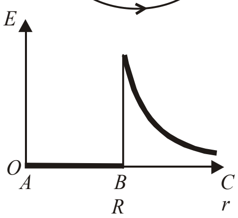
$= (V_B - V_A) \times q$,

V_A and V_B only depend on the initial and final positions and not on the path. Electrostatic force is a conservative force. If the loop is completed, $V_A - V_A = 0$. No net work is done as the initial and final potentials are the same.



Both the statements are true but statement-2 is not the reason for statement-1.

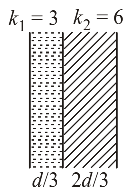
47. (b) : The electric field for a uniformly charged spherical shell is given in the figure. Inside the shell, the field is zero and it is maximum at the surface and then decreases, i.e.,



$E \propto 1/r^2$.

$$E = \frac{Q}{4\pi\varepsilon_0\cdot r^2} \text{ outside shell and zero inside.}$$

48. (d) : $C = \dfrac{\varepsilon_0 A}{d} = 9\times 10^{-12}$ F



With dielectric, $C = \dfrac{\varepsilon_0 kA}{d}$

$$C_1 = \frac{\varepsilon_0 A\cdot 3}{d/3} = 9C \ ; \ C_2 = \frac{\varepsilon_0 A\cdot 6}{2d/3} = 9C$$

$\therefore$ $C_{\text{total}} = \dfrac{C_1C_2}{C_1+C_2}$ as they are in series.

$$= \frac{9C\times 9C}{18C} = \frac{9}{2}\times C \text{ or } \frac{9}{2}\times 9\times 10^{-12} \text{ F} \Rightarrow C_{\text{total}} = 40.5 \text{ pF}$$

49. (a) : The potential energy of a charged capacitor

$$U_i = \frac{q^2}{2C}$$

where U_i is the initial potential energy.

If a dielectric slab is slowly introduced, the energy $=\dfrac{q^2}{2KC}$

Once is taken out, again the energy increases to the old value. Therefore after it is taken out, the potential energy come back to the old value. Total work done = zero.

50. (a) : Given : Potential $V(x)=\dfrac{20}{x^2-4}$

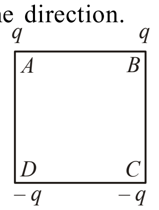
Electric field $E=\dfrac{-dV}{dx}=\dfrac{-d}{dx}\left(\dfrac{20}{x^2-4}\right)=\dfrac{40x}{(x^2-4)^2}$

At x = 4 μm

$\therefore \quad E=\dfrac{40\times 4}{[16-4]^2}=\dfrac{160}{144}=\dfrac{10}{9}$ V/μm

Positive sign indicate E is in the +ve x direction.

51. (a) : "Unit positive charge" will be repelled by A and B and attracted by $-q$ and $-q$ downwards in the same direction.



If they are exchanged, the direction of the field will be opposite. In the case of potential, as it is a scalar, they cancel each other whatever may be their position.

$\therefore$ Field is affected but not the potential.

52. (a) : Let E be emf of the battery

Work done by the battery $W = CE^2$

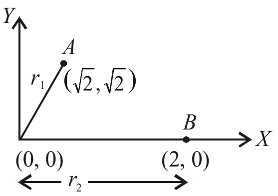
Energy stored in the capacitor $U=\dfrac{1}{2}CE^2 \therefore \dfrac{U}{W}=\dfrac{\frac{1}{2}CE^2}{CE^2}=\dfrac{1}{2}$

53. (c) : $\vec{r}_1=\sqrt{2}\hat{i}+\sqrt{2}\hat{j}$

$|\vec{r}_1|=r_1=\sqrt{(\sqrt{2})^2+(\sqrt{2})^2}=2$

$\vec{r}_2=2\hat{i}+0\hat{j}$

or $\quad |\vec{r}_2|=r_2=2$



Potential at point A is

$V_A=\dfrac{q}{4\pi\varepsilon_0 r_1}=\dfrac{1}{4\pi\varepsilon_0}\dfrac{10^{-3}\times 10^{-6}}{2}$

Potential at point B is $V_B=\dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r_2}=\dfrac{1}{4\pi\varepsilon_0}\dfrac{10^{-3}\times 10^{-6}}{2}$

$\therefore \quad V_A-V_B=0.$

54. (d) : When the spherical conductors are connected by a conducting wire, charge is redistributed and the spheres attain a common potential V.

$\therefore$ Intensity $E_A=\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q_A}{R_A^2}$

or $\quad E_A=\dfrac{1\times C_A V}{4\pi\varepsilon_0 R_A^2}=\dfrac{(4\pi\varepsilon_0 R_A)V}{4\pi\varepsilon_0 R_A^2}=\dfrac{V}{R_A}$

Similarly $E_B=\dfrac{V}{R_B} \quad \therefore \quad \dfrac{E_A}{E_B}=\dfrac{R_B}{R_A}=\dfrac{2}{1}$

55. (b) : An electron on plate 1 has electrostatic potential energy. When it moves, potential energy is converted into kinetic energy.

$\therefore$ Kinetic energy = Electrostatic potential energy

or $\quad \dfrac{1}{2}mv^2=e\Delta V$

or $\quad v=\sqrt{\dfrac{2e\times\Delta V}{m}}=\sqrt{\dfrac{2\times 1.6\times 10^{-19}\times 20}{9.11\times 10^{-31}}}$ or $v = 2.65 \times 10^6$ m/s

56. (d) : In a non-uniform electric field, the dipole will experience a torque as well as a translational force.

57. (b) : Energy of capacitor = Heat energy of block

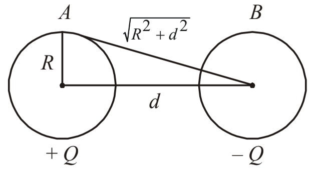
$\therefore \quad \dfrac{1}{2}CV^2=ms\Delta T \quad$ or $\quad V=\sqrt{\dfrac{2ms\,\Delta T}{C}}$

58. (c) : n plates connected alternately give rise to $(n-1)$ capacitors connected in parallel

$\therefore$ Resultant capacitance = $(n-1)C$.

59. (d) : $V_A=\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{R}-\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{\sqrt{R^2+d^2}}$

$V_B=\dfrac{1}{4\pi\varepsilon_0}\dfrac{(-Q)}{R}+\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{\sqrt{R^2+d^2}}$

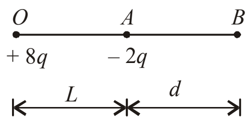


$\therefore V_A-V_B=\dfrac{1\times Q}{4\pi\varepsilon_0}\left[\dfrac{2}{R}-\dfrac{2}{\sqrt{R^2+d^2}}\right]$

$=\dfrac{Q}{2\pi\varepsilon_0}\left[\dfrac{1}{R}-\dfrac{1}{\sqrt{R^2+d^2}}\right]$

60. (c) : Resultant intensity = 0

$\dfrac{1}{4\pi\varepsilon_0}\dfrac{8q}{(L+d)^2}-\dfrac{1}{4\pi\varepsilon_0}\dfrac{2q}{d^2}=0$



or $\quad (L+d)^2 = 4d^2$

or $\quad d = L$

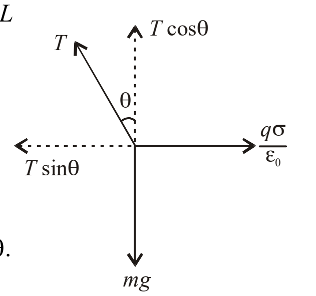
$\therefore$ Distance from origin = $2L$

61. (b) : $T\sin\theta = \sigma q/\varepsilon_0$

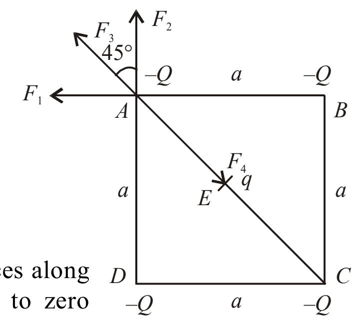
$T\cos\theta = mg$

$\therefore \quad \tan\theta=\dfrac{\sigma q}{\varepsilon_0 mg}$

$\therefore$ σ is proportional to tanθ.



62. (b) : Consider the four forces F_1, F_2, F_3 and F_4 acting on charge $(-Q)$ placed at A.



Distance $CA=\sqrt{2}\,a$

Distance $EA=\dfrac{\sqrt{2}\,a}{2}=\dfrac{a}{\sqrt{2}}$

For equilibrium, consider forces along DA and equate the resultant to zero

$\therefore \quad \dfrac{1}{4\pi\varepsilon_0}\dfrac{Q\times Q}{(DA)^2}+\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q\times Q}{(CA)^2}\cos 45°-\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q\times q}{(EA)^2}\cos 45°=0$

or $\quad \dfrac{Q}{a^2}+\dfrac{Q}{2a^2}\times\dfrac{1}{\sqrt{2}}-\dfrac{q}{a^2/2}\times\dfrac{1}{\sqrt{2}}=0$ or $Q\left[1+\dfrac{1}{2\sqrt{2}}\right]=q\sqrt{2}$

or $\quad q=\dfrac{Q}{\sqrt{2}}\left[\dfrac{2\sqrt{2}+1}{2\sqrt{2}}\right]=\dfrac{Q}{4}(1+2\sqrt{2})$

63. (d) : Energy is conserved in the phenomenon

Initially, $\frac{1}{2}mv^2 = \frac{kqQ}{r}$ ...(i)

Finally, $\frac{1}{2}m(2v)^2 = \frac{kqQ}{r_1}$ ...(ii)

From eqns (i) and (ii), we get

$\frac{1}{4} = \frac{r_1}{r} \Rightarrow r_1 = \frac{r}{4}$

64. (d) : Initially, $F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2}$ ...(i)

When the third equal conductor touches B, the charge of B is shared equally between them.

$\therefore$ Charge on $B = \frac{q}{2}$ = charge on third conductor.

Now this third conductor with charge $\left(\frac{q}{2}\right)$ touches C, their total charge $\left(q+\frac{q}{2}\right)$ is equally shared between them.

$\therefore$ Charge on $C = \frac{3q}{4}$ = Charge of third conductor

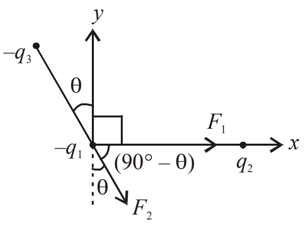
$\therefore$ New force between B and $C = \frac{1}{4\pi\varepsilon_0 d^2}\left(\frac{q}{2}\times\frac{3q}{4}\right) = \frac{3}{8}F$

65. (b) : Force on $(-q_1)$ due to $q_2 = \frac{-q_1q_2}{4\pi\varepsilon_0 b^2}$

$\therefore$ $F_1 = \frac{q_1q_2}{4\pi\varepsilon_0 b^2}$ along (q_1q_2)

Force on $(-q_1)$ due to $(-q_3) = \frac{(-q_1)(-q_3)}{4\pi\varepsilon_0 a^2}$

$F_2 = \frac{q_1q_3}{4\pi\varepsilon_0 a^2}$ as shown



F_2 makes an angle of $(90° - \theta)$ with (q_1q_2)

Resolved part of F_2 along q_1q_2

$= F_2 \cos(90° - \theta)$

$= \frac{q_1q_3\sin\theta}{4\pi\varepsilon_0 a^2}$ along (q_1q_2)

$\therefore$ Total force on $(-q_1) = \left[\frac{q_1q_2}{4\pi\varepsilon_0 b^2} + \frac{q_1q_3\sin\theta}{4\pi\varepsilon_0 a^2}\right]$ along x-axis

$\therefore$ x-component of force $\propto \left[\frac{q_2}{b^2} + \frac{q_3}{a^2}\sin\theta\right]$.

66. (d) : Energy of condenser

$$= \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\times\frac{(8\times10^{-18})^2}{(100\times10^{-6})} = 32\times10^{-32}\text{ J}$$

67. (c) : Potential at any internal point of charged shell $= \frac{q}{4\pi\varepsilon_0 R}$

Potential at P due to Q at centre $= \frac{1}{4\pi\varepsilon_0}\frac{2Q}{R}$

$\therefore$ Total potential point $= \frac{q}{4\pi\varepsilon_0 R} + \frac{2Q}{4\pi\varepsilon_0 R} = \frac{1}{4\pi\varepsilon_0 R}(q+2Q)$

68. (b) : Aluminium is a good conductor. Its sheet introduced between the plates of a capacitor is of negligible thickness. The capacity remains unchanged.

With air as dielectric, $C = \frac{\varepsilon_0 A}{d}$

With space partially filled, $C' = \frac{\varepsilon_0 A}{(d-t)} = \frac{\varepsilon_0 A}{d} = C$

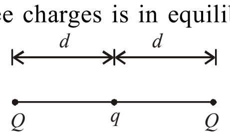
69. (a) : According to Gauss theorem,

$(\phi_2 - \phi_1) = \frac{Q}{\varepsilon_0} \Rightarrow Q = (\phi_2 - \phi_1)\varepsilon_0$

The flux enters the enclosure if one has a negative charge ($-q_2$) and flux goes out if one has a +ve charge ($+q_1$). As one does not know whether $\phi_1 > \phi_2$, $\phi_2 > \phi_1$, $Q = q_1 \sim q_2$

70. (a) : $C = 4\pi\varepsilon_0 R = \frac{1}{9\times10^9} = 1.1\times10^{-10}$ F

71. (d) : When the system of three charges is in equilibrium,



$\frac{Q\times q}{4\pi\varepsilon_0 d^2} + \frac{Q\times Q}{4\pi\varepsilon_0 (2d)^2} = 0$

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

72. (b) : Total capacity = nC $\therefore$ Energy $= \frac{1}{2}nCV^2$

73. (*) : Electric flux through $ABCD$ = Zero for the charge placed outside the box as the charged enclosed is zero. But for the charge inside the cube, it is $\frac{q}{\varepsilon_0}$ through all the surfaces.

For one surface, it is $\frac{q}{6\varepsilon_0}$.

* (Option not given).

74. (a) : $W = QV$ $\therefore$ $V = \frac{W}{Q} = \frac{2}{20} = 0.1$ volt