Multiple Choice Questions with One Correct Choice

Q 1. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface to 10 V. The potential at the centre of the sphere is

(a) zero (b) 10 V

(c) the same as that at a point 5 cm away from the surface

(d) the same as that at a point 25 cm away from the surface

Q 2. 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 a point (2a, 0) on the x-axis. The charge Q will

(a) execute simple harmonic motion about the origin

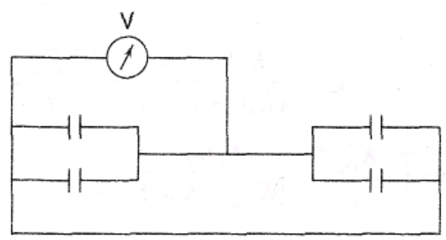
(b) move to the origin and remain at rest there

(c) move to infinity

(d) execute oscillatory but not simple harmonic motion.

Q 3. Four capacitors, each of capacitance 50 μF are connected as shown in Fig. If the voltmeter reads 100 V, the charge on each capacitor is

(a) 2×10^{-3} C (b) 5×10^{-3}C (c) 0.2 C (d) 0.5 C



Q 4. Three point charges 4q, Q and q are placed in a straight line of length l at points distant 0,l/2 and l respectively. The net force on charge q is zero. The value of Q is

(a) -q (b) -2q (c) $-\frac{1}{2}q$ (d) 4q

Q 5. Two positive point charges of 12 and 8 microcoulornbs respectively are placed 10 cm apart in air. The work done to bring them 4 cm closer is

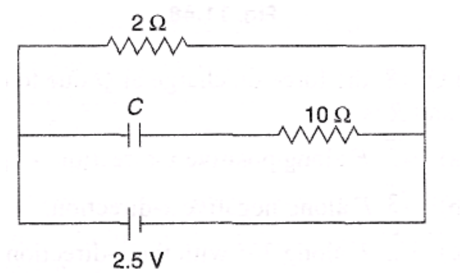
(a) zero (b) 3.8 J (c) 4.8 J (d) 5.8 J

Q 6. The work done is carrying a charge q once round a circle of radius r with a charge Q at the centre is

(a) $\frac{qQ}{4\pi\varepsilon_0 r}$ (b) $\frac{qQ}{4\pi\varepsilon_0}\frac{1}{\pi r}$ (c) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{1}{2\pi r}\right)$ (d) zero

Q 7. A capacitor of capacitance C = 2 μF is connected as shown in Fig. If the internal resistance of the ceil is 0.5 O, the charge on the capacitor plates is

(a) zero (b) 2 μC (c) 4 μC (d) 6 μC



Q 8. 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) $-\frac{Q}{2}$ (b) $-\frac{Q}{4}$ (c) $+\frac{Q}{2}$ (d) $+\frac{Q}{4}$

Q 9. The electric potential V (in volt) varies with x (in metre) according to the relation $F = 5 + 4x^2$ The force experienced by a negative charge of 2×10^{-6} C located at x = 0.5 m is

(a) 2×10^{-6}N (b) 4×10^{-6} N (c) 6×10^{-6} N (d) 8×10^{-6}N

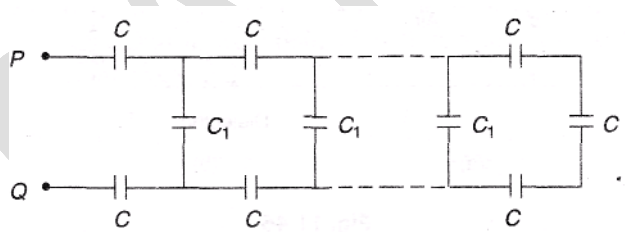
Q 10. Two parallel plate capacitors of capacitances C and 2C are connected in parallel and charged to a potential difference V by a battery. The battery is then disconnected and the space between the plates of capacitor C is completely filled with a material of dielectric constant K. The potential difference across the capacitors now becomes

(a) $\frac{V}{K+1}$ (b) $\frac{2V}{K+2}$ (c) $\frac{3V}{K+2}$ (d) $\frac{3V}{K+3}$

Q 11. The force of attraction between the plates of air filled parallel plate capacitor having charge Q and area of each plate A is given by

(a) $\frac{2Q^2}{\varepsilon_0 A}$ (b) $\frac{Q^2}{\varepsilon_0 A}$ (c) $\frac{Q^2}{2\varepsilon_0 A}$ (d) $\frac{Q^2}{4\varepsilon_0 A}$

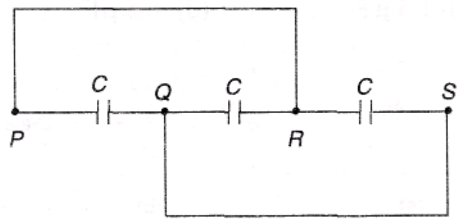
Q 12. In the network shown in Fig., $C_1 = 6\ \mu F$ and $C = 9\ \mu F$. The equivalent capacitance between points P and Q is



(a) 3 μF (b) 6 μF (c) 9 μF (d) 12 μF

Q 13. Three capacitors, each of capacitance C = 3 μF, are connected as shown in Fig. The equivalent capacitance between points P and S is

(a) 1 μF (b) 3 μF (c) 6 μF (d) 9 μF



Q 14. A parallel plate capacitor of capacitance 100 pF is to be constructed by using paper sheets of 1.0 mm thickness as dielectric. If the dielectric constant of paper is 4.0, the number of circular metal foils of diameter 2.0 cm each required for this purpose is

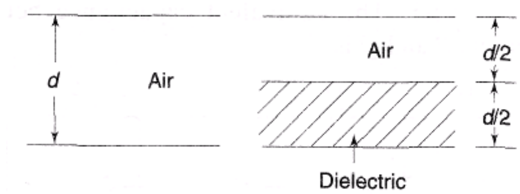
(a) 10 (b) 20 (c) 30 (d) 40

Q 15. One thousand spherical water droplets, each of radius r and each carrying a charge q. coalesce to form a single spherical drop. If v is the electrical potential of each droplet and V that of the bigger drop, then

(a) $\frac{V}{v}=\frac{1}{1000}$ (b) $\frac{V}{v}=\frac{1}{100}$ (c) $\frac{V}{v}=100$ (d) $\frac{V}{v}=1000$

Q 16. A parallel plate air filled capacitor shown in Fig.

(a) has a capacitance of 2 μF. When it is half filled with a dielectric of dielectric constant k = 3 as shown in Fig. (b), its capacitance becomes

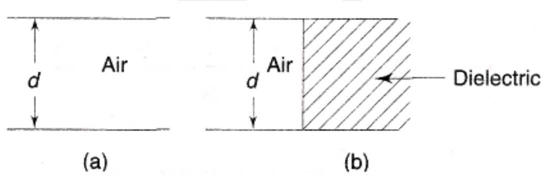


(a) $\frac{1}{3}$ μF (b) 1μF (c) 3 μF (d) 9 μF

Q 17. A parallel plate air filled capacitor shown in Fig.

(a) has a capacitance of 2 μF. When it is half filled with a dielectric of dielectric constant k = 3 as shown in Fig. (b), its capacitance becomes

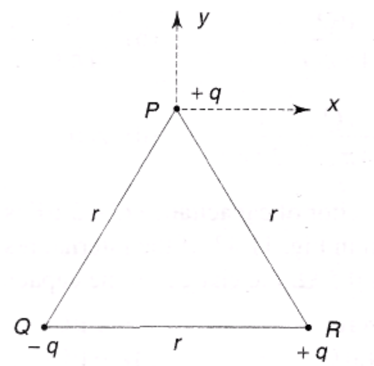
(a) 4μF (b) 4μF (c) 1.5μF (d) 0.5μF



Q 18. Three point charges + q, - q and + q are placed at the vertices P, Q and R of an equilateral triangle as shown in Fig. If $F=\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$, where r is the side of the triangle, the force on charge at P due to charges at Q and R is

(a) F along positive x-direction (b) F along negative x-direction

(c) $\sqrt{2}$ F along positive x-direction (d) $\sqrt{2}$ F along negative x-direction.



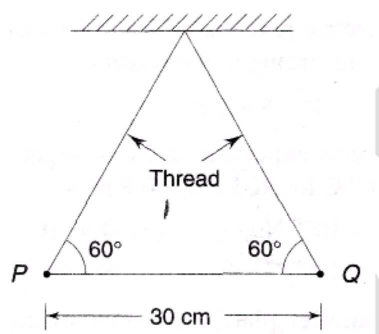
Q 19. In Q. 18, the force on charge at Q due to charges at P and R is

(a) $\sqrt{2}$ F along positive x-direction. (b) $\sqrt{3}$ F along negative x-direction.

(c) $\sqrt{2}$ F along 30° with the x-direction. (d) $\sqrt{3}$ F along 30° with the x-direction.

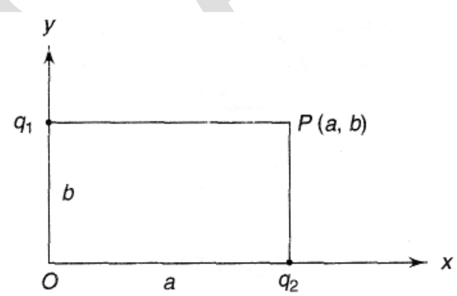
Q 20. Two small identical balls P and Q, each of mass $\sqrt{3}/10$ gram, carry identical charges and are suspended by threads of equal lengths. At equilibrium, they position themselves as shown in Fig. What is the charge on each ball. Given $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ Nm^2C^{-2} and take g = 10 ms^{-2}.

(a) 10^{-3}C (b) 10^{-5}C (c) 10^{-7}C (d) 10^{-9}C



Q 21. Two point charges q_1 = 2 μC and q_2 = 1 μC are placed at distances b = 1 cm and a = 2 cm from the origin on the y and x axes as shown in Fig. The electric field vector at point P (a, b) will subtend an angle θ with the x-axis given by

(a) tan θ = 1 (b) tan θ=2 (c) tan θ = 3 (d) tan θ = 4



Q 22. An electric dipole placed with its axis in the direction of a uniform electric field experiences

(a) a force but no torque (b) a torque but no force

(c) a force as well as a torque (d) neither a force nor a torque

Q 23. An electric dipole placed with its axis inclined at an angle to the direction of a uniform electric field experiences

(a) a force but no torque
(b) a torque but no force
(c) a force as well as a torque
(d) neither a force nor a torque

Q 24. An electric dipole placed in a non-uniform electric field experiences

(a) a force but no torque
(b) a torque but no force
(c) a force as well as a torque
(d) neither a force nor a torque.

Q 25. Four point charges + q, + q,- q and - q are placed respectively at the comers A,B,C and D of a square of side a. The electric potential at the centre O of the square is

(a) $\frac{1}{4\pi\varepsilon_0}.\frac{q}{a}$
(b) $\frac{1}{4\pi\varepsilon_0}.\frac{2q}{a}$
(c) $\frac{1}{4\pi\varepsilon_0}.\frac{4q}{a}$
(d) zero

Q 26. A cube of side b has a charge q at each of its vertices. What is the electric potential at the centre of the cube?

(a) $\frac{4q}{\sqrt{3}\pi\varepsilon_0 b}$
(b) $\frac{\sqrt{3}q}{\pi\varepsilon_0 b}$
(c) $\frac{2q}{\pi\varepsilon_0 b}$
(d) zero

Q 27. In Q. 26, the Electric field at the centre of the cube is

(a) $\frac{4q}{3\pi\varepsilon_0 b^2}$
(b) $\frac{3q}{\pi\varepsilon_0 b^2}$
(c) $\frac{2q}{\pi\varepsilon_0 b^2}$
(d) zero

Q 28. Two point charges - q and + q are located at points (0, 0, - a) and (0, 0, a) respectively. What is the electric potential at point (0, 0, z)?

(a) $\frac{qa}{4\pi\varepsilon_0 z^2}$
(b) $\frac{q}{4\pi\varepsilon_0 a}$
(c) $\frac{2qa}{4\pi\varepsilon_0 (z^2 - a^2)}$
(d) $\frac{2qa}{4\pi\varepsilon_0 (z^2 + a^2)}$

Q 29. In Q. 28, how much work is done in moving a small test charge q_0 from point (5,0, 0) to a point (-7, 0, 0) along the x-axis?

(a) $\frac{5}{7}\times\frac{q_0 q}{4\pi\varepsilon_0 a}$
(b) $\frac{7}{5}\times\frac{q_0 q}{4\pi\varepsilon_0 a}$
(c) $\frac{1}{12}\times\frac{q_0 q}{4\pi\varepsilon_0 a}$
(d) zero

Q 30. A neutral hydrogen molecule has two protons and two electrons. If one of the electrons is removed we get a hydrogen molecular ion (H_2^+). In the ground state of H_2^+ the two protons are separated by roughly 1.5 Å and the electron is roughly 1 Å from each proton. What is the potential energy of the system?

(a) -38.4 eV
(b) - 19.2 eV
(c) -9.6 eV
(d) zero

Q 31. In a hydrogen atom, the electron and the proton are bound together at a separation of about 0.53 Å. If the zero of potential energy is taken in an infinite separation of the electron from the proton, the potential energy of the electron-proton system is

(a) - 54.4 eV
(b) - 27.2 eV
(c) -13.6 eV
(d) zero

Q 32. In Q. 31, what is the minimum work required to free the electron from the proton if the kinetic energy of the electron in its orbit is half the potential energy of the electron-proton system?

(a) 2.2×10^{-12} J (b) 2.2×10^{-14} J (c) 2.2×10^{-16} J (d) 2.2×10^{-18} J

Q 33. In Q. 31, what will be the potential energy of the electron-proton system if the zero of potential energy is taken at a separation of 1.06 Å?

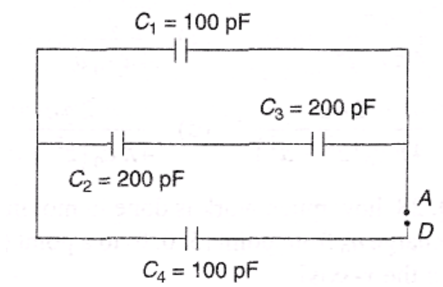
(a) zero (b) -13.6 eV (c) -21.2 eV (d) -54.4eV

Q 34. What is the answer to Q. 32 if the zero of potential energy is taken at a separation of 1.06 Å?

(a) zero (b) 1.1×10^{-14} J (c) 1.1×10^{-16} J (d) 1.1×10^{-18} J

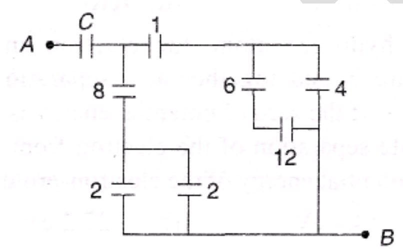
Q 35. What is the equivalent capacitance between A and D of the network shown in Fig. ?

(a) 200 pF (b) 100 pF (c) $\frac{200}{3}$ pF (d) 50 pF



Q 36. Figure shows a network of capacitors where the numbers indicate capacitances in microfarad. What must be the value of capacitance C if the equivalent capacitance between points A and B is to be 1 μ F?

(a) $\frac{31}{23}$ μF (b) $\frac{32}{23}$ μF (c) $\frac{33}{23}$ μF (d) $\frac{34}{23}$ μF

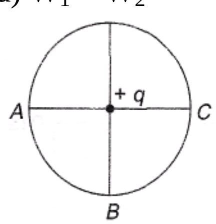


Q 37. A 2 μF capacitor C_1 is charged to a voltage 100 V and a 4 μF capacitor C_2 is charged to a voltage 50 V. The capacitors are then connected in parallel. What is the loss of energy due to parallel connection?

(a) 1.7 J (b) 1.7×10^{-1} J (c) 1.7×10^{-2} J (d) 1.7×10^{-3} J

Q 38. A positive charge (+ q) is located at the centre of a circle as shown in Fig. W_1 is the work done in taking a unit positive charge from A to B and W_2 is the work done in taking the same charge from A to C. Then

(a) $W_1 > W_2$ (b) $W_1 < W_2$ (c) $W_1 = W_2$ (d) $W_1 = W_2 = 0$



Q 39. Two concentric spheres of radii r_1 and r_2 carry charges q_1 and q_2 respectively. If the surface charge density (σ) is the same for both spheres, the electric potential at the common centre will be

(a) $\frac{\sigma}{\varepsilon_0}.\frac{r_1}{r_2}$ (b) $\frac{\sigma}{\varepsilon_0}.\frac{r_2}{r_1}$ (c) $\frac{\sigma}{\varepsilon_0}(r_1 - r_2)$ (d) $\frac{\sigma}{\varepsilon_0}(r_1 + r_2)$

Q 40. The magnitude of the electric field on the surface of a sphere of radius r having a uniform surface charge density σ is

(a) $\frac{\sigma}{\varepsilon_0}$ (b) $\frac{\sigma}{2\varepsilon_0}$ (c) $\frac{\sigma}{\varepsilon_0 r}$ (d) $\frac{\sigma}{2\varepsilon_0 r}$

Q 41. The electric field due to an extremely short dipole at a distance r from it is proportional to

(a) $\frac{1}{r}$ (b) $\frac{1}{r^2}$ (c) $\frac{1}{r^3}$ (d) $\frac{1}{r^4}$

Q 42. The electric potential due to an extremely short di pole at a distance r from it is proportional to

(a) $\frac{1}{r}$ (b) $\frac{1}{r^2}$ (c) $\frac{1}{r^3}$ (d) $\frac{1}{r^4}$

Q 43. A soap bubble of radius r is charged to a potential V. If the radius is increased to n r, the potential on the bubble will become

(a) nV (b) n^2V (c) $\frac{V}{n}$ (d) $\frac{V}{n^2}$

Q 44. If n drops, each of capacitance C, coalesce to form a single big drop, the capacitance of the big drop will be

(a) n^3C (b) nC (c) $n^{1/2}C$ (d) $n^{1/3}C$

Q 45. If n drops, each charged to a potential V, coalesce to form a single drop, the potential of the big drop will be

(a) $\frac{V}{n^{2/3}}$ (b) $\frac{V}{n^{1/3}}$ (c) $Vn^{1/3}$ (d) $Vn^{2/3}$

Q 46. If n drops, each of capacitance C and charged to a potential V, coalesce to form a big drop, the ratio of the energy stored in the big drop to that in each small drop will be

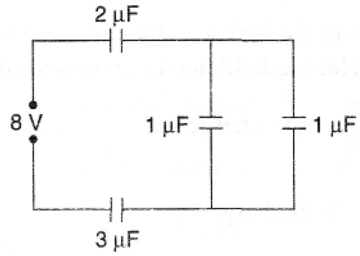
(a) n : 1 (b) $n^{4/3}$: 1 (c) $n^{5/3}$: 1 (d) n^2 : 1

Q 47. A parallel plate capacitor is made by stacking 10 identical metallic plates equally spaced from one another and having the same dielectric between plates. The alternate plates are then connected. If the capacitor formed by two neighbouring plates has a capacitance C, the total capacitance of the combination will be

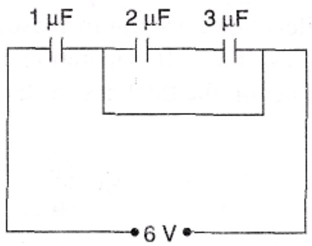
(a) $\frac{C}{10}$ (b) $\frac{C}{9}$ (c) 9C (d) 10 C

Q 48. Figure shows four capacitors connected to an 8 V power supply. What is the potential difference across each 1μF capacitor?

(a) 1 V (b) 2 V (c) 3 V (d) 4 V

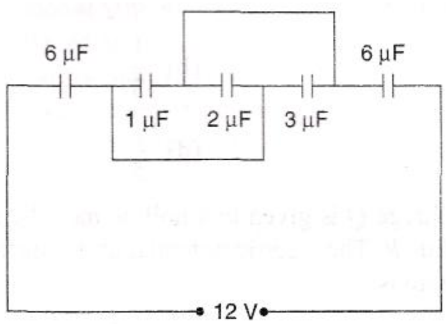


Q 49. Figure shows three capacitors connected to a 6 V power supply. What is the charge on the 2 μF capacitor?



(a) 1μC (b) 2μC (c) 3μC (d) 4μC

Q 50. Figure shows five capacitors connected across a 12 V power supply. What is the charge on the 2μF capacitor?



(a) 6μC (b) 8μC (c) 10 μC (d) 12 μC

Q 51. Six charges, each equal to + q, are placed at the corners of a regular hexagon of side a. The electric potential at the point where the diagonals of the hexagon intersect will be given by

(a) zero (b) $\frac{1}{4\pi\varepsilon_0}.\frac{q}{a}$ (c) $\frac{1}{4\pi\varepsilon_0}.\frac{6q}{a}$ (d) $\frac{1}{4\pi\varepsilon_0}.\frac{\sqrt{3}q}{2a}$

Q 52. In Q. 51, the electric field at the point of intersection of diagonals is

(a) zero (b) $\frac{1}{4\pi\varepsilon_0}.\frac{q}{a^2}$ (c) $\frac{1}{4\pi\varepsilon_0}.\frac{6q}{a^2}$ (d) $\frac{1}{4\pi\varepsilon_0}.\frac{\sqrt{3}q}{2a^2}$

Q 53. A parallel plate capacitor with air as dielectric is charged to a potential V. It is then connected to an uncharged parallel plate capacitor filled with wax of dielectric constant k. The common potential of both capacitors is

(a) V (b) kV (c) (1 + K)V (d) $\frac{V}{(1+k)}$

Q 54. A capacitor of capacitance C is fully charged by a 200 V supply. It is then discharged through a small coil of resistance wire embedded in a thermally insulated block of specific heat 2.5×10^2 $Jkg^{-1} K^{-1}$ and of mass 0.1 kg. If the temperature of the block rises by 0.4 K, what is the value of C ?

(a) 500 μF (b) 400 μF (c) 300 μF (d) 200 μF

Q 55. A charge having magnitude Q is divided into two parts q and (Q - q) which are held a certain distance r apart. The force of repulsion between the two parts will be maximum if the ratio q/Q is

(a) $\frac{1}{2}$ (b) $\frac{1}{3}$ (c) $\frac{1}{4}$ (d) $\frac{1}{5}$

Q 56. A charge Q is given to a hollow metallic sphere of radius R. The electric potential at the surface of the sphere is

(a) zero (b) $\frac{1}{4\pi\varepsilon_0}.\frac{Q}{R}$ (c) $\frac{1}{4\pi\varepsilon_0}.\frac{Q}{R^2}$ (d) $4\pi\varepsilon_0$ Q/R

Q 57. In Q. 56, the potential at a distance r from the centre of the sphere where r < R is

(a) zero (b) $\frac{1}{4\pi\varepsilon_0}.\frac{Q}{(R-r)}$ (c) $\frac{1}{4\pi\varepsilon_0}.\frac{Q}{R+r}$ (d) $\frac{4\pi\varepsilon_0 Q}{(R-r)}$

Q 58. The electric potential V at any point (x, y, z) in space is given by $V = 4x^2$ volt where x, y and z are all in metre. The electric field at the point (1 m, 0, 2 m) in Vm^{-1} is

(a) 8 along negative x-axis (b) 8 along positive x-axis

(c) 16 along negative x-axis (d) 16 along positive x-axis

Q 59. A charge Q is situated at the centre of a cube. The electric flux through one of the faces of the cube is

(a) $\frac{Q}{\varepsilon_0}$ (b) $\frac{Q}{2\varepsilon_0}$ (c) $\frac{Q}{4\varepsilon_0}$ (d) $\frac{Q}{6\varepsilon_0}$

Q 60. Eight dipoles of charges of magnitude q are placed inside a cube. The total electric flux through the cube will be

(a) $\frac{8q}{\varepsilon_0}$ (b) $\frac{16q}{\varepsilon_0}$ (c) $\frac{q}{\varepsilon_0}$ (d) zero

Q 61. The magnitude of the electric field in the annular region of a charged cylindrical capacitor

(a) is the same throughout

(b) is higher near the outer cylinder than near the inner cylinder

(c) varies as 1lr where r is the distance from the axis

(d) varies as $1/r^2$ where r is the distance from the axis.

Q 62. An identical capacitors are joined in parallel and the combination is charged to voltage V. The total energy stored is U. The capacitors are now disconnected and joined in series. The total energy stored in the series combination will be

(a) $\frac{U}{n}$ (b) U (c) nU (d) n^2U

Q 63. Two spheres of radii r and R carry charges q and Q respectively. When they are connected by a wire, there will be no loss of energy of the system if

(a) $qr = QR$ (b) $qR = Qr$ (c) $qr^2 = QR^2$ (d) $qR^2 = Qr^2$

Q 64. Two equal point charges of 1 μC each are located at points (i + j + k) m and (2i + 3j - k) m. What is the magnitude of electrostatic force between them?

(a) 10^{-3}N (b) 10^{-6}N (c) 10^{-9}N (d) 10^{-12}N

Q 65. Two point charges q and 4q are held at a separation r. The electric field due to them is zero at a distance

(a) $\frac{r}{\sqrt{3}}$ form charge 4q (b) $\frac{r}{3}$ from charge 4q

(c) $\frac{2r}{\sqrt{3}}$ from charge 4q (d) $\frac{2r}{3}$ from charge 4q

Q 66. The introduction of a metal plate between the plates of a parallel plate capacitor increases its capacitance by 4.5 times. If d is the separation of the two plates of the capacitor, the thickness of the metal plate introduced is

(a) $\frac{d}{3}$ (b) $\frac{5d}{9}$ (c) $\frac{7d}{9}$ (d) d

Q 67. If the potential difference between the plates of a capacitor is increased by 20%, the energy stored in the capacitor increases by exactly

(a) 20% (b) 22% (c) 40% (d) 44%

Q 68. If the potential difference between the plates of a capacitor is increased by 0.1%, the energy stored in the capacitor increases by very nearly

(a) 0.1% (b) 0.11% (c) 0.144% (d) 0.2%

Q 69. Three capacitors connected in series have an effective capacitance of 2 μF. If one of the capacitors is removed, the effective capacitance becomes 3 μF. The capacitance of the capacitor that is removed is

(a) 1μF (b) $\frac{3}{2}$ μF (c) $\frac{2}{3}$ μF (d) 6 μF

Q 70. The effective capacitance of two capacitors of capacitances C_1 and C_2 (with $C_2 > C_1$) connected in parallel is $\frac{25}{6}$ times the effective capacitance when they are connected in series. The ratio C_2/C_1 is

(a) $\frac{3}{2}$ (b) $\frac{4}{3}$ (c) $\frac{5}{3}$ (d) $\frac{25}{6}$

Q 71. Three equal point charges q are placed at the corners of an equilateral triangle. Another charge Q is placed at the centroid of the triangle. The system of charges will be in equilibrium if Q equals

(a) $\frac{q}{\sqrt{3}}$ (b) $-\frac{q}{\sqrt{3}}$ (c) $\frac{q}{3}$ (d) $-\frac{q}{3}$

Q 72. A metallic sphere A of radius a carries a charge Q. It is brought in contact with an uncharged sphere B of radius b. The charge on sphere A now will be

(a) $\frac{aQ}{b}$ (b) $\frac{bQ}{a}$ (c) $\frac{bQ}{a+b}$ (d) $\frac{aQ}{a+b}$

Q 73. A solid conducting sphere having a charge Q is surrounded by an uncharged concentric conducting hollow spherical shell. The potential difference between the surface of the solid sphere and the outer surface of the hollow shall is 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

Q 74. Two identical thin rings, each of radius R are coaxially placed at a distance R apart. If Q_1 and Q_2 are the charges uniformly spread on the two rings, the work done in moving a charge q from the centre of one ring to the centre of the other is

(a) zero

(b) $\frac{q}{4\pi\varepsilon_0\sqrt{2}R}(Q_1-Q_2)(\sqrt{2}-1)$

(c) $\frac{q\sqrt{2}}{4\pi\varepsilon_0 R}(Q_1+Q_2)$

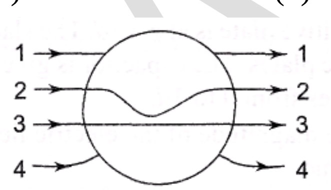
(d) $\frac{(\sqrt{2}+1)q(Q_1+Q_2)}{\sqrt{2}\,4\pi\varepsilon_0 R}$

Q 75. 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 t_2/t_1 is nearly equal to

(a) 1 (b) $\left(\frac{m_p}{m_e}\right)^{1/2}$ (c) $\left(\frac{m_e}{m_p}\right)^{1/2}$ (d) 1836

Q 76. A metallic solid sphere is placed in a uniform electric field. In Fig., which path will the lines of force follow?

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

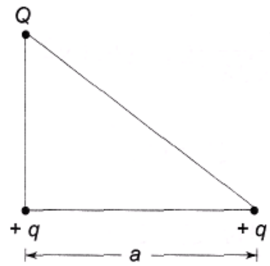


Q 77. A charge + q is fixed at each of the points $x = x_0$, $x = 3x_0$, $x = 5x_0$ ... upto infinity and a charge - q is fixed at each of the points $x = 2x_0$, $x = 4x_0$, $x = 6x_0$ ... upto infinity. Here x_0 is a positive constant. The potential at the origin of this system of charges is

(a) zero (b) $\frac{q}{4\pi\varepsilon_0 x_0\,\text{In}(2)}$ (c) infinity (d) $\frac{q\ln(2)}{4\pi\varepsilon_0 x_0}$

Q 78. Three charges Q, + q and + q are placed at the vertices of a right-angled isosceles triangle as shown in Fig. The net electrostatic energy of the configuration is zero if Q is equal to

(a) $\dfrac{-q}{1+\sqrt{2}}$ (b) $\dfrac{-2q}{2+\sqrt{2}}$ (c) -2q (d) +q



Q 79. A parallel plate capacitor of capacitance C is connected to a battery and is charged to a potential difference V. Another capacitor of capacitance 2C is similarly charged to a potential difference 2 V. The charging battery is then disconnected and the capacitors are connected in parallel to each other in such a way that the positive terminal of one is connected to the negative terminal of the other. The final energy of the configuration is

(a) zero (b) $\dfrac{3}{2}CV^2$ (c) $\dfrac{25}{6}CV^2$ (d) $\dfrac{9}{2}CV^2$

Q 80. A dielectric slab of thickness d is inserted in a parallel plate capacitor whose negative plate is at x = 0 and positive plate is at x = 3d. The slab is equidistant from the plates. The capacitor is given some charge. As x goes from 0 to 3d,

(a) the magnitude of the electric field remains the same

(b) the direction of the electric field changes continuously

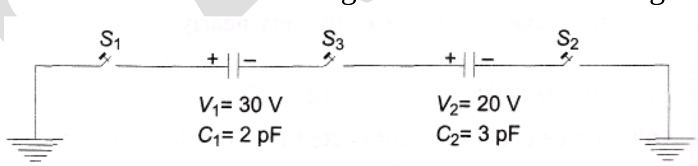
(c) the electric potential increases continuously

(d) the electric potential increases at first, then decreases and again increases.

Q 81. Two identical metal plates are given positive charges Q_1 and Q_2 ($< Q_1$) respectively. If they are brought close together to form a parallel plate capacitor with capacitance C. the potential difference between them is

(a) $\dfrac{Q_1+Q_2}{2C}$ (b) $\dfrac{Q_1+Q_2}{C}$ (c) $\dfrac{Q_1-Q_2}{C}$ (d) $\dfrac{Q_1-Q_2}{2C}$

Q 82. For the circuit shown in Fig. which of the following statements is true?



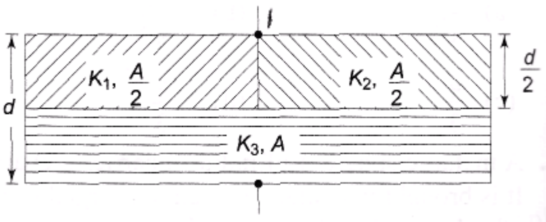
(a) With S_1 closed, $V_1 = 15$ V, $V_2 = 20$ V (b) With S_3 closed, $V_1 = V_2 = 25$ V

(c) With S_1 and S_2 closed $V_1 = V_2 = 0$ (d) With S_1 and S_3 closed $V_1 = 30$ V and $V_2 = 20$ V

Q 83. A parallel plate capacitor of area A, plate separation d and capacitance C is filled with three different dielectric materials having dielectric constant K_1, K_2 and K_3 as shown in Fig. If a single dielectric material is to be used to have the same capacitance C in this capacitor, then its dielectric constant K is given by

(a) $\frac{1}{K}=\frac{1}{K_1}+\frac{1}{K_2}+\frac{1}{2K_3}$ (b) $\frac{1}{K}=\frac{1}{K_1+K_2}+\frac{1}{2K_3}$

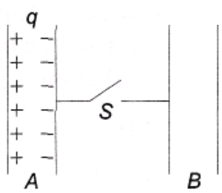
(c) $K=\frac{K_1K_2}{K_1+K_2}+2K_3$ (d) $K=K_1+K_2+K_3$



Q 84. A quantity X is given by $\varepsilon_0 L \frac{\Delta L}{\Delta t}$ where ε_0 is the permittivity of free space, L is a length, ΔV is a potential difference and Δt is a time interval. The dimensional formula for X is the same as that of

(a) resistance (b) charge (c) voltage (d) current

Q 85. Consider the situation shown in Fig. The capacitor A has a charge q on it whereas B is uncharged. The charge appearing on the capacitor B a long time after the switch is closed is



(a) zero (b) q/2 (c) q (d) 2q

Q 86. 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) $V_A > V_C$

Q 87. 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) 1/x

Q 88. There is a uniform electric field of strength 10^3 Vm^{-1} along the y-axis. A body of mass 1 g and charge 10^{-6} C is projected into the field from the origin along the positive x-axis with a velocity of 10 ms^{-1}. Its speed (in ms^{-1}) after 10 second will be (neglect gravitation)

(a) 10 (b) $5\sqrt{2}$ (c) $10\sqrt{2}$ (d) 20

Q 89. Two identical charges are placed at the two corners of an equilateral triangle. The potential energy of the system is U. The work done in bringing an identical charge from infinity to the third vertex is

(a) U (b) 2 U (c) 3U (d) 4 U

Q 90. A parallel plate capacitor of capacitance 5 μF and plate separation 6 cm is connected to a 1 V battery and charged. A dielectric of dielectric constant 4 and thickness 4 cm is introduced between the plates of the capacitor. The additional charge that flows into the capacitor from the battery is

(a) 2 μC (b) 3 μC (c) 5 μC (d) 10 μC

Q 91. A capacitor of capacitance 4 μF is charged to 80 V and another capacitor of capacitance 6 μF is charged to 30 V. When they are connected together, the energy lost by the 4 μF capacitor is

(a) 7.8 mJ (b) 4.6 mJ (c) 3.2 mJ (d) 2.5 mJ

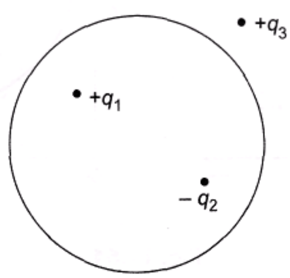
Q 92. The magnitude of electric field at a distance x from a charge q is E. An identical charge is placed at a distance 2x from it. Then the magnitude of the force it experiences is

(a) qE (b) 2qE (c) $\frac{qE}{2}$ (d) $\frac{qE}{4}$

Q 93. The flux of electric field E = 200 i NC^{-1} through a cube of side 10 cm, oriented so that its faces are parallel to the co-ordinate axes is

(a) zero (b) $2NC^{-1}m^2$ (c) $6NC^{-1}m^2$ (d) $12NC^{-1}m^2$

Q 94. Figure shows a spherical Gaussian surface and a charge distribution. When calculating the flux of electric field through the Gaussian surface, the electric field will be due to

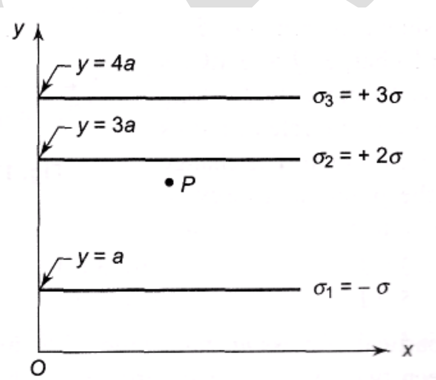


(a) $+q_3$ alone (b) $+ q_1$ and $+ q_3$ (c) $+ q_1 + q_3$ and $-q_2$ (d) $+q_1$ and $-q_2$

Q 95. Three infinite long plane sheets carrying uniform charge densities

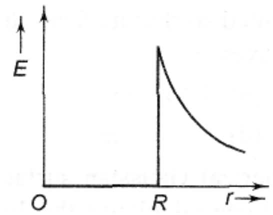
$$\sigma_1 = -\sigma,\ \sigma_2 = +2\sigma \text{ and } \sigma_3 = +3\sigma$$

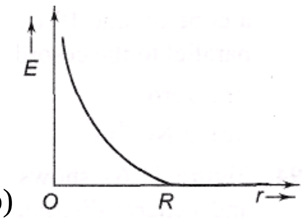
are placed parallel to the x-z plane at y = a, y = 3a and y = 4a as shown in Fig. The electric field at point P is

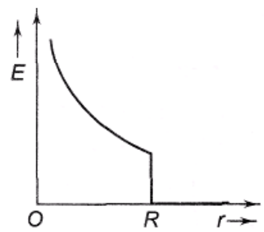


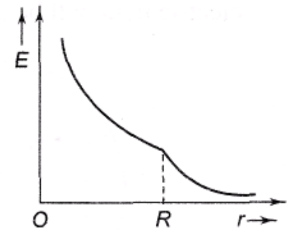
(a) zero (b) $-\frac{2\sigma}{\varepsilon_0}j$ (c) $-\frac{3\sigma}{\varepsilon_0}j$ (d) $-\frac{3\sigma}{\varepsilon_0}j$

Q 96. A metallic spherical shell of radius R has a charge - Q distributed uniformly on it. A point charge + Q is placed at the center of the shell. Which graph shown in Fig. represents the variation of electric field E with distance r from the centre of the shell?

(a) 

(b) 

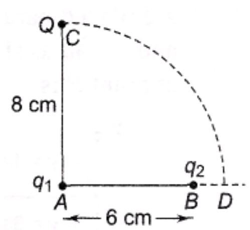
(c) 

(d) 

Q 97. A metallic sphere of radius R is charged to a potential V, The magnitude of the electric field at a distance r (> R) from the center of the sphere is

(a) $\frac{V}{r}$ (b) $\frac{Vr}{R^2}$ (c) $\frac{VR}{r^2}$ (d) zero

Q 98. Two point charges $q_1 = 1\ \mu C$ and $q_2 = 2\ \mu C$ are placed at points A and B 6 cm apart as shown in Fig. A third charge $Q = 5\ \mu C$ is moved from C to D along the arc of a circle of radius 8 cm as shown. The change in the potential energy of the system is



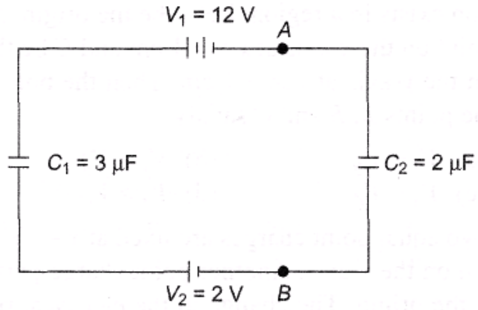
(a) 3.0 J (b) 3.6 J (c) 5.0 J (d) 7.2 J

Q 99. A partical of mass m and charge + q is midway between two fixed charged particles, each having a charge + q and at a distance 2L apart. The middle charge is displaced slightly along the line joining the fixed charges and released. The time period of oscillation is proportional to.

(a) $L^{1/2}$ (b) L (c) $L^{3/2}$ (d) L^2

Q 100. The potential difference between points A and B in the circuit shown in Fig. is

(a) 6 V (b) 2 V (c) 10 V (d) 14 V



Q 101. An electric field of 200 Vm^{-1} exists in the region between the plates of a parallel plate capacitor of plate separation 5 cm. The potential difference between the plates when a slab of dielectric constant 4 and thickness 1 cm is inserted between the plates is

(a) 7.5 V (b) 8.5 V (c) 9.0 V (d) 10 V

Q 102. A parallel plate capacitor is maintained at a certain potential difference. When a dielectric slab of thickness 3 mm is introduced between the plates, the plate separation had to be increased by 2 mm in order to maintain the same potential difference between the plates. The dielectric constant of the slab is

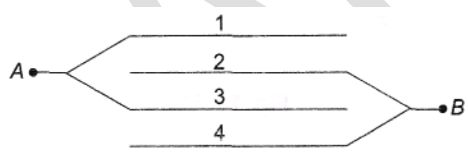
(a) 2 (b) 3 (c) 4 (d) 5

Q 103. A capacitor of capacitance C_1 is charged by connecting it to a battery. The battery is now removed and this capacitor is connected to a second uncharged capacitor of capacitance C_2. If the charge distributes equally on the two capacitors, the ratio of the total energy stored in the capacitors after connection to the total energy stored in them before connection is

(a) 1 (b) $\frac{1}{2}$ (c) $\frac{1}{\sqrt{2}}$ (d) $\frac{1}{3}$

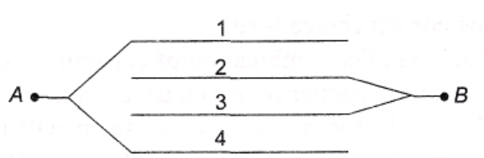
Q 104. Four metal plates numbered 1,2,3 and 4 are arranged as shown is Fig. The area of each plate is A and the separation between adjacent plates is d. The capacitance of the arrangement is

(a) $\frac{\varepsilon_0 A}{d}$ (b) $\frac{2\varepsilon_0 A}{d}$ (c) $\frac{3\varepsilon_0 A}{d}$ (d) $\frac{4\varepsilon_0 A}{d}$



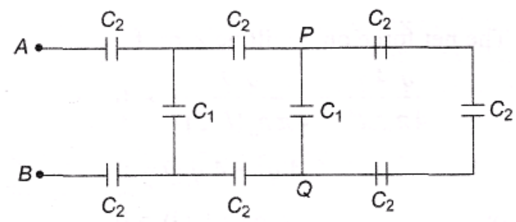
Q 105. Four metal plates numbered 1,2,3 and 4 are arranged as shown in Fig. The area of each plate is A and the separation between the plates is d. The capacitance of the arrangement is

(a) $\frac{\varepsilon_0 A}{d}$ (b) $\frac{2\varepsilon_0 A}{d}$ (c) $\frac{3\varepsilon_0 A}{d}$ (d) $\frac{4\varepsilon_0 A}{d}$



Q 106. The equivalent capacitance between points A and B in the network shown in Fig. is ($C_1 = 2\ \mu F$ and $C_2 = 3 \mu F$)

(a) 1 μF (b) 2 μF (c) 3 μF (d) 4 μF



Q 107. A capacitor of capacitance $C_1 = C$ is charged to a voltage V. It is then connected in parallel with a series combination of two uncharged capacitors of capacitances $C_2 = C$ and $C_3 = C$. The charge that will flow through the connecting wires is

(a) $\frac{CV}{3}$ (b) $\frac{2CV}{3}$ (c) CV (d) zero

Q 108. The capacitance of a sphere of radius R_1 is increased 3 times when it enclosed by an earthed sphere of radius R_2- The ratio R_2/R_1 is

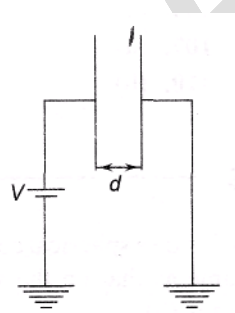
(a) 2 (b) $\frac{3}{2}$ (c) $\frac{4}{3}$ (d) 3

Q 109. A parallel plate capacitor of plate area A and plate separation d is charged by a battery of voltage V. The battery is then disconnected. The work needed to pull the plates to a separation 2d is

(a) $\frac{AV^2\varepsilon_0}{d}$ (b) $\frac{2AV^2\varepsilon_0}{d}$ (c) $\frac{AV^2\varepsilon_0}{2d}$ (d) $\frac{3AV^2\varepsilon_0}{2d}$

Q 110. One plate of a parallel plate capacitor of plate area A and plate separation d is connected to the positive terminal to a batter}' of the voltage V. The negative terminal of the battery and the other plate of the capacitor are earthed as shown in Fig. The charge that flows from the battery to the capacitor plates is

(a) zero (b) $\frac{\varepsilon_0 AV}{d}$ (c) $\frac{Vd}{\varepsilon_0 A}$ (d) $\frac{\varepsilon_0 AV}{2d}$



Answers

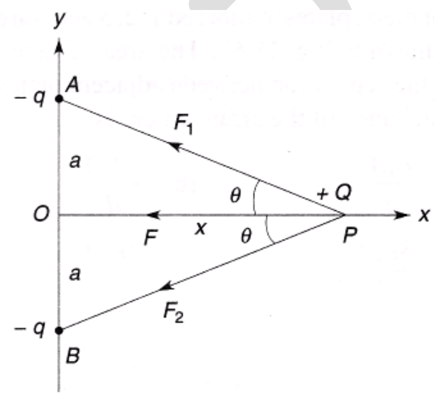
1. (b) 2. (d) 3. (b) 4. (a) 5. (d) 6. (d) 7. (c) 8. (b) 9. (d) 10. (c)
11. (c) 12. (a) 13. (d) 14. (a) 15. (c) 16. (c) 17. (a) 18. (b) 19. (d) 20. (c)
21. (b) 22. (d) 23. (b) 24. (c) 25. (d) 26. (a) 27. (d) 28. (c) 29. (d) 30. (b)

31. (b) 32. (d) 33. (b) 34. (a) 35. (c) 36. (b) 37. (d) 38. (d) 39. (d) 40. (a)
41. (c) 42. (b) 43. (c) 44. (d) 45. (d) 46. (c) 47. (c) 48. (c) 49. (b) 50. (b)
51. (c) 52. (a) 53. (d) 54. (a) 55. (a) 56. (b) 57. (a) 58. (a) 59. (d) 60. (d)
61. (c) 62. (b) 63. (b) 64. (a) 65. (d) 66. (c) 67. (d) 68. (d) 69. (d) 70. (a)
71. (b) 72. (d) 73. (a) 74. (b) 75. (b) 76. (d) 77. (d) 78. (b) 79. (b) 80. (c)
81. (d) 82. (b) 83. (b) 84. (d) 85. (a) 86. (b) 87. (b) 88. (c) 89. (b) 90. (c)
91. (a) 92. (d) 93. (a) 94. (c) 95. (c) 96. (a) 97. (c) 98. (b) 99. (c) 100. (a)
101. (b) 102. (b) 103. (b) 104. (c) 105. (c) 106. (a) 107. (a) 108. (b) 109. (c) 110. (b)

SOLUTIONS

1. The potential inside a spherical conductor is constant and is the same as that on the surface. Hence the correct choice is (b).

2. Let the charge Q be at P, with OP = x. The resultant force F is along the x-axis directed towards the origin. The charge Q moves to O, and acquires kinetic energy. It will cross O and move to -ve x-axis until it comes to rest. It is again attracted towards O and cross it and this process continues. Therefore charge Q executes periodic motion (see Fig.).



Let AP = BP = r. Then

$$F_1 = F_2 = \frac{qQ}{4\pi\varepsilon_0 r^2}$$

The resultant force on Q is

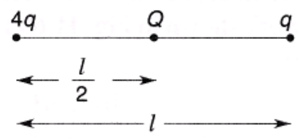
$$F = F_1\cos\theta + F_2\cos\theta = \frac{2qQ}{4\pi\varepsilon_0 r^2}\cos\theta$$

$$F = \frac{2qQx}{4\pi\varepsilon_0 r^3} = \frac{2qQ}{4\pi\varepsilon_0} = \frac{x}{(a^2+x^2)^{3/2}}$$

Thus F is not of the form F = kx (where k = constant) and hence the motion is not simple harmonic. Hence the correct choice is (d).

3. Each parallel combination of capacitors is equivalent to a capacitance of 100 μF connected in series. Potential drop across each of them will be 50 V. Charge Q = CV= $100 \times 10^{-6} \times 50 = 5 \times 10^{-3}$ C Hence the correct choice is (b).

4. Refer to Fig.



The net force on q will be zero if

$$\frac{q.4q}{4\pi\varepsilon_0 l^2} + \frac{qQ}{4\pi\varepsilon_0 (l/2)^2} = 0$$

$4q^2 + 4qQ = 0$

or $4\ q\ (q + Q) = 0$

$Q = -q$

Hence the correct choice is (a).

5. Electrostatic potential energy when the charges are 10 cm = 0.1 m apart is

$$W_1 = \frac{q_1 q_2}{4\pi\varepsilon_0 r} = \frac{12\times10^{-6}\times8\times10^{-6}}{4\pi\varepsilon_0\times0.1}$$

$$= \frac{96\times10^{-11}}{4\pi\varepsilon_0}$$

Potential energy when the charges are brought 4 cm closer, i.e., when they are 6 cm = 0.06 m apart is

$$W_2 = \frac{12\times10^{-6}\times8\times10^{-6}}{4\pi\varepsilon_0\times0.06} = \frac{16\times10^{-10}}{4\pi\varepsilon_0}$$

$\therefore$ Work done = $W_2 - W_1 = \dfrac{10^{-10}}{4\pi\varepsilon_0}(16 - 9.6)$

$= 9 \times 10^9 \times 10^{-10} \times 6.4$

$= 5.76$ J $= 5.8$ J

Hence the correct choice is (d).

6. The work done in carrying a charge round a closed path is zero. Hence the correct choice is (d).

7. When the capacitor is fully charged, no current flows in the 10 Ω resistor. The current in the circuit is

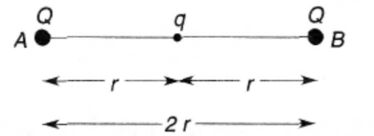
$$I = \frac{2.5}{2+0.5} = 1A$$

$\therefore$ Potential drop across 2Ω resistor = 2Ω × 1A = 2V. This is also the potential drop across the capacitor plates. Therefore, the charge on capacitor plates is

$Q = CV = 2 \times 10^{-6} \times 2 = 4 \times 10^{-6}$ C $= 4\ \mu$C

Hence the correct choice is (c).

8. Refer to Fig.



The three charges will be in equilibrium if no net force acts on each charge. The charge q is in equilibrium because the forces exerted on q by charge Q at A and charge Q at B are equal and opposite. The charge Q at A will be in equilibrium if the forces exerted on it by charge q and charge Q at B are equal and opposite, i.e. if

$$\frac{qQ}{4\pi\varepsilon_0 r^2} = -\frac{Q\times Q}{4\pi\varepsilon_0 (2r)^2}$$

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

Similarly, charge Q at B will be in equilibrium if $q = -\frac{Q}{4}$. Hence the correct choice is (b).

9. Electric field $E = -\frac{dV}{dx} = -\frac{d}{dx}(5 + 4x^2) = -8x$

Force on charge (-q)= -q E = + 8qx

At x = 0.5m,force = $8 \times 2 \times 10^{-6} \times 0.5 = 8 \times 10^{-6}$N

Hence the correct choice is (d).

10. Original capacitance of the parallel combination of C and 2C = C + 2C = 3C. Total charge Q = 3CV. When the capacitor C is filled with dielectric, its capacitance becomes KC. Therefore, the capacitance of the combination after the capacitor C is filled with dielectric, C' = KC + 2C = (K+ 2)C. Since the charge remains the same, Q = 3CV, the potential difference across the capacitors will be

$$\frac{Q}{C'} = \frac{3CV}{(K+2)C} = \frac{3V}{K+2}$$

Hence the correct choice is (c).

11. The capacitance of the capacitor is $C = \varepsilon_0 A/x$ where x is the distance between the plates. The energy stored in the capacitor is

$$U = \frac{1}{2}CV^2 = \frac{\varepsilon_0 AV^2}{2x}$$

Differentiating w.r.t x we get

$$\frac{dU}{dx} = \frac{\varepsilon_0 AV^2}{2}\frac{d}{dx}\left(\frac{1}{x}\right) = -\frac{\varepsilon_0 AV^2}{2x^2}$$

The force of attraction between the plates is

$$F = -\frac{dU}{dx} = \frac{\varepsilon_0 AV^2}{2x^2} \qquad \text{(i)}$$

Now $\quad Q = CV = \dfrac{\varepsilon_0 AV}{x} \qquad$ or $\qquad V = \dfrac{Qx}{\varepsilon_0 A} \qquad$ (ii)

Using (ii) in (i) we get

$$F = \frac{Q^2}{2\varepsilon_0 A}$$

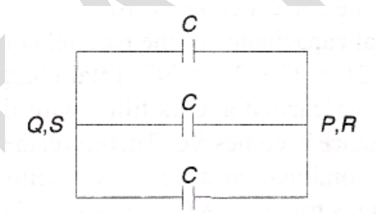
Hence the correct choice is (c).

12. The last three capacitors on the right, each of capacitance C = 9 μF are in series and are equivalent to a capacitance C'' given by

$$\frac{1}{C'} = \frac{1}{9} + \frac{1}{9} + \frac{1}{9} = \frac{1}{3} \text{ or } C' = 3\mu F.$$

Since C is in parallel with C_1, the equivalent capacitance of the last part of the network is C'' = C' + C_1 = 3 + 6 = 9 μF. Continuing this process of calculation towards the left, we notice that we are finally left with the combination whose equivalent capacitance is 3μF. Hence the correct choice is (a).

13. The three capacitors can be rearranged as shown in Fig. The capacitance between points P and S or between points Q and R = sum of the three capacitances = 3C = 9 μF. Hence the correct choice is (d).



14. C = 100 pF = 100×10^{-12} F = 10^{-10} F

Let the number of sheets of foils required be n. They will form (n - 1) capacitors. If K is the dielectric constant of the dielectric, the capacitance is given

$$C = \frac{K\varepsilon_0 (n-1)A}{d}$$

Or $\quad n - 1 = \dfrac{Cd}{K\varepsilon_0 A} = \dfrac{Cd}{K.4\pi\varepsilon_0} \cdot \dfrac{4\pi}{\pi r^2}$

$$= \frac{4Cd}{K.4\pi\varepsilon_0 r^2}$$

$$= \frac{4 \times 10^{-10} \times 1 \times 10^{-3} \times 9 \times 10^{9}}{4 \times (1.0 \times 10^{-2})^2} = 9$$

or $\quad$ n = 10

Hence the correct choice is (a).

15. If R is the radius of the big drop, we have

$$\frac{4\pi R^3}{3} = 1000 \times \frac{4\pi r^3}{3}$$

which gives R = 10 r. The electrical potential of each droplet is

$$v = \frac{q}{4\pi\varepsilon_0 r}$$

and that of the big drop is

$$V = \frac{1000q}{4\pi\varepsilon_0 R}$$

$$\therefore \qquad \frac{V}{v} = \frac{1000r}{R} = 100 \qquad \text{(R = 10r)}$$

Hence the correct choice is (c).

16. If A is the area of each plate, the capacitance of the air capacitor shown in Fig.(a) is

$$C_0 = \frac{\varepsilon_0 A}{d}, \text{ where } C_0 = 2\ \mu F \text{ (given).}$$

The capacitance of air capacitor in Fig. (b) is

$$C_1 = \frac{\varepsilon_0 A}{d/2} = \frac{2\varepsilon_0 A}{d} = 2C_0$$

The capacitance of the dielectric filled capacitor in Fig. (b) is

$$C_2 = \frac{k\varepsilon_0 A}{d/2} = \frac{2k\varepsilon_0 A}{d} = 2kC_0$$

where k is the dielectric constant. Now capacitors C_1 and C_2 are in series. Therefore, the capacitance C of the capacitor shown in Fig. (b) is given by

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{2C_0} + \frac{1}{2kC_0} = \frac{(k+1)}{2C_0 k}$$

Or $$C = \frac{2C_0 k}{(k+1)} = \frac{2 \times 2\mu F \times 3}{(3+1)} = 3\mu F$$

Hence the correct choice is (c).

17. If A is the area of each plate, the capacitance of the air-filled capacitor shown in Fig. (a) is

$$C_0 = \frac{\varepsilon_0 A}{d}, \text{ where } C_0 = 2\mu F \text{ (given).}$$

The capacitance of air capacitor in Fig. (b) is

$$C_1 = \frac{\varepsilon_0 A/2}{d} = \frac{\varepsilon_0 A}{2d} = \frac{C_0}{2}$$

The capacitance of dielectric filled capacitor in Fig. (b)is

$$C_2 = \frac{k\varepsilon_0 A/2}{d} = \frac{k\varepsilon_0 A}{2d} = \frac{kC_0}{2}$$

Since C_1 and C_2 are in parallel, the capacitance C of the capacitor shown in Fig. (b) is

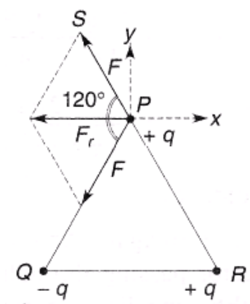
$$C = C_1 + C_2 = \frac{C_0}{2} + \frac{kC_0}{2}$$

$$= \frac{C_0}{2}(1+k) = \frac{2\mu F}{2}(1+3) = 4\mu F$$

Hence the correct choice is (a).

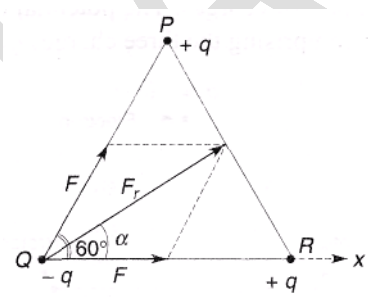
18. Refer to Fig. The charge at Q exerts an attractive force F on charge at P along PQ. The charge at R exerts a repulsive on charge at P along PS of magnitude F. The angle between these two forces is 120°. From parallelogram law, the magnitude of the resultant force is

$$F^2{}_1 = F^2 + F^2 + 2F^2 \cos 120° = 2F^2 - F^2 = F^2$$



or $F_r = F$. As shown in the figure, the direction of the resultant force is along the negative x-direction. Hence the correct choice is (b).

19. Refer to Fig. Charges at P and R both exert an attractive force on charge at Q. The angle between these forces is 60°. The resultant force has a magnitude



$$F^2 = F^2 + F^2 + 2F^2 \cos 60°$$

$$= 2F^2 + F^2 = 3F^2$$

$\therefore \quad F_r = \sqrt{3}F$

The angle α is given by

$$\tan\alpha = \frac{F\sin 60^o}{F + F\cos 60^o} = \frac{1}{\sqrt{3}}$$

$\therefore \quad \alpha = 30°.$

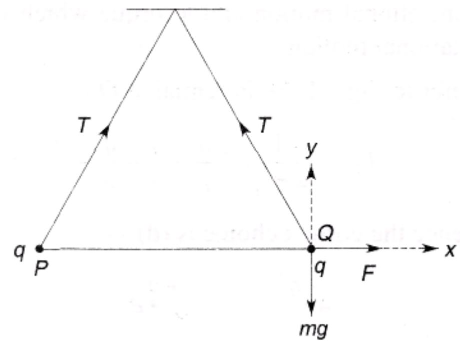
Hence the correct choice is (d).

20. Refer to Fig. Let us consider forces on a ball, say, Q. Three forces act on it: (i) tension T in the thread, (ii) force mg due to gravity and (iii) force F due to Coulomb repulsion along +ve x-direction. For equilibrium, the sum of the x and y components of these forces must be zero, i.e.

$$T \cos 60° - F = 0$$

and $\qquad T \sin 60° - mg = 0$

These equations give $F = mg \cot 60° = \frac{\sqrt{3}}{10} \times 10^{-3} \times 10 \times \frac{1}{\sqrt{3}} = 10^{-3}$ N. Now

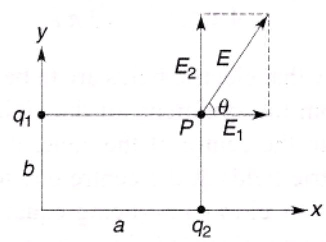


$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2}$$

Putting $F = 10^{-3}$ N, r = 0.3 m and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$, we get $q = 10^{-7}$ coulomb.

21. Refer to Fig. The electric field E_1 at (a, b) due to q_1 has a magnitude

$$E_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{a^2}$$



and is directed along + x-axis. The electric field E_2 at (a, b) due to q_2 has a magnitude

$$E_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{b^2}$$

and is directed along +y-axis. The angel θ subtended by the resultant field E with the x-axis is given by

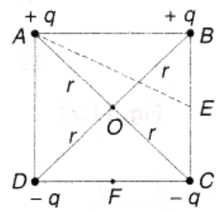
$$\tan\theta = \frac{E_2}{E_1} = \frac{q_2}{q_1} \cdot \frac{a^2}{b^2} = \frac{1}{2} \times \left(\frac{2}{1}\right)^2 = 2$$

Hence the correct choice is (b).

22. The correct choice is (d). The electric field E exerts a force qE on charge + q and a force - qE on charge - q of the dipole. Since these forces are equal and opposite, they add upto zero.
23. The correct choice is (b). A torque acts on the dipole which tends to align it along the field.
24. The correct choice is (c). In a non-uniform electric field, a dipole experiences a force which gives it a translational motion and a torque which gives it a rotational motion.
25. Refer to Fig. Potential at O is

$$V_0 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r}+\frac{q}{r}-\frac{q}{r}-\frac{q}{r}\right)=0$$

Hence the correct choice is (d).

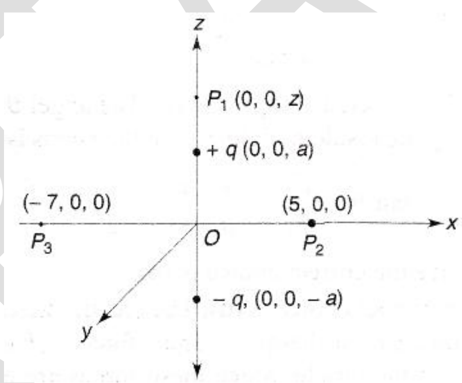


26. The distance of a vertex from the centre of the cube of side b is $r = \sqrt{3}\,b/2$. Now the potential due to charge q at the centre is $q/4\pi\varepsilon_0 r$. Hence the potential due to the arrangement of eight charges (each of magnitude q) at the centre is

$$V = \frac{8q}{4\pi\varepsilon_0 r} = \frac{4q}{\sqrt{3}\pi\varepsilon_0 b}$$

27. We know that electric fields are to be added vectorially. From the symmetry of the eight charges with respect to the centre of the cube, it is evident that the electric fields at the centre due to two opposite charges cancel in pairs (being equal and opposite). Hence the net electric field at the centre of the cube will be zero.

28. Refer to Fig. The distance of point P_1 from charge + q is $r_1 = z - a$ and from charge - q is $r_2 = z + a$.



$$\therefore \text{ Potential at } P_1 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r_1}-\frac{q}{r_2}\right)$$

$$= \frac{q}{4\pi\varepsilon_0}\cdot\frac{r_2 - r_1}{r_1 r_2}$$

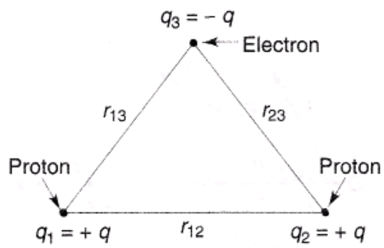
$$= \frac{2qa}{4\pi\varepsilon_0 (z^2 - a^2)},$$

which is choice (c).

29. Refer to Fig. again. Any point on the perpendicular bisector passing through the centre of the dipole is at the same distance from the two charges. Hence the potentials at point $P_2(5, 0, 0)$ and that at point P_3 (- 7, 0, 0) are zero. Since P_2 and P_3 are at the same potential (zero), the potential

difference between them is zero. Hence no work will be done in moving a charge from P_2 to P_3, The answer will not change if the path of the charge is changed because the work done is independent of the path taken.

30. Refer to Fig. The total potential energy of the arrangement of charges is the sum of the energies of each pair of charges. The potential energy of the system comprising the three charges q_1, q_2 and q_3 is



$$U = W_1 + W_2 + W_3$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right) \qquad \text{(i)}$$

Here $q_1 = q_2 = q = +1.6 \times 10^{-19}$ C (proton), $q_3 = -q = -1.6 \times 10^{-19}$ C (electron), $r_{12} = 1.5$ Å $= 1.5 \times 10^{-10}$ m, $r_{13} = r_{23} = 1$ Å $= 1 \times 10^{-10}$ m and $1/4 n\varepsilon_0 = 9 \times 10^9$ Nm^2C^{-2}. Thus

$$U = \frac{-4}{3}.\frac{q^2 \times 10^{10}}{4\pi\varepsilon_0} \text{ joule}$$

$$= -\frac{4}{3}.\frac{q \times 10^{10}}{4\pi\varepsilon_0} \text{eV}$$

$$= -\frac{4 \times 1.6 \times 10^{-19} \times 10^{10} \times 9 \times 10^9}{3}$$

$$= 19.2\text{eV}$$

31. Charge on electron $(-e) = -1.6 \times 10^{-19}$ C, charge on proton $(e) = 1.6 \times 10^{-19}$ C, separation $r = 0.53$ Å $= 0.53 \times 10^{-10}$ m. If the zero of potential energy is taken to be at infinite separation, the potential energy of the electron-proton system is

$$U = -\frac{1}{4\pi\varepsilon_0}.\frac{e^2}{r} \text{ joule}$$

$$= -\frac{1}{4\pi\varepsilon_0}.\frac{e}{r}\text{eV}$$

$$= \frac{9 \times 10^9 \times (1.6 \times 10^{-19})}{0.53 \times 10^{-10}} = -27.2\,\text{eV}$$

Hence the correct choice is (b).

32. If the electron was at rest, 27.2 eV of the energy will have to be supplied (or $27.2 \times 1.6 \times 10^{-19}$ J of work will have to be done) to free the electron from the attraction of the proton and remove it to infinity. Since the electron is moving (round the proton) with a kinetic energy = U/2 = 1/2 × (-

27.2) = - 13.6 eV, the electron itself is supplying an energy of 13.6 eV due to centrifugal action. Hence the minimum amount of work required to free the electron = 27.2 - 13.6 = 13.6 eV = 13.6 × 1.6 × 10^{-19} = 2.2 × 10^{-18} J. Hence the correct choice is (d).

33. The potential energy of electron-proton system at a separation of 1.06 Å = half that at a separation of 0.53 Å = half of - 27.2 eV = - 13.6 eV. If the zero of potential energy at a separation of 1.06 Å is taken to be zero (instead of- 13.6 eV), the potential energy of the electron-proton system would be

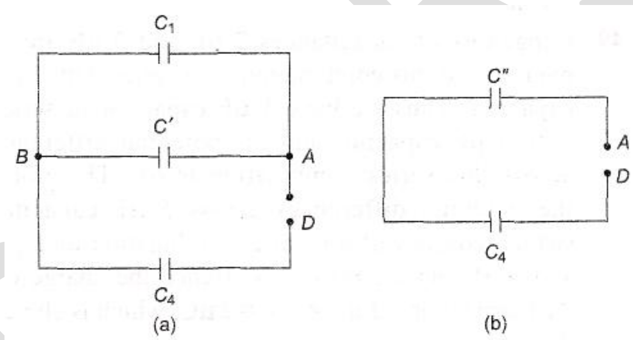
= - 27.2 - (- 13.6) = - 13.6 eV, which is choice (b).

34. Since the potential energy of the system is now - 13.6 eV, the energy supplied by the electron itself is 13.6 eV by virtue of its orbital motion round the proton. Hence the minimum work to pull the electron from the atom will be zero.

35. The series combination of C_2 and C_3 is equivalent to a capacitance C' given by

$$\frac{1}{C'} = \frac{1}{C_2} + \frac{1}{C_3}$$

Or $$C' = \frac{C_2C_3}{C_2 + C_3} = \frac{200 \times 200}{200 + 200} = 100\text{pF}$$



Therefore the circuit reduces to the one shown in Fig. (a). The equivalent capacitance between points A and B is

$C'' = C_1 + C = 100 + 100 = 200$ pF

The circuit may be further simplified to that in Fig. (b). The equivalent capacitance C of the entire network, i.e., between points A and D, is now that of the series combination of C'' and C_4. Thus

$$\frac{1}{C} = \frac{1}{C''} + \frac{1}{C^4} = \frac{1}{200} + \frac{1}{100}$$

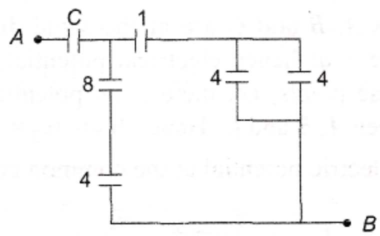
$$= \frac{3}{200} \text{ or } C = \frac{200}{3}\text{ pF}$$

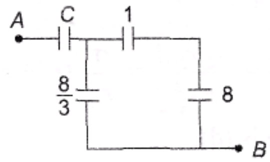
Hence the correct choice is (c).

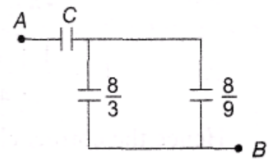
36. The series combination of 6 and 12 is equivalent to 4 and the parallel combination of 2 and 2 is also equivalent to 4. Therefore the network can be simplified as shown in Fig.

The parallel combination of 4 and 4 is equivalent to 8 and the series combination of 8 and 4 is equivalent to 8/3. Thus the combination in Fig.1 reduces to that in Fig.2

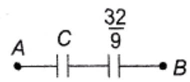
The series combination of 1 and 8 in Fig.2 yields 8/9 as shown in Fig. 3

(1) 

(2) 

(3) 

Now 8/3 and 8/9 are in parallel and their equivalent is 32/9. Therefore, the network finally reduces to that in Fig. 4.

(4) 

Since the total capacitance between A and B is to be (i.e. 1μF), we have

$$1 = \frac{1}{C} + \frac{9}{32}$$

$\Rightarrow\ C = \dfrac{32}{23}$ μF. Hence the correct choice is (b).

37. Charge Q_1 and $C_1 = C_1V_1 = 2 \times 10^{-6} \times 100 = 2 \times 10^{-4}$ C. Charge Q_2 on $C_2 = C_2V_2 = 4 \times 10^{-6} \times 50 = 2 \times 10^{-4}$ C. Total charge $Q = Q_1 + Q_2 = 4 \times 10^{-4}$ C. Total energy before connection is

$$E_1 = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$$

$$= \frac{1}{2} \times 2 \times 10^{-6} \times (100)^2 + \frac{1}{2} \times 4 \times 10^{-6} \times (50)^2$$

$$= 1.5 \times 10^{-2}\ \text{J}$$

The common potential difference F after connection is given by

$$C_1V + C_2V = Q \qquad \text{or} \qquad V = \frac{Q}{C_1 + C_2}$$

Therefore, total energy after connection is

$$E_2 = \frac{1}{2}(C_1 + C_2)V^2 = \frac{1}{2} \times \frac{Q^2}{(C_1 + C_2)}$$

$$= \frac{1}{2} \times \frac{(4 \times 10^{-4})^2}{(2+4) \times 10^{-6}} = 1.33 \times 10^{-2}\ \text{J}$$

Loss of energy = $E_1 - E_2 = 0.17 \times 10^{2}$ J. Hence the correct choice is (d).

38. Points A, B and C are at the same distance from charge + q; hence electrical potential is the same at these points, i.e. there is no potential difference between A, B and C. Hence $W_1 = W_2 = 0$.

39. The electric potential at the common centre is

$$V = \frac{q_1}{4\pi\varepsilon_0 r_1} + \frac{q_2}{4\pi\varepsilon_0 r_2}$$

Now $\quad \sigma = \dfrac{q_1}{4\pi r_1^2} = \dfrac{q_2}{4\pi r_2^2}$

$$\therefore \qquad V = \frac{1}{\varepsilon_0}\left[\frac{q_1 r_1}{4\pi r_1^2} + \frac{q_2 r_2}{4\pi r_2^2}\right] = \frac{\sigma}{\varepsilon_0}(r_1 + r_2)$$

Hence the correct choice is (d).

40. If q is charge on the sphere, the electric field on its surface is

$$E = \frac{q}{4\pi\varepsilon_0 r}$$

But $\sigma = \frac{q}{4\pi r}$. Therefore q = 4 π r^2 σ. Hence

$$E = \frac{4\pi r^2 \sigma}{4\pi\varepsilon_0 r^2} = \frac{\sigma}{\varepsilon_0}$$

Thus the correct choice is (a).

41. The correct choice is (c)

42. The correct choice is (b).

43. If the radius of a bubble is increased by a factor n, its capacitance is also increased by a factor n, i.e. C' = nC. Since the charge Q on the bubble remains unchanged, we have

$$Q = CV = C'V'$$

Or $$V' = \frac{CV}{C'} = \frac{CV}{nC} = \frac{V}{n}$$

Hence the correct choice is (c).

44. If p is the density of a small drop and r its radius, then the mass of each small drop is m = $\frac{4\pi}{3} r^3 \rho$.

If n such drops coalesce to form a big drop of radius R, then the mass of the big drop is nm = $\frac{4\pi}{3} R^3 \rho$.

Hence R = $n^{1/3}$ r. Now, the capacitance of a sphere is proportional to its radius. Hence the capacitance of the big drop will be C' = $n^{1/3}$ C. Hence the correct choice is (d).

45. If Q is the charge on each small drop, charge on the big drop is Q' = nQ. Now Q' = C'V = Q = CV. Therefore

$$\frac{V'}{V} = \frac{Q'}{Q} \times \frac{C}{C'} = \frac{n}{n^{1/3}} = n^{2/3}$$

Hence the correct choice is (d).

46. $E = \frac{1}{2}CV^2, E' = \frac{1}{2}C'V'$. Therefore,

$$\frac{E'}{E} = \frac{C'}{C} \cdot \frac{V'^2}{V} = n^{1/3} \times (n^{2/3})^2 = n^{5/3}$$

Hence the correct choice is (c).

47. The combination is equivalent to(10 - 1) = 9 capacitors, each of capacitance C connected in parallel. Hence the correct choice is (c).

48. The total capacitance across power supply = $\frac{6}{8}$ μF. The charge on 2 μF capacitor or 3 μF capacitor $= 9\times\frac{6}{8} = 6\mu C$. So the charge on each 1 μF capacitor = 3 μC. Therefore, potential difference across each 1 μF capacitor = charge/capacitance = 3μC/1μF = 3 volts.

49. Capacitors of capacitances 2 μF and 3 μF are in parallel and this combination is in series with 1 μF capacitor. Thus we have 1 μF capacitor in series with 5 μF capacitor and the potential difference across this series combination is 6V. Therefore, the potential differences across 5 μF capacitor (which consists of a parallel combination of 2 μF and 3 μF capacitors) is 1 V. Hence the charge on 2 μF capacitor = 2 μF × 1 V = 2 μC, which is choice (b).

50. Capacitors 1 μF, 2 μF and 3 μF are in parallel, their total capacitance is 6 μF. Thus, we have three capacitors in series each of capacitance 6 μF across the 12 V power supply. So the potential drop across each is 12/3 = 4 V. This is also the potential across 1 μF capacitor and 2 μF capacitor and 3 μF capacitor, because they are in parallel. Therefore, charge on 2 μF capacitor = 2 μF × 4V = 8 μC. Hence the correct choice is (b).

51. The distance of the point of intersection of diagonals = side of the hexagon = a. The potential at this point due to each charge = $\frac{1}{4\pi\varepsilon_0}.\frac{q}{a}$. Therefore, total potential = $\frac{1}{4\pi\varepsilon_0}.\frac{6q}{a}$ which is choice (c).

52. The net electric field at the point of intersection of diagonals is zero because the electric field at this point due to equal charges at opposite corners with cancel each other in pairs.

53. If C is the capacitance of the air-filled capacitor, the total charge on its plates, before connection, is Q = CV. After it is connected with an uncharged capacitor, let V' be the common potential and Q_1 be the charge on capacitor C and Q_2 on the other capacitor $Q_1 = V' C$ and $Q_2 = V' kC$. Also $Q = Q_1 + Q_2$. Therefore,

$$CV = V' C + V' kC$$

or $$V = V' (1 + k)$$

or $$V' = \frac{V}{(1+k)}$$. Hence the correct choice is (d).

54. Energy stored in the capacitor is

$$\frac{1}{2}CV^2 = \frac{1}{2} \times C \times (200)^2 = 2 \times 10^4 \times C \text{ joule}$$

Energy appearing as heat in the block is

$$m\, c\, \theta = 0.1 \times 2.5 \times 102 \times 0.4 = 10 \text{ J Therefore,}$$

$$2 \times 10^4 \times C = 10$$

or $$C = 5 \times 10^{-4} F = 500\mu F$$

55. The force of repulsion between the two parts is given by

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q(Q-q)}{r^2}$$

For F to be maximum, $\frac{dF}{dq} = 0$, i.e.

$$\frac{d}{dq}\left[\frac{1}{4\pi\varepsilon_0} \cdot \frac{q(Q-q)}{r^2}\right] = 0$$

Since r is fixed, we have

$$\frac{d}{dq}[q(Q - q)] = 0 \text{ or } 1(Q - q) + q(0 - 1) = 0 \text{ or } \frac{q}{Q} = \frac{1}{2}$$

Hence the correct choice is (a).

56. For points on the surface of the sphere or outside the sphere, a charged sphere behaves as if the charge is concentrated at its center. Therefore, the potential at the surface of the sphere is given by

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{R}$$, which is choice (b).

57. At points inside a charged metallic sphere, i.e. for $r < R$, the potential is zero. Hence the correct choice is (a).

58. $E = -\frac{dV}{dx} i$ where i is a unit vector along the positive x-axis. Hence E at a point whose x-coordinate is x = 1 m is

$$E = -\frac{d}{dx}(4x^2)i = -8xi = -8i \text{ Vm}^{-1}.$$

The negative sign shows that E is along the negative x-axis. Hence the correct choice is (a).

59. If a symmetrical closed surface has n identical surfaces and a charge Q is placed at its centre, then the flux through each face = $\frac{Q}{n\varepsilon_0}$. For a cube n = 6.

Hence the correct choice is (d).

60. Since a dipole consists of two equal and opposite charges, the net charge of a dipole is zero. Hence the correct choice is (d).

61. The correct choice is (c).

62. Let C be the capacitance of each capacitor. For parallel combination, the net capacitance is $C_1 = nC$. Also $V_1 = V$. Therefore, the energy stored in the parallel combination is

$$U_1 = \frac{1}{2}C_1V_1^2 = \frac{1}{2} \times nC \times V^2 = \frac{1}{2}nCV^2$$

For series combination, we have $C_2 = C/n$ and $V_2 = nV$. Therefore, the energy stored in the series combination is

$$U_2 = \frac{1}{2}C_2V_2^2 = \frac{1}{2} \times \frac{C}{n} \times (nV)^2 = \frac{1}{2}nCV^2$$

Hence the correct choice is (b).

63. There will be no loss of energy if the potential of the spheres is the same i.e. if

$$V = \frac{q}{4\pi\varepsilon_0 r} = \frac{Q}{4\pi\varepsilon_0 R}$$

Or $\frac{q}{r} = \frac{Q}{R}$. Hence the correct choice is (b).

64. r = (2i +3j + k) - (i + j - k) = (i + 2j + 2k)m.

The magnitude of r is

$$r = \sqrt{1^2 + 2^2 + 2^2} = \sqrt{1+4+4} = 3\text{m}$$

$$\therefore \quad F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

$$= \frac{9\times10^9 \times 10^{-6} \times 10^{-6}}{(3)^2} = 10^{-3}\,\text{N}$$

Hence the correct choice is (a).

65. Let the electric field be zero at a distance x from charge 4q. Then

$$\frac{1}{4\pi\varepsilon_0} \cdot \frac{4q}{x^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r-x)^2}$$

or 2(r - x) - x or x - 2r/3 which is choice (d),

66. Initial capacitance $C = \frac{\varepsilon_0 A}{d}$. When a metal plate of thickness t is introduced, the capacitance becomes $C' = \frac{\varepsilon_0 A}{(d-t)}$. Given C' = 4.5 C

Thus $\frac{\varepsilon_0 A}{d-t} = \frac{\varepsilon_0 A}{d} \times \frac{9}{2}$

which gives 9(d - t) = 2d or t = $\frac{7d}{9}$ which is choice (c).

67. $U_1 = \frac{1}{2}CV^2, U_2 = \frac{1}{2}C(1.2V)^2 = \frac{1}{2}CV^2 \times 1.44$

$\therefore \quad \frac{U_2 - U_1}{U_1}$ × 100 = (1.44 - 1) × 100 = 44% Thus the correct choice is (d).

68. $U_1 = \frac{1}{2}CV^2$. Therefore, δU = CV δV. Therefore

$$\frac{dU}{U} \times 100 = \frac{CV\delta V}{\frac{1}{2}CV^2} \times 100 = \frac{2\delta V}{V} \times 100$$

$$= \frac{2 \times 0.1 \times 100}{100} = 0.2\%$$

Hence the correct choice is (d).

69. Given $\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}=\frac{1}{2}$ (1)

and $\frac{1}{C_1}+\frac{1}{C_2}=\frac{1}{3}$ (2)

Using (2) in (1), we have

$\frac{1}{3}+\frac{1}{C_3}=\frac{1}{2}$ which gives $C_3 = 6\ \mu F$ Hence the correct choice is (d).

70. Given $C_1 + C_2 = \frac{C_1C_2}{C_1+C_2}\times\frac{25}{6}$

or $6(C_1 + C_2)^2 = 25\ C_1C_2$

or $6C_1^2+6C_2^2+12C_1C_2=25C_1C_2$

or $6C_1^2+6C_2^2-13C_1C_2=0$

Let $C_2 = xC_1$. Then, we have

$6C_1^2+6x^2C_1^2-13xC_1^2=0$

or $6x^2 - 13x + 6 = 0$

which gives $x=\frac{3}{2}$ or $\frac{2}{3}$. Since $C_2 > C_1$, $x=\frac{3}{2}$ is not possible. Hence the correct choice is (a).

71. The system be in equilibrium if the net force on charge q at one vertex due to charges q at the other two vertices is equal and opposite to the force due to charge Q at the centroid. i.e. (here a is the side of the triangle)

$$-\frac{\sqrt{3}q^2}{4\pi\varepsilon_0 a^2}=\frac{Qq}{4\pi\varepsilon_0\left(\frac{a}{\sqrt{3}}\right)^2}$$

which gives $Q=-\frac{q}{\sqrt{3}}$. Hence the correct choice is (b).

72. Charge will flow from A to B until their potentials become equal. If charge q flows from A to B, then

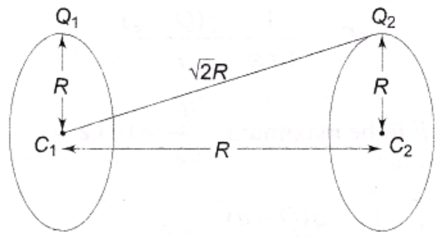
$$\frac{Q-q}{4\pi\varepsilon_0 a}=\frac{q}{4\pi\varepsilon_0 b}$$

or $Q-q=\frac{a}{b}q$ which gives $q=\frac{bQ}{a+b}$. Hence charge left on A = Q - q = Q - $\frac{bQ}{a+b}=\frac{aQ}{a+b}$.

Hence the correct choice is (d).

73. When any additional negative charge is given to a hollow spherical shell, the potential on its surface falls, but the potential at each point within the shell also falls by the same amount. Hence the potential difference between the given surfaces remains unchanged. Thus the correct choice is (a).

74. Refer to Fig.



Potential at C_1 is

$$V_1 = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1}{R} + \frac{Q_2}{\sqrt{2}R}\right)$$

Potential at C_2 is

$$V_2 = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_2}{R} + \frac{Q_1}{\sqrt{2}R}\right)$$

$\therefore$ Work done = $q(V_1 - V_2)$

$$= \frac{1}{4\pi\varepsilon_0}\left[\left(\frac{Q_1}{R} + \frac{Q_2}{\sqrt{2}R}\right) - \left(\frac{Q_2}{R} + \frac{Q_1}{\sqrt{2}R}\right)\right]$$

$$= \frac{1}{4\pi\varepsilon_0\sqrt{2}R}(Q_1 - Q)(\sqrt{2} - 1)$$

Hence the correct choice is (b).

75. Force F = qE. Therefore, acceleration a = qE/m. Now distance moved in time t is

$$s = \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{qE}{m}\right)t^2.$$

For electron : $s_e = \frac{1}{2}\left(\frac{qE}{m_e}\right)t_1^2$

For proton: $s_p = \frac{1}{2}\left(\frac{qE}{m_p}\right)t_2^2$

Given $s_e = s_p$. Therefore

$$\frac{t_1^2}{m_e} = \frac{t_2^2}{m_p} \text{ or } \frac{t_2}{t_1} = \left(\frac{m_p}{m_e}\right)^{1/2}$$

Hence the correct choice is (b).

76. The electric field is always perpendicular to the surface of a conductor. On the surface of a metallic solid sphere, the electric field is perpendicular to the surface and directed towards the centre of the sphere. Hence the correct choice is (d).

77. $V = \frac{1}{4\pi\varepsilon_0}\left\{\frac{q}{x_0} + \frac{q}{3x_0} + \frac{q}{5x_0} + \text{....upto infinity}\right\}$

$$+\frac{1}{4\pi\varepsilon_0}\left\{\frac{-q}{2x_0}+\frac{-q}{4x_0}+\frac{-q}{5x_0}+....\text{upto infinity}\right\}$$

$$=\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{x_0}\left\{1-\frac{1}{2}+\frac{1}{3}-\frac{1}{4}+\frac{1}{5}-\frac{1}{6}....\text{upto infinity}\right\}$$

$$=\frac{1}{4\pi\varepsilon_0 x_0}\ln\ (1+1)=\frac{q\ln(2)}{4\pi\varepsilon_0 x_0}$$

Hence the correct choice is (d).

78. Since the hypotenuse side of triangle = $\sqrt{2}$ a, the net electrostatic energy is

$$U=\frac{1}{4\pi\varepsilon_0}\left(\frac{Qq}{a}+\frac{Qq}{\sqrt{2}a}+\frac{qq}{a}\right)$$

For U= 0, we require

$$\frac{Qq}{a}+\frac{Qq}{\sqrt{2}a}+\frac{q^2}{a}=0$$

which gives $Q=-q\left(\frac{\sqrt{2}}{\sqrt{2}+1}\right)=\frac{-2q}{2+\sqrt{2}}$

Hence the correct choice is (b).

79. Q_1 = CV and Q_2 = (2C) × (2V) = 4CV. Since the capacitors are connected in parallel such that the plates of opposite polarity are connected together, the common potential is

$$V'=\frac{Q_2-Q_1}{C_1+C_2}=\frac{4CV-CV}{C+2C}=V$$

Equivalent capacitance C' = C + 2C = 3C. Therefore, the final energy of the configuration is

$$U'=\frac{1}{2}C'V'^2=\frac{1}{2}\times 3C\times V^2=\frac{3}{2}CV^2,$$

which is choice (b).

80. The insertion of the dielectric slab decreases the electric field without changing its direction. The electric potential increases as we go from the negative to the positive plate. Hence the correct choice is (c).

81. Within the plates electric fields due to charges Q_1 and Q_2 are

$$E_1=\frac{Q_1}{2\varepsilon_0 A}\text{ and } E_2=\frac{Q_2}{2\varepsilon_0 A}$$

As these fields are in opposite directions and $Q_1 > Q_2$, the net electric field within the plates is

$$E = E_1 - E_2 = \frac{1}{2\varepsilon_0 A}(Q_1 - Q_2)$$

Hence $V=Ed=\frac{d}{2\varepsilon_0 A}(Q_1-Q_2)=\frac{Q_1-Q_2}{2C}$ which is choice (d).

82. When switch S_3 is closed, the potential difference across C_1 and C_2 will become equal to the average of V_1 and V_2, i.e. (30 + 20)/2 = 25 V. Hence the correct choice is (b).

83. We have $C_1 = \frac{(A/2)\varepsilon_0 K_1}{(d/2)} = \frac{A\varepsilon_0 K_1}{d}$

$$C_2 = \frac{(A/2)\varepsilon_0 K_2}{(d/2)} = \frac{A\varepsilon_0 K_2}{d} \text{ and}$$

$$C_3 = \frac{A\varepsilon_0 K_3}{(d/2)} = \frac{2A\varepsilon_0 K_3}{d}$$

The capacitors C_1 and C_2 are in parallel and their equivalent capacitance is

$$C' = C_1 + C_2 = \frac{A\varepsilon_0}{d}(K_1 + K_2)$$

This combination is in series with C_3. Hence the net capacitance is

$$\frac{1}{C''} = \frac{1}{C'} + \frac{1}{C_3} = \frac{d}{A\varepsilon_0(K_1+K_2)} + \frac{d}{2A\varepsilon_0 K_3}$$

$$= \frac{d}{\varepsilon_0 A}\left[\frac{1}{(K_1+K_2)} + \frac{1}{2K_3}\right]$$

or $$C'' = \frac{A\varepsilon_0 K}{d} \text{ where } \frac{1}{K} = \frac{1}{(K_1+K_2)} + \frac{1}{2K_3}$$

Hence the correct choice is (b).

84. The capacitance of a parallel plane capacitor is given by C = ε_0 A/d. Hence the dimensions of ε_0L are the same as those of capacitance.

$\therefore$ Dimensions of $\varepsilon_0 L \frac{\Delta L}{\Delta t}$

$$= \frac{\text{dimension of } C \times \text{dimensions of } V}{\text{time}}$$

$$= \frac{\text{dimension of } Q}{\text{time}}$$

$$= \frac{\text{charge}}{\text{time}} = \text{current}$$

Hence the correct choice is (d).

85. Since the outer plate of B is free, charge cannot flow from A to B. Hence the correct choice is (a).

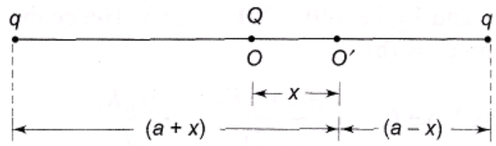
86. Electric field is the negative gradient of potential, i.e.

$$E = -\frac{dV}{dx}$$

Thus V decreases as dx increases in the direction of the field. This implies that $V_A > V_B$, which is choice (b).

87. Potential energy of the system when charge Q is at O' is

$$U_0 = \frac{qQ}{a} + \frac{qQ}{a} = \frac{2qQ}{a}$$



When charge Q is shifted to position O', the potential energy will be (see Fig.)

$$U = \frac{qQ}{(a+x)} + \frac{qQ}{(a-x)}$$

$$= \frac{qQ(2a)}{(a^2 - x^2)} = \frac{2qQ}{a} \times \left(1 - \frac{x^2}{a^2}\right)^{-1}$$

$$\simeq \frac{2qQ}{a} \times \left(1 + \frac{x^2}{a^2}\right)$$

$\therefore \qquad \Delta U = U - U_0$

$$= \frac{2qQ}{a} \times \left(1 + \frac{x^2}{a^2}\right) - \frac{2qQ}{a} = \frac{2qQ}{a^3}(x^2)$$

Hence $\Delta U \propto x^2$ which is choice (b).

88. Given $v_x = 10\ ms^{-1}$. Since the electric field is directed along the y-axis, the acceleration of the body along the y-direction is

$$a_y = \frac{qE}{m} = \frac{10^{-6} \times 10^3}{10^{-3}} = 1 ms^{-2}$$

Therefore, the velocity of the body along the y-axis at time t = 10 s is

$$v_y = at = 1 \times 10 = 10\ ms^{-1}$$

$\therefore$ Resultant velocity v = $\sqrt{v_x^2 + v_y^2}$

$$= \sqrt{(10)^2 + (10)^2} = 10\sqrt{2} ms^{-1}$$

Hence the correct choice is (c).

89. Let Q be the magnitude of each charge and a the length of each side of the triangle. The potential energy of the system of two equal charges placed at vertex A and B is U (given). This means that U is the work done in bringing a charge Q from infinity to vertex B. Hence the work done in bringing an identical charge Q from infinity to the third vertex C = work done to overcome the force of repulsion of Q placed at A at a distance a + work done to overcome the force of repulsion of Q placed at B at the same distance a= U + U= 2U, which is choice (b).

90. Charge on capacitor plates without the dielectric is

$$Q = CV = (5 \times 10^{-6}\ F) \times 1\ V = 5 \times 10^{-6}\ C = 5\ \mu C$$

The capacitance after the dielectric is introduced is

$$C' = \frac{\varepsilon_0 A}{d - \left(t - \frac{t}{K}\right)} = \frac{\varepsilon_0 A / d}{1 - \left(\frac{t - \frac{t}{K}}{d}\right)}$$

$$= \frac{5\mu F}{1 - \left(\frac{4-1}{6}\right)} = 10\mu F$$

$\therefore$ Charge on capacitor plates now will be

$Q' = C'V = 10\ \mu F \times 1\ V = 10\ \mu C$

Additional charge transferred = $Q' - Q = 10\ \mu C - 5\ \mu C = 5\ \mu C$, which is choice (c).

91. Common potential is $V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$

$$= \frac{(4\times10^{-6})\times80 + (6\times10^{-6})\times30}{4\times10^{-6} + 6\times10^{-6}} = 50V$$

$\therefore$ Energy lost by 4 μF capacitor

$$= \frac{1}{2}C_1V_1^2 - \frac{1}{2}C_1V^2$$

$$= \frac{1}{2}C_1(V_1^2 - V^2)$$

$$= \frac{1}{2}\times(4\times10^{-6})\times\{(80)^2 - (50)^2\}$$

$= 7.8 \times 10^{-3}J = 7.8mJ$ Hence the correct choice is (a).

92. Given $E = \frac{q}{4\pi\varepsilon_0 x^2}$. Hence the magnitude of the electric field at a distance 2x from charge q is

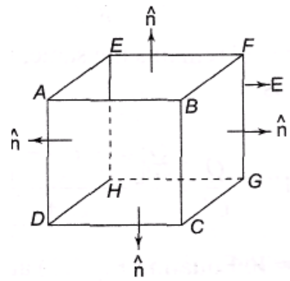
$$E' = \frac{q}{4\pi\varepsilon_0(2x)^2} = \frac{q}{4\pi\varepsilon_0 x^2}\times\frac{1}{4} = \frac{E}{4}$$

Therefore, the force experienced by a similar charge q at a distance 2x is

$$F = qE' = \frac{qE}{4}$$

Hence the correct choice is (d).

93. Refer to Fig. Let 5 be the surface area of each face of the cube. The flux through surfaces ABCD and EFGH is zero because these surfaces are parallel to the electric field E (θ = 90°).



Flux through face BFGC is ϕ_1 = ES cos 0° = ES. Flux through face AEHD is ϕ_2 = ES cos 180° = -ES. Total flux through the cube = $\phi_1 + \phi_2$ = ES - ES = 0. Hence the correct choice is (a).

94. The electric flux is given by the surface integral $\int E.ds$. Here the electric field E is due to all the charges, both inside and outside the Gaussian surface. Hence the correct choice is (c).

95. The electric field at a point P due to an infinite long plane sheet carrying a uniform charge density a is given by

$$E = \frac{\sigma}{2\varepsilon_0}$$

It is independent of the distance of point P from the sheet and is, therefore, uniform. The direction of the electric field is away from the sheet and perpendicular to it if σ is positive and is towards the sheet and perpendicular to it if σ is negative. Hence

$$E_1 = \frac{\sigma}{2\varepsilon_0}(-j) \text{ along -ve j-direction}$$

$$E_2 = \frac{2\sigma}{2\varepsilon_0}(-j) \text{ along -ve y-direction}$$

and $$E_3 = \frac{3\sigma}{2\varepsilon_0}(-j) \text{ along – vey – direction}$$

From the superposition principle, the net electric field at point P is

$$E = E_1 + E_2 + E_3$$

$$= \frac{\sigma}{2\varepsilon_0}(-j) + \frac{2\sigma}{2\varepsilon_0}(-j) + \frac{3\sigma}{2\varepsilon_0}(-j)$$

$$= -\frac{3\sigma}{\varepsilon_0} j \text{, which is choice (c).}$$

96. Electric field due to charge - Q on the shell at a distance r from its center is (for r > R)

$$E_1 = \frac{Q}{4\pi\varepsilon_0 r^2}$$

directed towards the centre.

Electric field due to charge + Q at the centre at a distance r is

$$E_2 = \frac{Q}{4\pi\varepsilon_0 r^2}$$

directed away from the centre.

$\therefore$ Net electric field E (for r > R) = $E_1 - E_2 = 0$. For r < R, the electric field due to the shell is zero. In this region, the electric field due to charge + Q at the centre decreases as $1/r^2$. Hence the correct graph is (a).

97. Let the charge on the sphere be Q. Then

$$V = \frac{Q}{4\pi\varepsilon_0 R}$$

which gives $Q = 4\pi\varepsilon_0 RV$

The electric field at a distance r is

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} = \frac{4\pi\varepsilon_0 RV}{4\pi\varepsilon_0 r^2} = \frac{RV}{r^2}$$

thus the correct choice is (c).

98. If charge Q is moved from C to D along the arc, the potential energy between pairs (q_1, Q) and (q_1, q_2) will not change as the distance between them remains unchanged ($\because$ AC = AD). The potential energy of the pair of charges q_2 and Q will change.

Now, distance BC = $\sqrt{(8)^2 + (6)^2}$ = 10 cm and BD

= 8-6 = 2 cm. Therefore, change in P.E. is

$$\Delta U = \frac{q^2 Q}{4\pi\varepsilon_0}\left[\frac{1}{BD} - \frac{1}{BC}\right]$$

$$= (2 \times 10^{-6}) \times (5 \times 19^{-6}) \times (9 \times 10^{-9}) \left(\frac{1}{0.02} - \frac{1}{0.1}\right)$$

= 3.6 J, which is choice (b).

99. If the middle charge is displaced by a distance x, the net force acting it, when it is released, is

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{q^2}{(L+x)^2} - \frac{1}{4\pi\varepsilon_0} \times \frac{q^2}{(L-x)^2}$$

$$= \frac{4q^2 Lx}{4\pi\varepsilon_0 (L^2 - x^2)^2}$$

For x << L, F = $= \frac{q^2 x}{\pi\varepsilon_0 L^3}$ = -kx

Where $k = \frac{q^2}{\pi\varepsilon_0 L^3}$

Now $T = 2\pi\sqrt{\frac{m}{k}}$

So, the correct choice is (c).

100. The batteries are in opposition as their positive terminals are connected together. Hence the effective voltage is

$$V = V_1 - V_2 = 12 - 2 = 10V$$

As the capacitors C_1 and C_2 are in series, the effective capacitance of the circuit is given by

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{3} + \frac{1}{2} = \frac{5}{6}$$

or

$$C = \frac{6}{5} = 1.2\,\mu F$$

Therefore, charge on capacitors is

$$Q = CV = 1.2\ \mu F \times 10V = 12\ \mu C$$

$\therefore$ Potential difference across A and B = potential difference across capacitor C,

$$= \frac{Q}{C_2} = \frac{12\mu C}{2\mu F} = 6V$$

101. Potential difference between the plates before the slab is introduced is

$$V = E \times d = 200 \times 0.05 = 10V$$

The capacitance of the capacitor is given by

$$C = \frac{\varepsilon_0 A}{d} = \frac{\varepsilon_0 A}{0.05} \qquad \text{or} \qquad \varepsilon_0 A = 0.05\ C$$

When a slab of dielectric constant K and thickness t is introduced, the capacitance becomes

$$C' = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)} = \frac{0.05C}{0.05 - 0.01\left(1 - \frac{1}{4}\right)} = \frac{20C}{17}$$

Now Q = CV= C'V. Therefore,

$$V' = \frac{CV}{C'} = \frac{CV}{20C/17} = \frac{17V}{20} = \frac{17 \times 10}{20} = 8.5V\,|$$

102. The capacitance before the introduction of the slab is $C = \frac{\varepsilon_0 A}{d}$.

If Q is the charge on the plates, the potential difference is

$$V = \frac{Q}{C} = \frac{Qd}{\varepsilon_0 A} \qquad (1)$$

Let d' be the new separation between the plates. When a slab of thickness t and dielectric constant K is introduced, the new capacitance is

$$C' = \frac{\varepsilon_0 A}{d' - t\left(1 - \frac{1}{K}\right)}$$

Since charge Q remains the same, the new potential difference is

$$V' = \frac{Q}{C'} = \frac{Q\left[d' - t\left(1 - \frac{1}{K}\right)\right]}{\varepsilon_0 A} \qquad (2)$$

Given V' = V. Equating Eqs. (1) and (2), we get

$$d = d' - t\left(1 - \frac{1}{K}\right) \text{or } d' - d = t\left(1 - \frac{1}{K}\right)$$

Given d' = d = 2 mm and t = 3 mm. Thus

$$2 = 3\left(1 - \frac{1}{K}\right)$$

which gives K= 3. Hence the correct choice is (b).

103. If Q is the initial charge on capacitor C_1, the initial energy is given by

$$U_i = Q2/2C_1$$

When the two capacitors are connected together, and as the charge is distributed equally, the charge on each capacitor is Q/2. Since the potential difference (in a parallel connection) across the two capacitors is also the same, it follows that their capacitances are equal (since C = Q/V). Thus $C_1 = C_2 = C$(say). Also $Q_1 = Q_2 = Q/2$.

Therefore, final energy stored in the two capacitors is

$$U_f = \frac{Q_1^2}{2C_1} + \frac{Q_2^2}{2C_2} = \frac{(Q/2)^2}{2C} + \frac{(Q/2)^2}{2C} = \frac{Q^2}{4C}$$

But $\quad U_i = \dfrac{Q^2}{2C}$

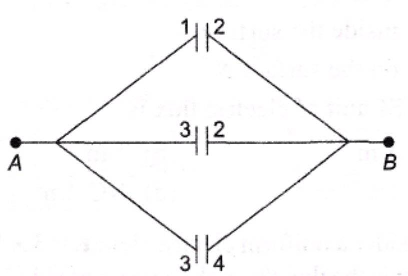
$\therefore \quad \dfrac{U_f}{U_i} = \dfrac{1}{2}$, which is choice (b).

104. Plate 1 is connected to plate 3 and plate 2 is connected to plate 4. Thus, there are three capacitors in parallel, each of capacitance

$$C = \frac{\varepsilon_0 A}{d}$$

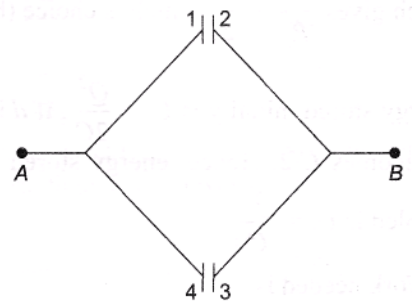
as shown in Fig. Hence the equivalent capacitance is

$$C' = 3C = \frac{3\varepsilon_0 A}{d}, \text{ which is choice (c).}$$

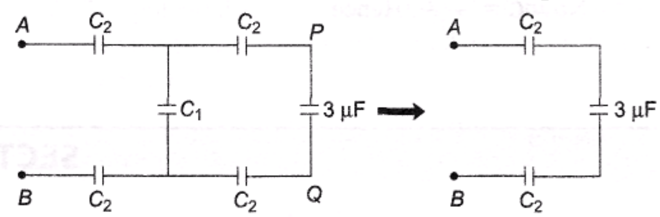


105. The inner plates 2 and 3 are connected together. Hence they act as a single conductor. Since the outer plates 1 and 4 are connected together, there are effectively two capacitors (between plates 1 and 2 and plates 3 and 4) in parallel, each of capacitance $C = \varepsilon_0 A/d$ as shown in Fig. Thus the equivalent capacitance is

$$C' = 2C = \frac{2\varepsilon_0 A}{d}$$, which is choice (b).



106. The network reduces to that shown in Fig. The correct choice is (a).



107. Charge on C_1 is $Q_1 = C_1 V = CV$. This charge is shared by the three capacitors. The equivalent capacitance of the series combination of C_2 and C_3 is

$$C' = \frac{C_2 C_3}{C_2 + C_3} = \frac{C}{2} \qquad (C_2 = C_3 = C)$$

The common potential of C_1 and C' is

$$V' = \frac{Q_1}{C_1 + C'} = \frac{C_1 V}{C_1 + C'}$$

$$= \frac{CV}{C + C/2} = \frac{2V}{3}$$

$\therefore$ Final charge on C_1 is

$$Q_1' = C_1 V' = \frac{2CV}{3}$$

$\therefore$ Charge that will flow through the connecting wires is

$$Q'' = Q_1 - Q_1' = CV - \frac{2CV}{3} = \frac{CV}{3}$$, which is choice (a).

108. $C_1 = 4\pi\varepsilon_0 R_1$

$$C_2 = \frac{4\pi\varepsilon_0 (R_1 R_2)}{(R_2 - R_1)}$$

Given $C_2 = 3C_1$. Hence

$$\frac{4\pi\varepsilon_0 (R_1 R_2)}{(R_2 - R_1)} = 3 \times 4\pi\varepsilon_0 R_1$$

which gives $\frac{R_2}{R_1} = \frac{3}{2}$, which is choice (b).

109. Energy stored initially is $U_i = \frac{Q^2}{2C}$. if d is doubled, C becomes C/2. Hence, energy stored when d is doubled is $U_f = \frac{Q^2}{C}$

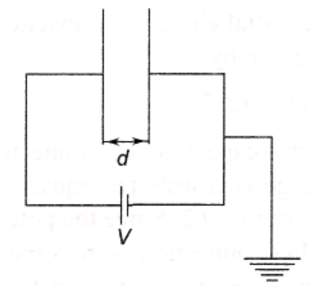
$\therefore$ Work needed is

$$W = U_f - U_i = \frac{Q^2}{C} - \frac{Q^2}{2C} = \frac{Q^2}{2C} = \frac{1}{2}CV^2$$

Now $C = \frac{A\varepsilon_0}{d}$. Hence

$$W = \frac{A\varepsilon_0 V^2}{2d}$$, which is choice (c)

110. The circuit can be redrawn as shown in Fig.



The charge on the capacitor plates is

$$Q = CV = \frac{A\varepsilon_0 V}{d}$$

So the correct choice is (b).