CHAPTER 2

Electrostatic Potential and Capacitance

2.2 Electrostatic Potential

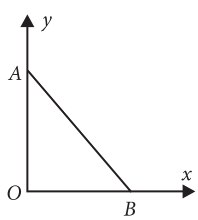
1. In a certain region of space with volume 0.2 m^3, the electric potential is found to be 5 V throughout. The magnitude of electric field in this region is
(a) zero (b) 0.5 N/C
(c) 1 N/C (d) 5 N/C *(NEET 2020)*

2. A bullet of mass 2 g is having a charge of 2 μC. Through what potential difference must it be accelerated, starting from rest, to acquire a speed of 10 m/s ?
(a) 5 kV (b) 50 kV (c) 5 V (d) 50 V *(2004)*

2.3 Potential due to a Point Charge

3. The electric potential at a point in free space due to charge Q coulomb is $Q \times 10^{11}$ volts. The electric field at that point is
(a) $4\pi\varepsilon_0 Q \times 10^{20}$ volt/m
(b) $12\pi\varepsilon_0 Q \times 10^{22}$ volt/m
(c) $4\pi\varepsilon_0 Q \times 10^{22}$ volt/m
(d) $12\pi\varepsilon_0 Q \times 10^{20}$ volt/m *(2008)*

4. As per the diagram a point charge $+q$ is placed at the origin O. Work done in taking another point charge $-Q$ from the point A [coordinates $(0, a)$] to another point B [coordinates $(a, 0)$] along the straight path AB is



(a) zero
(b) $\left(\dfrac{qQ}{4\pi\varepsilon_0}\dfrac{1}{a^2}\right)\cdot\sqrt{2}\,a$ (c) $\left(\dfrac{-qQ}{4\pi\varepsilon_0}\dfrac{1}{a^2}\right)\cdot\sqrt{2}\,a$
(d) $\left(\dfrac{qQ}{4\pi\varepsilon_0}\dfrac{1}{a^2}\right)\cdot\dfrac{a}{\sqrt{2}}$ *(2005)*

2.4 Potential due to an Electric Dipole

5. A short electric dipole has a dipole moment of 16×10^{-9} C m. The electric potential due to the dipole at a point at a distance of 0.6 m from the centre of the dipole, situated on a line making an angle of 60° with the dipole axis is $\left(\dfrac{1}{4\pi\varepsilon_0} = 9\times10^9 \text{ N m}^2/\text{C}^2\right)$
(a) 50 V (b) 200 V
(c) 400 V (d) zero *(NEET 2020)*

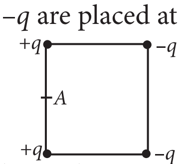
2.5 Potential due to a System of Charges

6. Two metal spheres, one of radius R and the other of radius $2R$ respectively have the same surface charge density σ. They are brought in contact and separated. What will be the new surface charge densities on them?
(a) $\sigma_1 = \dfrac{5}{6}\sigma,\ \sigma_2 = \dfrac{5}{2}\sigma$
(b) $\sigma_1 = \dfrac{5}{2}\sigma,\ \sigma_2 = \dfrac{5}{6}\sigma$
(c) $\sigma_1 = \dfrac{5}{2}\sigma,\ \sigma_2 = \dfrac{5}{3}\sigma$
(d) $\sigma_1 = \dfrac{5}{3}\sigma,\ \sigma_2 = \dfrac{5}{6}\sigma$ *(Odisha NEET 2019)*

7. A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the centre of the sphere respectively are
(a) zero and $\dfrac{Q}{4\pi\varepsilon_0 R^2}$ (b) $\dfrac{Q}{4\pi\varepsilon_0 R}$ and zero
(c) $\dfrac{Q}{4\pi\varepsilon_0 R}$ and $\dfrac{Q}{4\pi\varepsilon_0 R^2}$ (d) both are zero *(2014)*

8. Four point charges $-Q, -q, 2q$ and $2Q$ are placed, one at each corner of the square. The relation between Q and q for which the potential at the centre of the square is zero is
(a) $Q = -q$ (b) $Q = -\dfrac{1}{q}$
(c) $Q = q$ (d) $Q = \dfrac{1}{q}$ *(2012)*

9. Four electric charges $+q, +q, -q$ and $-q$ are placed at the corners of a square of side $2L$ (see figure). The electric potential at point A, midway between the two charges $+q$ and $+q$, is



(a) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{2q}{L}\left(1+\sqrt{5}\right)$ (b) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{2q}{L}\left(1+\dfrac{1}{\sqrt{5}}\right)$
(c) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{2q}{L}\left(1-\dfrac{1}{\sqrt{5}}\right)$ (d) zero *(2011)*

10. Three concentric spherical shells have radii a, b and c ($a < b < c$) and have surface charge densities σ, $-\sigma$ and σ respectively. If V_A, V_B and V_C denote the potentials of the three shells, then, for $c = a + b$, we have

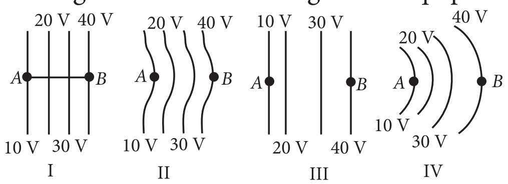
(a) $V_C = V_B \neq V_A$ (b) $V_C \neq V_B \neq V_A$
(c) $V_C = V_B = V_A$ (d) $V_C = V_A \neq V_B$ *(2009)*

11. A hollow metallic sphere of radius 10 cm is charged such that potential of its surface is 80 V. The potential at the centre of the sphere would be

(a) 80 V (b) 800 V (c) zero (d) 8 V *(1994)*

2.6 Equipotential Surfaces

12. The diagrams below show regions of equipotentials.



A positive charge is moved from A to B in each diagram.

(a) In all the four cases the work done is the same.
(b) Minimum work is required to move q in figure (I).
(c) Maximum work is required to move q in figure (II).
(d) Maximum work is required to move q in figure (III). *(NEET 2017)*

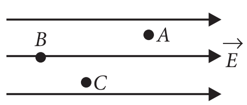
13. If potential (in volts) in a region is expressed as $V(x, y, z) = 6xy - y + 2yz$, the electric field (in N/C) at point (1, 1, 0) is

(a) $-(2\hat{i}+3\hat{j}+\hat{k})$ (b) $-(6\hat{i}+9\hat{j}+\hat{k})$
(c) $-(3\hat{i}+5\hat{j}+3\hat{k})$ (d) $-(6\hat{i}+5\hat{j}+2\hat{k})$ *(2015)*

14. In a region, the potential is represented by $V(x, y, z) = 6x - 8xy - 8y + 6yz$, where V is in volts and x, y, z are in metres. The electric force experienced by a charge of 2 coulomb situated at point (1, 1, 1) is

(a) $6\sqrt{5}$ N (b) 30 N (c) 24 N (d) $4\sqrt{35}$ N *(2014)*

15. A, B and C are three points in a uniform electric field. The electric potential is



(a) maximum at C
(b) same at all the three points A, B and C
(c) maximum at A
(d) maximum at B *(NEET 2013)*

16. The electric potential V at any point (x, y, z), all in metres in space is given by $V = 4x^2$ volt. The electric field at the point (1, 0, 2) in volt/meter, 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 *(Mains 2011)*

17. The electric potential at a point (x, y, z) is given by $V = -x^2y - xz^3 + 4$. The electric field at that point is

(a) $\vec{E} = \hat{i}\,2xy + \hat{j}\,(x^2 + y^2) + \hat{k}\,(3xz - y^2)$

(b) $\vec{E} = \hat{i}\,z^3 + \hat{j}\,xyz + \hat{k}\,z^2$

(c) $\vec{E} = \hat{i}\,(2xy - z^3) + \hat{j}\,xy^2 + \hat{k}\,3z^2x$

(d) $\vec{E} = \hat{i}\,(2xy + z^3) + \hat{j}\,x^2 + \hat{k}\,3xz^2$ *(2009)*

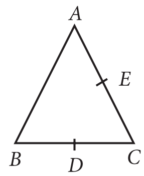
18. Charge q_2 is at the centre of a circular path with radius r. Work done in carrying charge q_1, once around this equipotential path, would be

(a) $\dfrac{1}{4\pi\varepsilon_0} \times \dfrac{q_1 q_2}{r^2}$ (b) $\dfrac{1}{4\pi\varepsilon_0} \times \dfrac{q_1 q_2}{r}$

(c) zero (d) infinite. *(1994)*

2.7 Potential Energy of a System of Charges

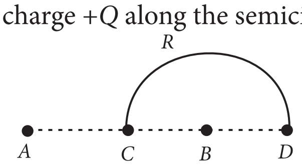
19. Three charges, each $+q$, are placed at the corners of an isosceles triangle ABC of sides BC and AC, $2a$. D and E are the mid points of BC and CA. The work done in taking a charge Q from D to E is



(a) $\dfrac{3qQ}{4\pi\varepsilon_0 a}$ (b) $\dfrac{3qQ}{8\pi\varepsilon_0 a}$

(c) $\dfrac{qQ}{4\pi\varepsilon_0 a}$ (d) zero *(Mains 2011)*

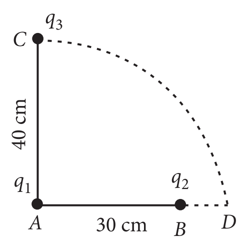
20. Charges $+q$ and $-q$ are placed at points A and B respectively which are a distance $2L$ apart, C is the midpoint between A and B. The work done in moving a charge $+Q$ along the semicircle CRD is



(a) $\dfrac{qQ}{2\pi\varepsilon_0 L}$ (b) $\dfrac{qQ}{6\pi\varepsilon_0 L}$

(c) $-\dfrac{qQ}{6\pi\varepsilon_0 L}$ (d) $\dfrac{qQ}{4\pi\varepsilon_0 L}$ *(2007)*

21. Two charges q_1 and q_2 are placed 30 cm apart, as shown in the figure. A third charge q_3 is moved along the arc of a circle of radius 40 cm from C to D. The change in the potential energy of the system is $\dfrac{q_3}{4\pi\varepsilon_0}k$, where k is



(a) $8q_1$
(b) $6q_1$
(c) $8q_2$
(d) $6q_2$ *(2005)*

22. Identical charges $(-q)$ are placed at each corners of cube of side b, then electrostatic potential energy of charge $(+q)$ which is placed at centre of cube will be

(a) $\dfrac{-4\sqrt{2}\,q^2}{\pi\varepsilon_0 b}$ (b) $\dfrac{-8\sqrt{2}\,q^2}{\pi\varepsilon_0 b}$

(c) $\dfrac{-4\,q^2}{\sqrt{3}\pi\varepsilon_0 b}$ (d) $\dfrac{8\sqrt{2}\,q^2}{4\pi\varepsilon_0 b}$ *(2002)*

23. In bringing an electron towards another electron, the electrostatic potential energy of the system

(a) becomes zero (b) increases
(c) decreases (d) remains same *(1999)*

2.8 Potential Energy in an External Field

24. An electric dipole of dipole moment p is aligned parallel to a uniform electric field E. The energy required to rotate the dipole by 90° is

(a) p^2E (b) pE (c) infinity (d) pE^2 *(Karnataka NEET 2013)*

25. An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when $\theta = 90°$, the torque and the potential energy of the dipole will respectively be

(a) $pE\sin\theta, -pE\cos\theta$ (b) $pE\sin\theta, -2pE\cos\theta$
(c) $pE\sin\theta, 2pE\cos\theta$ (d) $pE\cos\theta, -pE\sin\theta$ *(2012)*

26. An electric dipole of moment $\vec{p}$ is lying along a uniform electric field $\vec{E}$. The work done in rotating the dipole by 90° is

(a) pE (b) $\sqrt{2}pE$ (c) $pE/2$ (d) $2pE$ *(2006)*

27. An electric dipole has the magnitude of its charge as q and its dipole moment is p. It is placed in a uniform electric field E. If its dipole moment is along the direction of the field, the force on it and its potential energy are respectively

(a) $2q \cdot E$ and minimum
(b) $q \cdot E$ and $p \cdot E$
(c) zero and minimum
(d) $q \cdot E$ and maximum *(2004)*

28. There is an electric field E in x-direction. If the work done on moving a charge of 0.2 C through a distance of 2 m along a line making an angle 60° with x-axis is 4 J, then what is the value of E ?

(a) 5 N/C (b) 20 N/C
(c) $\sqrt{3}$ N/C (d) 4 N/C *(1995)*

29. An electric dipole of moment p is placed in the position of stable equilibrium in uniform electric field of intensity E. This is rotated through an angle θ from the initial position. The potential energy of the electric dipole in the final position is

(a) $-pE\cos\theta$ (b) $pE(1 - \cos\theta)$
(c) $pE\cos\theta$ (d) $pE\sin\theta$ *(1994)*

2.9 Electrostatics of Conductors

30. Some charge is being given to a conductor. Then its potential is

(a) maximum at surface
(b) maximum at centre
(c) remain same throughout the conductor
(d) maximum somewhere between surface and centre. *(2002)*

2.11 Capacitors and Capacitance

31. Two metallic spheres of radii 1 cm and 3 cm are given charges of -1×10^{-2} C and 5×10^{-2} C, respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is

(a) 2×10^{-2} C (b) 3×10^{-2} C
(c) 4×10^{-2} C (d) 1×10^{-2} C *(Mains 2012)*

32. Two metallic spheres of radii 1 cm and 2 cm are given charges 10^{-2} C and 5×10^{-2} C respectively. If they are connected by a conducting wire, the final charge on the smaller sphere is

(a) 3×10^{-2} C (b) 4×10^{-2} C
(c) 1×10^{-2} C (d) 2×10^{-2} C *(1995)*

2.12 The Parallel Plate Capacitor

33. The electrostatic force between the metal plates of an isolated parallel plate capacitor C having a charge Q and area A, is

(a) independent of the distance between the plates
(b) linearly proportional to the distance between the plates
(c) proportional to the square root of the distance between the plates
(d) inversely proportional to the distance between the plates. *(NEET 2018)*

34. A parallel plate air capacitor has capacity C, distance of separation between plates is d and potential difference V is applied between the plates. Force of attraction between the plates of the parallel plate air capacitor is

(a) $\dfrac{CV^2}{d}$ (b) $\dfrac{C^2V^2}{2d^2}$ (c) $\dfrac{C^2V^2}{2d}$ (d) $\dfrac{CV^2}{2d}$ *(2015)*

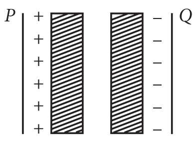
35. A parallel plate air capacitor is charged to a potential difference of V volts. After disconnecting the charging battery the distance between the plates of the capacitor is increased using an insulating handle. As a result the potential difference between the plates

(a) increases (b) decreases
(c) does not change (d) becomes zero *(2006)*

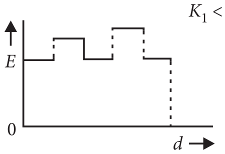
2.13 Effect of Dielectric on Capacitance

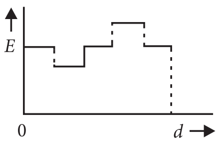
36. The capacitance of a parallel plate capacitor with air as medium is 6 μF. With the introduction of a dielectric medium, the capacitance becomes 30 μF. The permittivity of the medium is ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2})
(a) 0.44×10^{-13} C^2 N^{-1} m^{-2}
(b) 1.77×10^{-12} C^2 N^{-1} m^{-2}
(c) 0.44×10^{-10} C^2 N^{-1} m^{-2}
(d) 5.00 C^2 N^{-1} m^{-2} *(NEET 2020)*

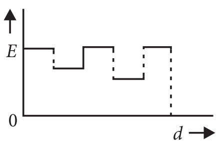
37. Two thin dielectric slabs of dielectric constants K_1 and K_2 ($K_1 < K_2$) are inserted between plates of a parallel plate capacitor, as shown in the figure. The variation of electric field E between the plates with distance d as measured from plate P is correctly shown by

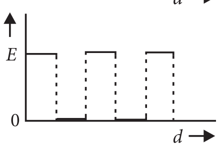


$K_1 < K_2$

(a)


(b)


(c)


(d)


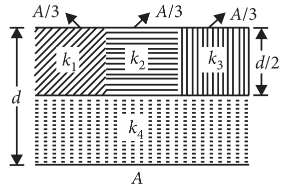
(2014)

38. Two parallel metal plates having charges $+Q$ and $-Q$ face each other at a certain distance between them. If the plates are now dipped in kerosene oil tank, the electric field between the plates will
(a) become zero (b) increase
(c) decrease (d) remain same *(Mains 2010)*

39. A parallel plate condenser with oil between the plates (dielectric constant of oil $K = 2$) has a capacitance C. If the oil is removed, then capacitance of the capacitor becomes
(a) $\frac{C}{\sqrt{2}}$ (b) $2C$ (c) $\sqrt{2}C$ (d) $\frac{C}{2}$ *(1999)*

2.14 Combination of Capacitors

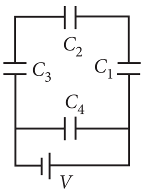
40. A parallel-plate capacitor of area A, plate separation d and capacitance C is filled with four dielectric materials having dielectric constants k_1, k_2, k_3 and k_4 as shown in the figure. If a single dielectric material is to be used to have the same capacitance C in this capacitor, then its dielectric constant k is given by
(a) $k = k_1 + k_2 + k_3 + 3k_4$
(b) $k = \frac{2}{3}(k_1 + k_2 + k_3) + 2k_4$
(c) $\frac{2}{k} = \frac{3}{k_1 + k_2 + k_3} + \frac{1}{k_4}$
(d) $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{3}{2k_4}$



(NEET -II 2016)

41. Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance and breakdown voltage of the combination will be
(a) $3C, \frac{V}{3}$ (b) $\frac{C}{3}, 3V$
(c) $3C, 3V$ (d) $\frac{C}{3}, \frac{V}{3}$ *(2009)*

42. A network of four capacitors of capacity equal to $C_1 = C$, $C_2 = 2C$, $C_3 = 3C$ and $C_4 = 4C$ are connected to a battery as shown in the figure. The ratio of the charges on C_2 and C_4 is
(a) 4/7
(b) 3/22
(c) 7/4
(d) 22/3

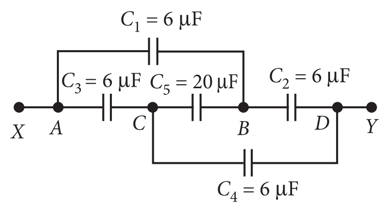


(2005)

43. Three capacitors each of capacity 4 μF are to be connected in such a way that the effective capacitance is 6 μF. This can be done by
(a) connecting all of them in series
(b) connecting them in parallel
(c) connecting two in series and one in parallel
(d) connecting two in parallel and one in series. *(2003)*

44. A capacitor of capacity C_1 is charged upto V volt and then connected in parallel to an uncharged capacitor of capacity C_2. The final potential difference across each will be
(a) $\frac{C_2 V}{C_1 + C_2}$ (b) $\frac{C_1 V}{C_1 + C_2}$
(c) $\left(1 + \frac{C_2}{C_1}\right)$ (d) $\left(1 - \frac{C_2}{C_1}\right)V$ *(2002)*

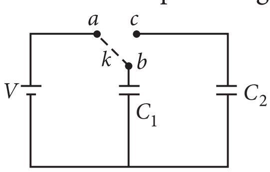
45. What is the effective capacitance between points X and Y?



(a) 12 μF (b) 18 μF (c) 24 μF (d) 6 μF *(1999)*

2.15 Energy Stored in a Capacitor

46. Two identical capacitors C_1 and C_2 of equal capacitance are connected as shown in the circuit. Terminals a and b of the key k are connected to charge capacitor C_1 using battery of emf V volt. Now disconnecting a and b, the terminals b and c are connected. Due to this, what will be the percentage loss of energy ?



(a) 75%
(b) 0%
(c) 50%
(d) 25%

(Odisha NEET 2019)

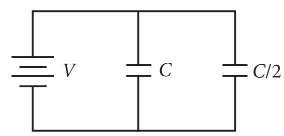
47. A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system
(a) decreases by a factor of 2
(b) remains the same
(c) increases by a factor of 2
(d) increases by a factor of 4. *(NEET 2017)*

48. A parallel plate air capacitor of capacitance C is connected to a cell of emf V and then disconnected from it. A dielectric slab of dielectric constant K, which can just fill the air gap of the capacitor, is now inserted in it. Which of the following is incorrect?
(a) The change in energy stored is $\frac{1}{2}CV^2\left(\frac{1}{K}-1\right)$.
(b) The charge on the capacitor is not conserved.
(c) The potential difference between the plates decreases K times.
(d) The energy stored in the capacitor decreases K times. *(2015 Cancelled)*

49. A parallel plate capacitor has a uniform electric field E in the space between the plates. If the distance between the plates is d and area of each plate is A, the energy stored in the capacitor is
(a) $\frac{1}{2}\varepsilon_0 E^2$
(b) $\frac{E^2Ad}{\varepsilon_0}$
(c) $\frac{1}{2}\varepsilon_0 E^2 Ad$
(d) $\varepsilon_0 EAd$
(Mains 2012, 2011, 2008)

50. A series combination of n_1 capacitors, each of value C_1, is charged by a source of potential difference 4V. When another parallel combination of n_2 capacitors, each of value C_2, is charged by a source of potential difference V, it has the same (total) energy stored in it, as the first combination has. The value of C_2, in terms of C_1, is then
(a) $\frac{2C_1}{n_1 n_2}$
(b) $16\frac{n_2}{n_1}C_1$
(c) $2\frac{n_2}{n_1}C_1$
(d) $\frac{16C_1}{n_1 n_2}$ *(2010)*

51. Two condensers, one of capacity C and other of capacity $C/2$ are connected to a V-volt battery, as shown in the figure. The work done in charging fully both the condensers is



(a) $\frac{1}{4}CV^2$
(b) $\frac{3}{4}CV^2$
(c) $\frac{1}{2}CV^2$
(d) $2CV^2$ *(2007)*

52. Energy per unit volume for a capacitor having area A and separation d kept at potential difference V is given by
(a) $\frac{1}{2}\varepsilon_0\frac{V^2}{d^2}$
(b) $\frac{1}{2\varepsilon_0}\frac{V^2}{d^2}$
(c) $\frac{1}{2}CV^2$
(d) $\frac{Q^2}{2C}$ *(2001)*

53. A capacitor is charged with a battery and energy stored is U. After disconnecting battery another capacitor of same capacity is connected in parallel to the first capacitor. Then energy stored in each capacitor is
(a) $U/2$ (b) $U/4$ (c) $4U$ (d) $2U$ *(2000)*

54. The energy stored in a capacitor of capacity C and potential V is given by
(a) $\frac{CV}{2}$ (b) $\frac{C^2V^2}{2}$ (c) $\frac{C^2V}{2}$ (d) $\frac{CV^2}{2}$ *(1996)*

ANSWER KEY

1.	(a)	**2.**	(b)	**3.**	(c)	**4.**	(a)	**5.**	(b)	**6.**	(d)	**7.**	(b)	**8.**	(a)	**9.**	(c)	**10.**	(d)
11.	(a)	**12.**	(a)	**13.**	(d)	**14.**	(d)	**15.**	(d)	**16.**	(a)	**17.**	(d)	**18.**	(c)	**19.**	(d)	**20.**	(c)
21.	(c)	**22.**	(c)	**23.**	(b)	**24.**	(b)	**25.**	(a)	**26.**	(a)	**27.**	(c)	**28.**	(b)	**29.**	(b)	**30.**	(c)
31.	(b)	**32.**	(d)	**33.**	(a)	**34.**	(d)	**35.**	(a)	**36.**	(c)	**37.**	(c)	**38.**	(c)	**39.**	(d)	**40.**	(c)
41.	(b)	**42.**	(b)	**43.**	(c)	**44.**	(b)	**45.**	(d)	**46.**	(c)	**47.**	(a)	**48.**	(b)	**49.**	(c)	**50.**	(d)
51.	(b)	**52.**	(a)	**53.**	(b)	**54.**	(d)												

Hints & Explanations

1. (a) : Electric field in a region, $E = -\dfrac{dV}{dr}$

But here electric potential is constant. Therefore electric field will be zero.

2. (b) : Using $\dfrac{1}{2}mv^2 = qV$

$$V = \frac{1}{2}\times\frac{2\times10^{-3}\times10\times10}{2\times10^{-6}} = 50\text{ kV}$$

3. (c) : $V = \dfrac{1}{4\pi\varepsilon_0}\cdot\dfrac{Q}{r} = Q.10^{11}$ volts

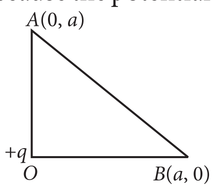
$\therefore\ \dfrac{1}{r} = 4\pi\varepsilon_0\times10^{11}$

$E = \dfrac{\text{potential}}{r} = Q\cdot10^{11}\times4\pi\varepsilon_0\cdot10^{11}$

$\Rightarrow\ E = 4\pi\varepsilon_0\cdot Q\cdot10^{22}$ volt/m

4. (a) : Work done is equal to zero because the potential of A and B are the same *i.e.*,

$\dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{a}.$



No work is done if a particle does not change its potential energy.

i.e., initial potential energy = final potential energy.

5. (b) : Potential due to dipole, $V = \dfrac{\vec{p}\cdot\hat{r}}{4\pi\varepsilon_0 r^2} = \dfrac{kp\cos\theta}{r^2}$

or $\quad V = \dfrac{(9\times10^9)(16\times10^{-9})\times\cos60^\circ}{(0.6)^2} = 200$ V

6. (d) : Before contact, $Q_1 = \sigma\cdot4\pi R^2$

and $Q_2 = \sigma\cdot4\pi(2R)^2$

As, surface charge density, $\sigma = \dfrac{\text{Net charge }(Q)}{\text{Surface area }(A)}$

Now, after contact, $Q_1' + Q_2' = Q_1 + Q_2 = 5Q_1$

$= 5(\sigma\cdot4\pi R^2)$ ...(i)

They will be at equal potentials, so,

$$\frac{Q_1'}{R} = \frac{Q_2'}{2R}\ \Rightarrow\ Q_2' = 2Q_1'$$

$\therefore\ 3Q_1' = 5(\sigma\cdot4\pi R^2)$ (From equation (i))

and $Q_2' = \dfrac{10}{3}(\sigma\cdot4\pi R^2)$

$\therefore\ \sigma_1 = \dfrac{5}{3}\sigma$ and $\sigma_2 = \dfrac{5}{6}\sigma$

7. (b) : For the conducting sphere,

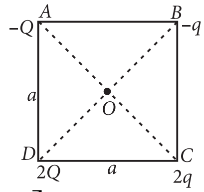
Potential at the centre = Potential on the sphere

$$= \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

Electric field at the centre = 0

8. (a) : Let a be the side of the square $ABCD$.

$\therefore\ AC = BD = \sqrt{a^2+a^2} = a\sqrt{2}$



$OA = OB = OC = OD = \dfrac{a\sqrt{2}}{2} = \dfrac{a}{\sqrt{2}}$

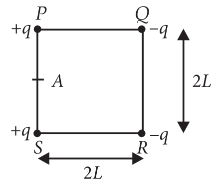
Potential at the centre O due to given charge configuration is

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{(-Q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{(-q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{(2q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{2Q}{\left(\frac{a}{\sqrt{2}}\right)}\right] = 0$$

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

9. (c) : A is the midpoint of PS

$\therefore\ PA = AS = L$



$AR = AQ = \sqrt{(SR)^2+(AS)^2}$

$= \sqrt{(2L)^2+(L)^2} = L\sqrt{5}$

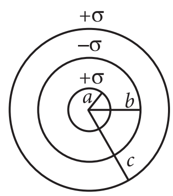
Electric potential at point A due to the given charge configuration is

$$V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{PA}+\frac{q}{AS}+\frac{(-q)}{AQ}+\frac{(-q)}{AR}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{L}+\frac{q}{L}-\frac{q}{L\sqrt{5}}-\frac{q}{L\sqrt{5}}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{2q}{L}-\frac{2q}{L\sqrt{5}}\right] = \frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left[1-\frac{1}{\sqrt{5}}\right]$$

10. (d) : $V_A = \dfrac{1}{4\pi\varepsilon_0}\left\{\dfrac{q_A}{a}+\dfrac{q_B}{b}+\dfrac{q_C}{c}\right\}$



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

$$V_A = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{a}-\frac{b^2\sigma}{b}+\frac{c^2\sigma}{c}\right\}$$

$$V_B = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{b}-\frac{b^2\sigma}{b}+\frac{c^2\sigma}{c}\right\},\quad V_C = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{c}-\frac{b^2\sigma}{c}+\frac{c^2\sigma}{c}\right\}$$

Using $c = a + b$, $V_A = \dfrac{2a\sigma}{\varepsilon_0}$

$$V_B = \frac{\sigma}{\varepsilon_0}\left(\frac{a^2}{b}+a\right) = \frac{\sigma}{\varepsilon_0}\frac{ac}{b}$$

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

$\therefore\ V_A = V_C \neq V_B$

11. (a) : Potential inside the sphere is the same as that on the surface *i.e.*, 80 V.

12. (a) : Work done is given as $W = q\Delta V$

In all the four cases the potential difference from A to B is same.

$\therefore$ In all the four cases the work done is same.

13. (d) : The electric field $\vec{E}$ and potential V in a region are related as $\vec{E}=-\left[\frac{\partial V}{\partial x}\hat{i}+\frac{\partial V}{\partial y}\hat{j}+\frac{\partial V}{\partial z}\hat{k}\right]$

Here, $V(x, y, z) = 6xy - y + 2yz$

$$\therefore\ \vec{E}=-\left[\frac{\partial}{\partial x}(6xy-y+2yz)\hat{i}+\frac{\partial}{\partial y}(6xy-y+2yz)\hat{j}+\frac{\partial}{\partial z}(6xy-y+2yz)\hat{k}\right]$$

$$=-[(6y)\hat{i}+(6x-1+2z)\hat{j}+(2y)\hat{k}]$$

At point (1, 1, 0),

$$\vec{E}=-[(6(1))\hat{i}+(6(1)-1+2(0))\hat{j}+(2(1))\hat{k}]\ =-(6\hat{i}+5\hat{j}+2\hat{k})$$

14. (d) : Here, $V(x, y, z) = 6x - 8xy - 8y + 6yz$

The x, y and z components of electric field are

$$E_x=-\frac{\partial V}{\partial x}=-\frac{\partial}{\partial x}(6x-8xy-8y+6yz)$$

$= -(6 - 8y) = -6 + 8y$

$$E_y=-\frac{\partial V}{\partial y}=-\frac{\partial}{\partial y}(6x-8xy-8y+6yz)$$

$= -(-8x - 8 + 6z) = 8x + 8 - 6z$

$$E_z=-\frac{\partial V}{\partial z}=-\frac{\partial}{\partial z}(6x-8xy-8y+6yz)=-6y$$

$$\vec{E}=E_x\hat{i}+E_y\hat{j}+E_z\hat{k}$$

$$=(-6+8y)\hat{i}+(8x+8-6z)\hat{j}-6y\hat{k}$$

At point (1, 1, 1)

$$\vec{E}=(-6+8)\hat{i}+(8+8-6)\hat{j}-6\hat{k}=2\hat{i}+10\hat{j}-6\hat{k}$$

The magnitude of electric field $\vec{E}$ is

$$\vec{E}=\sqrt{E_x^2+E_y^2+E_z^2}=\sqrt{(2)^2+(10)^2+(-6)^2}$$

$=\sqrt{140}=2\sqrt{35}\ \text{N C}^{-1}$

Electric force experienced by the charge

$F=qE=2\ \text{C}\times 2\sqrt{35}\ \text{N C}^{-1}=4\sqrt{35}\ \text{N}$

15. (d) : In the direction of electric field, electric potential decreases.

$\therefore\ V_B > V_C > V_A$

16. (a) : $\vec{E}=-\left[\hat{i}\frac{\partial V}{\partial x}+\hat{j}\frac{\partial V}{\partial y}+\hat{k}\frac{\partial V}{\partial z}\right]$

Here, $V=4x^2\ \therefore\ \vec{E}=-8x\hat{i}$

The electric field at point (1, 0, 2) is

$$\vec{E}_{(1,0,2)}=-8\hat{i}\ \text{Vm}^{-1}$$

So electric field is along the negative X-axis.

17. (d) : The electric potential at a point,

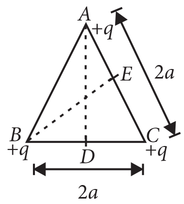
$V = -x^2y - xz^3 + 4.$

The field $\vec{E}=-\vec{\nabla}V=-\left(\frac{\partial V}{\partial x}\hat{i}+\frac{\partial V}{\partial y}\hat{j}+\frac{\partial V}{\partial z}\hat{k}\right)$

$$\therefore\ \vec{E}=\hat{i}(2xy+z^3)+\hat{j}x^2+\hat{k}(3xz^2)$$

18. (c) : Work done on carrying a charge from one place to another on an equipotential surface is zero.

19. (d) : Here, $AC = BC = 2a$



D and E are the midpoints of BC and AC.

$\therefore\ AE = EC = a$ and $BD = DC = a$

In ΔADC, $(AD)^2 = (AC)^2 - (DC)^2 = (2a)^2 - (a)^2 = 4a^2 - a^2 = 3a^2$

$\Rightarrow AD = a\sqrt{3}$

Similarly, potential at point D due to the given charge configuration is

$$V_D=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{BD}+\frac{q}{DC}+\frac{q}{AD}\right]$$

$$=\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a}+\frac{1}{a}+\frac{1}{\sqrt{3}a}\right]=\frac{q}{4\pi\varepsilon_0 a}\left[2+\frac{1}{\sqrt{3}}\right] \quad ...(i)$$

Potential at point E due to the given charge configuration is

$$V_E=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AE}+\frac{q}{EC}+\frac{q}{BE}\right]$$

$$=\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a}+\frac{1}{a}+\frac{1}{a\sqrt{3}}\right]=\frac{q}{4\pi\varepsilon_0 a}\left[2+\frac{1}{\sqrt{3}}\right] \quad ...(ii)$$

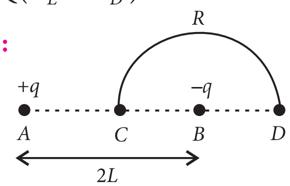
From (i) and (ii), it is clear that

$V_D = V_E$

The work done in taking a charge Q from D to E is

$W = Q(V_E - V_D) = 0 \qquad (\because V_D = V_E)$

20. (c) :



From figure, $AC = L$, $BC = L$, $BD = BC = L$

$AD = AB + BD = 2L + L = 3L$

Potential at C is given by

$$V_C=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AC}+\frac{(-q)}{BC}\right]=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{L}-\frac{q}{L}\right]=0$$

Potential at D is given by

$$V_D=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AD}+\frac{(-q)}{BD}\right]=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{3L}-\frac{q}{L}\right]$$

$$=\frac{1}{4\pi\varepsilon_0}\frac{q}{L}\left[\frac{1}{3}-1\right]=\frac{-q}{6\pi\varepsilon_0}.$$

Work done in moving charge $+Q$ along the semicircle CRD is given by

$$W=[V_D-V_C](+Q)=\left[\frac{-q}{6\pi\varepsilon_0}-0\right](Q)=\frac{-qQ}{6\pi\varepsilon_0 L}$$

Comments : Potential at C is zero because the charges are equal and opposite and the distances are the same. Potential at D due to $-q$ is greater than that at A $(+q)$, because D is closer to B. Therefore it is negative.

21. (c) : The potential energy when q_3 is at point C

$$U_1=\frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_3}{0.40}+\frac{q_2q_3}{\sqrt{(0.40)^2+(0.30)^2}}\right]$$

The potential energy when q_3 is at point D

$$U_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_3}{0.40}+\frac{q_2q_3}{0.10}\right]$$

Thus change in potential energy is $\Delta U = U_2 - U_1$

$$\Rightarrow \quad \frac{q_3}{4\pi\varepsilon_0}k = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_3}{0.40}+\frac{q_2q_3}{0.10}-\frac{q_1q_3}{0.40}-\frac{q_2q_3}{0.50}\right]$$

$$\Rightarrow \quad k = \frac{5q_2 - q_2}{0.50} = \frac{4q_2}{0.50} = 8q_2$$

22. (c) : There are eight corners of a cube and in each corner there is a charge of $(-q)$. At the centre of the corner there is a charge of $(+q)$. Each corner is equidistant from the centres of the cube and the distance (d) is half of the diagonals of the cube.

Diagonal of the cube $= \sqrt{b^2+b^2+b^2} = \sqrt{3}\,b$

$\therefore \quad d = \sqrt{3}\,b/2$

Now, electric potential energy of the charge $(+q)$ due to a charge $(-q)$ at one corner $= U$

$$= \frac{q_1q_2}{4\pi\varepsilon_0 r} = \frac{(+q)\times(-q)}{4\pi\varepsilon_0(\sqrt{3}b/2)} = -\frac{q^2}{2\pi\varepsilon_0(\sqrt{3}b)}$$

$\therefore$ Total electric potential energy due to all the eight identical charges

$$= 8U = -\frac{8q^2}{2\pi\varepsilon_0\sqrt{3}b} = \frac{-4q^2}{\sqrt{3}\,\pi\varepsilon_0 b}$$

23. (b) : In bringing an electron towards another electron, work has to be done (since same charges repel each other). The work done stored as electrostatic potential energy, and hence, electrostatic potential energy of the system increases.

24. (b) : Potential energy of dipole,

$U = -pE(\cos\theta_2 - \cos\theta_1)$

Here, $\theta_1 = 0°$, $\theta_2 = 90°$

$\therefore \quad U = -pE(\cos 90° - \cos 0°) = -pE(0 - 1) = pE$

25. (a) : Torque, $\tau = pE\sin\theta$

Potential energy, $U = -pE\cos\theta$

26. (a) : Work done in deflecting a dipole through an angle θ is given by

$$W = \int_0^\theta pE\sin\theta\, d\theta = pE(1-\cos\theta)$$

Since $\theta = 90°$

$\therefore \quad W = pE(1 - \cos 90°)$ or, $W = pE$.

27. (c) : The total force on dipole is zero because $F = qE$ is applied on each charge but in opposite direction. The potential energy is $U = -\vec{p}\cdot\vec{E}$, which is minimum when $\vec{p}$ and $\vec{E}$ are parallel.

28. (b) : Charge $(q) = 0.2$ C; Distance $(d) = 2$ m;

Angle $\theta = 60°$ and work done $(W) = 4$ J

Work done in moving the charge (W)

$= F.d\cos\theta = qEd\cos\theta$

$$E = \frac{W}{qd\cos\theta} = \frac{4}{0.2\times2\times\cos 60°} = \frac{4}{0.4\times0.5}$$

$= 20$ N/C

29. (b) : To orient the dipole at any angle θ from its initial position, work has to be done on the dipole from $\theta = 0°$ to θ.

$\therefore$ Potential energy $= pE(1 - \cos\theta)$

30. (c) : Electric field intensity E is zero within a conductor due to charge given to it.

Also, $E = -\frac{dV}{dx}$ or $\frac{dV}{dx} = 0$ (inside the conductor)

$\therefore \quad V =$ constant.

So potential remains same throughout the conductor.

31. (b) : When the given metallic spheres are connected by a conducting wire, charge will flow till both the spheres acquire a common potential which is given by

$$V = \frac{q_1+q_2}{C_1+C_2} = \frac{-1\times10^{-2}+5\times10^{-2}}{4\pi\varepsilon_0 R_1 + 4\pi\varepsilon_0 R_2}$$

$$= \frac{4\times10^{-2}}{4\pi\varepsilon_0(1\times10^{-2}+3\times10^{-2})} = \frac{1}{4\pi\varepsilon_0}$$

$\therefore$ Final charge on the bigger sphere $= C_2V$

$$= 4\pi\varepsilon_0\times3\times10^{-2}\times\frac{1}{4\pi\varepsilon_0} = 3\times10^{-2}\text{ C}$$

32. (d) : Radii of spheres $R_1 = 1$ cm $= 1\times10^{-2}$ m; $R_2 = 2$ cm $= 2\times10^{-2}$ m and charges on sphere; $Q_1 = 10^{-2}$ C and $Q_2 = 5\times10^{-2}$ C

$$\text{Common potential}(V) = \frac{\text{Total charge}}{\text{Total capacity}} = \frac{Q_1+Q_2}{C_1+C_2}$$

$$= \frac{(1\times10^{-2})+(5\times10^{-2})}{4\pi\varepsilon_0 10^{-2}+4\pi\varepsilon_0(2\times10^{-2})} = \frac{6\times10^{-2}}{4\pi\varepsilon_0(3\times10^{-2})}$$

Therefore final charge on smaller sphere $= C_1V$

$$= 4\pi\varepsilon_0\times10^{-2}\times\frac{6\times10^{-2}}{4\pi\varepsilon_0\times3\times10^{-2}} = 2\times10^{-2}\text{ C}$$

33. (a) : Electrostatic force,

$$F_{\text{plate}} = QE = Q\times\frac{Q}{2\varepsilon_0 A} = \frac{Q^2}{2A\varepsilon_0}$$

F is independent of the distance between plates.

34. (d) : Force of attraction between the plates of the parallel plate air capacitor is $F = \frac{Q^2}{2\varepsilon_0 A}$

where Q is the charge on the capacitor, ε_0 is the permittivity of free space and A is the area of each plate.

But $Q = CV$ and $C = \frac{\varepsilon_0 A}{d}$ or $\varepsilon_0 A = Cd$

$$\therefore \quad F = \frac{C^2V^2}{2Cd} = \frac{CV^2}{2d}$$

35. (a) : Capacitance of a parallel plate capacitor

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

When battery is disconnected and the distance between the plates of the capacitor is increased then capacitance decreases and charge remains constant.

Since, Charge = Capacitance × Potential difference

$\therefore$ Potential difference increases.

36. (c) : Given : capacitance without dielectric, $C = 6\ \mu F$ and capacitance with dielectric, $C' = 30\ \mu F$.

$\therefore$ Dielectric constant, $K = \frac{C'}{C} = \frac{30}{6} = 5.$

Now, permittivity of the medium, $\varepsilon = K\varepsilon_0$
$= 5 \times 8.85 \times 10^{-12} = 0.44 \times 10^{-10}\ C^2\ N^{-1}\ m^{-2}$

37. (c) : $E_{\text{medium}} = \frac{E_{\text{vacuum}}}{K}$

The electric field inside the dielectrics will be less than the electric field in vacuum. The electric field inside the dielectric could not be zero. As $K_2 > K_1$ the drop in electric field for K_2 dielectric must be more than K_1.

38. (c) : Electric field between two parallel plates placed in vacuum is given by $E = \frac{\sigma}{\varepsilon_0}$

In a medium of dielectric constant K, $E' = \frac{\sigma}{\varepsilon_0 K}$

For kerosene oil $K > 1 \Rightarrow E' < E$

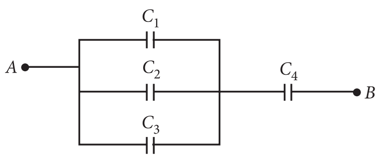
39. (d) : Capacitance of capacitor with oil between the plate, $C = \frac{K\varepsilon_0 A}{d}$

If oil is removed capacitance, $C' = \frac{\varepsilon_0 A}{d} = \frac{C}{K} = \frac{C}{2}$

40. (c) : Here, $C_1 = \frac{2\varepsilon_0 k_1 A}{3d}$, $C_2 = \frac{2\varepsilon_0 k_2 A}{3d}$

$$C_3 = \frac{2\varepsilon_0 k_3 A}{3d},\ C_4 = \frac{2\varepsilon_0 k_4 A}{d}$$

Given system of C_1, C_2, C_3 and C_4 can be simplified as



$$\therefore \frac{1}{C_{AB}} = \frac{1}{C_1 + C_2 + C_3} + \frac{1}{C_4}$$

Suppose, $C_{AB} = \frac{k\varepsilon_0 A}{d}$

$$\frac{1}{k\left(\frac{\varepsilon_0 A}{d}\right)} = \frac{1}{\frac{2}{3}\frac{\varepsilon_0 A}{d}(k_1 + k_2 + k_3)} + \frac{1}{\frac{2\varepsilon_0 A}{d}k_4}$$

$$\Rightarrow \frac{1}{k} = \frac{3}{2(k_1 + k_2 + k_3)} + \frac{1}{2k_4} \quad \therefore \frac{2}{k} = \frac{3}{k_1 + k_2 + k_3} + \frac{1}{k_4}$$

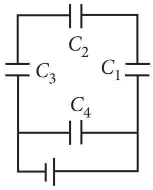
41. (b) : Three capacitors of capacitance C each are in series.

$\therefore$ Total capacitance, $C_{\text{total}} = \frac{C}{3}$

The charge is the same, Q, when capacitors are in series.

$$V_{\text{total}} = \frac{Q}{C} = \frac{Q}{C/3} = 3V$$

42. (b) : C_1, C_2 and C_3 are in series



$$\frac{1}{C'} = \frac{1}{C} + \frac{1}{2C} + \frac{1}{3C}$$

or, $\frac{1}{C'} = \frac{6+3+2}{6C} = \frac{11}{6C}$ or, $C' = \frac{6C}{11}$

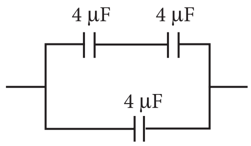
As the capacitors C_1, C_2 and C_3 are in series so the charge on each capacitor is

$Q' = \frac{6}{11}CV$

Also charge on capacitor C_4 is $Q = 4CV$

$\therefore$ Ratio $= \frac{Q'}{Q} = \frac{6CV}{11 \times 4CV} = \frac{3}{22}$

43. (c) : To get equivalent capacitance 6 μF. Out of the 4 μF capacitance, two are connected in series and third one is connected in parallel.



$$C_{eq} = \frac{4 \times 4}{4+4} + 4 = 2 + 4 = 6\ \mu F$$

44. (b) : Charge on first capacitor $= q_1 = C_1 V$

Charge on second capacitor $= q_2 = 0$

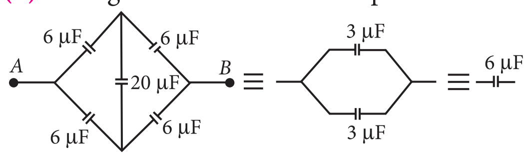
When they are connected, in parallel the total charge $q = q_1 + q_2 \ \therefore\ q = C_1 V$

and capacitance, $C = C_1 + C_2$

Let V' be the common potential difference across each capacitor, then $q = CV'$.

$$\therefore V' = \frac{q}{C} = \frac{C_1}{C_1 + C_2}V$$

45. (d) : The given circuit can be simplified as



46. (c) : As we know that, loss of electrostatic energy,

$$E_{\text{loss}} = \frac{1}{2}\frac{C_1 C_2}{(C_1 + C_2)}V^2 = \frac{1}{2} \times \frac{C^2}{2C}V^2$$

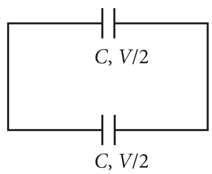
$$= \frac{1}{2}\left(\frac{1}{2}CV^2\right) = \frac{1}{2}E \qquad [\because C_1 = C_2 = C]$$

$\therefore$ Percentage of loss of energy $= \frac{\frac{1}{2}E}{E} \times 100\%$

$$= \frac{1}{2} \times 100\% = 50\%.$$

47. (a) : When the capacitor is charged by a battery of potential V, then energy stored in the capacitor,

$U_i = \frac{1}{2}CV^2$ ...(i)



When the battery is removed and another identical uncharged capacitor is connected in parallel

Common potential, $V' = \frac{CV}{C+C} = \frac{V}{2}$

Then the energy stored in the capacitor,

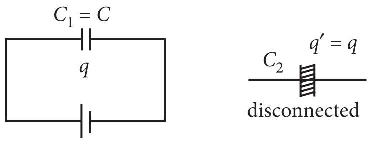
$$U_f = \frac{1}{2}(2C)\left(\frac{V}{2}\right)^2 = \frac{1}{4}CV^2 \quad \text{...(ii)}$$

$\therefore$ From eqns. (i) and (ii)

$$U_f = \frac{U_i}{2}$$

It means the total electrostatic energy of resulting system will decreases by a factor of 2.

48. (b) :



$q = CV \Rightarrow V = q/C$

Due to dielectric insertion, new capacitance

$C_2 = CK$

Initial energy stored in capacitor, $U_1 = \dfrac{q^2}{2C}$

Final energy stored in capacitor, $U_2 = \dfrac{q^2}{2KC}$

Change in energy stored, $\Delta U = U_2 - U_1$

$$\Delta U = \frac{q^2}{2C}\left(\frac{1}{K} - 1\right) = \frac{1}{2}CV^2\left(\frac{1}{K} - 1\right)$$

New potential difference between plates $V' = \dfrac{q}{CK} = \dfrac{V}{K}$

49. (c) : Capacitance of a parallel plate capacitor is

$$C = \frac{\varepsilon_0 A}{d} \quad \text{...(i)}$$

Potential difference between the plates is

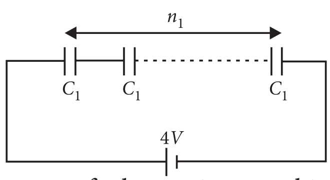
$$V = Ed \quad \text{...(ii)}$$

The energy stored in the capacitor is

$$U = \frac{1}{2}CV^2 = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(Ed)^2 \quad \text{(Using (i) and (ii))}$$

$$= \frac{1}{2}\varepsilon_0 E^2 Ad$$

50. (d) : A series combination of n_1 capacitors each of capacitance C_1 are connected to $4V$ source as shown in the figure.



Total capacitance of the series combination of the capacitors is

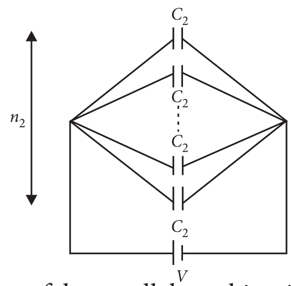
$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_1} + \frac{1}{C_1} + \text{.........upto } n_1 \text{ terms} = \frac{n_1}{C_1}$$

or $C_s = \dfrac{C_1}{n_1}$ ...(i)

Total energy stored in a series combination of the capacitors is

$$U_s = \frac{1}{2}C_s(4V)^2 = \frac{1}{2}\left(\frac{C_1}{n_1}\right)(4V)^2 \quad \text{(Using(i))} \quad \text{...(ii)}$$

A parallel combination of n_2 capacitors each of capacitance C_2 are connected to V source as shown in the figure.



Total capacitance of the parallel combination of capacitors is $C_p = C_2 + C_2 + \text{..........+ upto } n_2 \text{ terms} = n_2C_2$

or $C_p = n_2C_2$ ...(iii)

Total energy stored in a parallel combination of capacitors is

$$U_p = \frac{1}{2}C_pV^2 = \frac{1}{2}(n_2C_2)(V)^2 \quad \text{(Using(iii))} \quad \text{...(iv)}$$

According to the given problem,

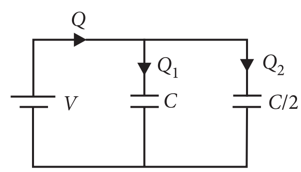
$U_s = U_p$

Substituting the values of U_s and U_p from equations (ii) and (iv), we get

$$\frac{1}{2}\frac{C_1}{n_1}(4V)^2 = \frac{1}{2}(n_2C_2)(V)^2$$

or $\dfrac{16C_1}{n_1} = n_2C_2$ or $C_2 = \dfrac{16C_1}{n_1n_2}$

51. (b) : As the capacitors are connected in parallel, therefore potential difference across both the condensers remains the same.



$\therefore$ $Q_1 = CV$;

$Q_2 = \dfrac{C}{2}V$

Also, $Q = Q_1 + Q_2$

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

Work done in charging fully both the condensers is given by $W = \dfrac{1}{2}QV = \dfrac{1}{2}\times\left(\dfrac{3}{2}CV\right)V = \dfrac{3}{4}CV^2$.

52. (a) : Energy density $= \dfrac{1}{2}\varepsilon_0\dfrac{V^2}{d^2}$

53. (b) : Let q be the charge on each capacitor.

$\therefore$ Energy stored, $U = \dfrac{1}{2}CV^2 = \dfrac{1}{2}\dfrac{q^2}{C}$

Now, when battery is disconnected and another capacitor of same capacity is connected in parallel to the first capacitor, then voltage across each capacitor, $V = \dfrac{q}{2C}$

$\therefore$ Energy stored $= \dfrac{1}{2}C\left(\dfrac{q}{2C}\right)^2 = \dfrac{1}{4}\cdot\dfrac{1}{2}\dfrac{q^2}{C} = \dfrac{1}{4}U$

54. (d)