CHAPTER : 2

Electrostatic Potential and Capacitance

STUDY NOTES

Potential difference: The potential difference between two points is defined as the amount of work done in bringing a unit positive charge from one point to another against the electrostatic forces.

$$\text{Potential difference} = \frac{\text{Work done}}{\text{Charge}}$$

$$V_{AB} = V_B - V_A = \frac{W_{AB}}{q}$$

SI unit of potential difference is volt (V). : $1V = 1\ JC^{-1} = 1\ Nm\ C^{-1}$

- **Electric potential:** It is defined as the amount of work done to bring a unit positive charge from infinity to the observation point against the electrostatic forces.

$$\text{Electric potential} = \frac{\text{Work done}}{\text{Charge}}$$

$$\text{or } V = \frac{W}{q}$$

It is a scalar quantity. SI unit of electric potential is volt.

- **Electric potential due to a point charge:** The electric potential of a point charge q at a distance r from it is given by

$$V = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r} \quad \text{i.e. } V \propto \frac{1}{r}$$

It is spherically symmetric.

- **Electric potential due to a dipole:** Electric potential at a point having position vector $\vec{r}$, due to a dipole of moment $\vec{p}$ at the origin is given by

$$V = \frac{1}{4\pi\varepsilon_0}.\frac{\vec{p}.\vec{r}}{r^3} = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

- At points on the axial line of the dipole (θ= 0 degree or 180 degrees)

$$V_{axial} = \pm\frac{1}{4\pi\varepsilon_0}.\frac{p}{r^2}$$

- At points on the equatorial line of the dipole (θ = 90 degrees)

$$V_{equa} = 0$$

- **Electric potential due to a group of N point charges:** If r_1, r_2, r_3 ... r_N are the distances of N point charges from the observation point, then

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \ldots + \frac{q_N}{r_N}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{q_i}{r_i}$$

- **Relation between electric field and electric potential:** The rate of change of potential with distance is called potential gradient. Electric field at any point is equal to the negative of the potential gradient at that point

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

SI unit of electric field = Vm^{-1}.The direction of E is in the direction of steepest decrease of potential.

- The rectangular components of E are given by

$$E_x = -\frac{dV}{dx}\ ;\ E_y = -\frac{dV}{dy};\ E_z = -\frac{dV}{dz}$$

- **Determination of electric potential from electric field:** The electric potential at a point having position vector $\bar{r}$ is given by

$$V = -\int_{\infty}^{r} \vec{E}.\vec{dr}$$

- **Equipotential surface:** Any surface that has the same electric potential at every point on it is called an equipotential surface.
- Some of the important properties of equipotential surface are as follows:
  (1) Work done in moving a test charge over an equipotential surface is zero.
  (2) Electric field is always normal to the equipotential surface at every point.
  (3) The distance between equipotential surfaces is less in the regions of strong field and more in the regions of weak field.
  (4) Two equipotential surfaces can never intersect each other.
- **Electric potential energy:** It is defined as the amount of work done in assembling the charges at their locations by bringing them in, from infinity.

  Potential energy of a charge = Charge × Electric potential at the given point

  Its unit is joule (J) or electron volt (eV).

$$1\ eV = 1.6 \times 10^{-19}\ J$$

- **Potential energy of a system of two point charges:** If q_1 and q_2 are two point charges separated by distance r_{12} , then their potential energy is

$$U = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{12}}$$

- **Potential energy of N point charges:** It is given by:

$$U = \frac{1}{4\pi\varepsilon_0} \sum_{\text{All pairs}} \frac{q_i q_j}{r_{ij}}$$

$$= \frac{1}{2} \cdot \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{N} \sum_{j=1}^{N} \frac{q_i q_j}{r_{ij}}$$

$$i \neq j$$

- **Potential energy of a dipole in a uniform electric field:** It is defined as the amount of work done in turning the dipole from orientation θ_1 to θ_2 in the field E

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

- If initially the dipole is perpendicular to the field E, $\theta_1 = 90$ degree to $\theta_2 = \theta$ then

$$U = -pE\cos\theta = -\vec{p}.\vec{E}$$

- When $\theta = 0°$, U = –pE i.e.,the potential energy of the dipole is minimum hence the dipole is in stable equilibrium.

  When $\theta = 90°$, U = 0

  When $\theta = 180°$, U = +pE i.e.,the potential energy of the dipole is maximum hence the dipole is in unstable equilibrium.

- **Conductors**. These are the substances which allow movement of large number of electric charges through them on application of external electric fields. They have a large number of free electrons.

Properties of conductors:

(a) Net electrostatic field is zero inside a conductor

(b) Just outside the surface, the electric field is normal to the surface of the conductor

(c) No charge can reside inside the conductor. Any excess charge will reside on the surface of the conductor

(d) Potential will be constant within and on the surface of conductor

(e) Electric field at the surface of a charged conductor is proportional to the surface charge density.

(f) Electric field is zero in the cavity of a hollow charged conductor

- **Insulator:** These are the substances which do not allow movement of electric charges through them even on application of electric field . They have a negligibly small number of free charge carriers.
- **Electrostatic shielding:** The process of making a region free from any electric field is called electrostatic shielding. It is due to the fact that the electric field vanishes inside the cavity of a hollow conductor.
- **Capacitance of a conductor:** It is defined as the charge required to increase the potential of a conductor by unit amount.

$$\text{Capacitance} = \frac{\text{charge}}{\text{potential}} \text{ or } C = \frac{q}{V}$$

- **Capacitance of a spherical conductor:** If R is the radius of the spherical conductor, then its capacitance is given by

$$C = 4\pi\varepsilon_0 R$$

- **Capacitor:** It is an arrangement of two conductors separated by an insulating medium that is used to store electric charge and electric energy.
- **Capacitance of a capacitor:** The capacitance of a capacitor is given by

$$C = \frac{q}{V}$$

The SI unit of capacitance is farad.

1 farad (F) is the capacitance developed if 1 coulomb of charge is transferred from one plate to another of a capacitor by applying a potential difference of 1 volt across the two plates.

- **Parallel plate capacitor:** It is an arrangement of two parallel conducting plates, each of area A, separated by a small distance d. Its capacitance is

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

- **Spherical capacitor:** It is an arrangement that consists of two concentric spherical conducting shells of inner and outer radii a and b and of common length. Its capacitance is

$$C = \frac{4\pi\varepsilon_o ab}{b-a}$$

- **Cylindrical capacitor:** It is an arrangement that consists of two coaxial conducting cylinders of inner and outer radii a and b and of common length l. Its capacitance is

$$C = 2\pi\varepsilon_0 \frac{l}{\log e\left(\frac{b}{a}\right)} = 2\pi\varepsilon_0 \frac{l}{2.303\log_{10}\left(\frac{b}{a}\right)}$$

- **Capacitors in series:** Its equivalent capacitance is given by

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

In a series combination of capacitors, the charge on each capacitor is same but the potential difference across any capacitor is different and is inversely proportional to its capacitance.

- **Capacitors in parallel:** The equivalent capacitance for capacitors connected in parallel is given by

$$C_p = C_1 + C_2 + C_3 + \ldots$$

In a parallel combination of capacitors, the potential difference across each capacitor is same but the charge on each capacitor is different and is proportional to its capacitance.

- **Energy stored in a capacitor:** The energy stored in a capacitor of having charge q with voltage V and capacitance C is

$$U = \frac{1}{2}CV^2 = \frac{1}{2}\cdot\frac{Q^2}{C} = \frac{1}{2}QV$$

- **Energy density:** The electrical energy stored per unit volume is known as energy density. The energy density in a region with electric field E is given by

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

- **Common potential:** It is given by

$$\frac{\text{Total charge}}{\text{Total capacitance}} = \frac{q_1 + q_2 + q_3 + \ldots}{C_1 + C_2 + C_3 + \ldots}$$

$$\frac{C_1V_1 + C_2V_2 + C_3V_3 + \ldots}{C_1 + C_2 + C_3 + \ldots}$$

- **Loss of energy on sharing charges:** Let two capacitors of two capacitances C_1 and C_2 be at potentials V_1 and V_2 respectively and are connected together. The loss of energy during this process is given by

$$\Delta U = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}(V_1 - V_2)^2$$

- **Dielectric:** A dielectric is a substance which acts an as insulator in absence of electric field but can be polarised through small localised displacements of its charges by application of electric field
  There are two types of dielectrics polar (that is made of polar molecules)and non-polar dielectrics(that is made of non- polar molecules)
- **Polarisation of dielectric:** If the medium between the plates of a capacitor is filled with a dielectric, the electric field due to the charged plates induces a net dipole moment in the dielectric. This effect is called polarisation which induces a field in the opposite direction.
- **Dielectric constant**. It is the ratio of the capacitance (C) of the capacitor with the dielectric as the medium to its capacitance (C_0) when conductors are in vacuum.

$$K = \frac{C}{C_0}$$

  It is also equal to the ratio of the applied electric field (E_0) to the net electric field (E) on inserting the dielectric slab between the plates of the capacitor.

$$K = \frac{E_0}{E} = \frac{E_0}{E_0 - E'}$$

  Here E' is the field developed due to polarisation of the dielectric in the opposite direction of E.
- **Capacitance of a parallel plate capacitor filled with a dielectric**

$$C = KC_0 = \frac{\varepsilon_0 KA}{d}$$

- **Capacitance of a parallel plate capacitor with a dielectric slab of thickness *t* between its plates:** Here $t < d$,

$$C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{k}\right)}$$

- **Capacitance of a parallel plate capacitor with conducting slab between its plates:** Here $t < d$,

$$C = \left(\frac{d}{d-t}\right)\frac{\varepsilon_0 A}{d} = \left(\frac{d}{d-t}\right)C_0$$

- **Van de Graaff generator:** It is an electrostatic generator that is used to develop high potential differences of the order of 10^7 volts. It works on the principle that when a charged conductor is brought into internal contact with a hollow conductor, it transfers all of its charge to the hollow conductor, however high the potential of the latter may be. It even uses the discharging action of sharp points.
  It is used to accelerate charged particles.

QUESTION BANK

MULTIPLE CHOICE QUESTIONS

1. Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximately

(a) spheres (b) planes (c) paraboloids (d) ellipsoids.

2. The potential to which a conductor is raised, depends on

(a) the amount of charge (b) geometry and size of the conductor

(c) both (a) and (b) (d) none of these

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

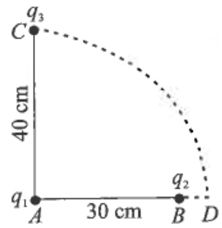
(a) $\frac{qQ}{4\pi\varepsilon_0 r}$ (b) Zero (c) $\frac{qQ}{4\pi\varepsilon_0 r^2}$ (d) None of these

4. Three charges 1μC, 2μC, 3μC are kept at vertices of an equilateral triangle of side 1 m. If they are brought nearer, so that they now form an equilateral triangle of side 0.5 m, then work done is

(a) 11 J (b) 0.01 J

(c) 1.1 J (d) 0.11 J

5. 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



(a) $8q_2$

(b) $8q_1$

(c) $6q_2$

(d) $6q_1$

6. A dipole is placed parallel to the electric field. If W is the work done in rotating the dipole by 60 degrees ; then work done in rotating it by 180° is

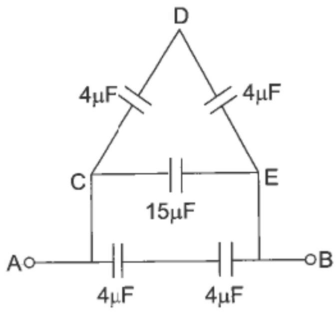
(a) 2 W (b) 3 W (c) 4 W (d) W/2

7. 8 drops of Hg are combined to form a bigger single drop. The capacitance of a single small drop and that of the single big drop will be in the ratio of

(a) 1:2 (b) 1:8

(c) 8:1 (d) none of these

8. The equivalent capacitance between A and B is :



(a) 8μF (b) 6μF

(c) 268μF (d) $\frac{1}{38\mu F}$

9. A 10 microfarad capacitor is charged to 500 V and then its plates are joined together through a resistance of 10 ohm. The heat produced in the resistance is

(a) 500 J (b) 250 J (c) 125 J (d) 1.25 J

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

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

11. A student connected a parallel plate capacitor to a battery. It stored energy U. Then he disconnected the battery and connected another identical capacitor across it, then the energy stored by both capacitors of the system was

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

12. An electric charge 10 μC is placed at the origin (0,0) of X-Y co-ordinate system. Two points A and B are situated at (√2, √2) and (2, 0) respectively. The potential difference between the points A and B will be:

(a) 9 volt (b) zero (c) 2 volt (d) 4.5 volt

13. Ten charges are placed on the circumference of a circle of radius R with constant angular separation between successive charges. Alternate charges 1, 3, 5, 7, 9 have charge (+q) each, while 2, 4, 6, 8, 10 have charge (–q) each. The potential V and the electric field E at the centre of the circle are respectively.(Take V = 0 at infinity)

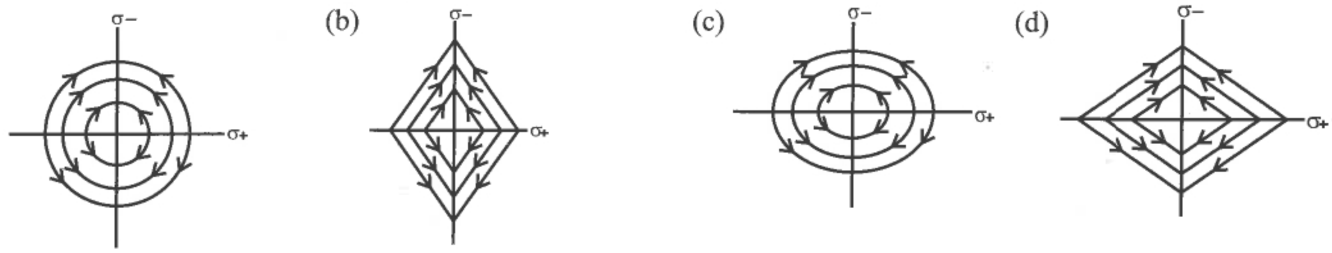
(a) V = 0, E = 0
(b) $V = \frac{10q}{4\pi\varepsilon_0 R}$; $E = \frac{10q}{4\pi\varepsilon_0 R^2}$
(c) $V = \frac{10q}{4\pi\varepsilon_0 R}$; E = 0
(d) V = 0, $E = \frac{10q}{4\pi\varepsilon_0 R^2}$

14. Two isolated conducting spheres S_1 and S_2 of radius 2R/3 and R/3 have 12μC and –3μC charges respectively, and are at a large distance from each other. They are now connected by a conducting wire. A long time after this is done the charges on S_1 and S_2 are respectively :

(a) 4.5 μC on both
(b) +4.5 μC and –4.5 μC
(c) 6 μC and 3 μC
(d) 3 μC and 6 μC

15. Two charged thin infinite plane sheets of uniform surface charge density σ_+ and σ_- where $|\sigma_+| > |\sigma_-|$, intersect at right angle.Which of the following best represents the electric field lines for this system:?

(a) (b) (c) (d)



16. A parallel plate capacitor is charged. If the plates are pulled apart,

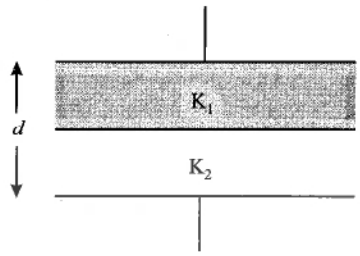
(a) the capacitance increases
(b) the potential difference increases
(c) the total charge increases
(d) the charge and potential difference remain the same.

17. A parallel plate air capacitor is charged and then isolated. When dielectric material is inserted between the plates of the capacitor, then which of the following does not change?

(a) Electric field between the plates
(b) Potential difference across the plates
(c) Charge on the plates
(d) Energy stored in the capacitor

18. A parallel plate capacitor of plate area A and separation d is filled with dielectric as shown in figure.

The dielectric constants are K_1 and K_2 . Net capacitance is



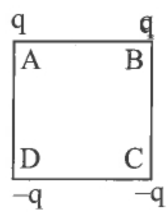
(a) $\frac{\varepsilon_0 A}{d}\left(K + K_2\right)$
(b) $\frac{\varepsilon_0 A}{d}\left(\frac{K_1 + K_2}{K_1 K_2}\right)$
(c) $\frac{2\varepsilon_0 A}{d}\left(\frac{K_1 K_2}{K_1 + K_2}\right)$
(d) $\frac{2\varepsilon_0 A}{d}\left(\frac{K_1 + K_2}{K_1 K_2}\right)$

19. An air filled parallel plate condenser has a capacity of 2 pF. The separation of the plates is doubled and the interspace between the plates is filled with wax. If the capacity is increased to 6 pF, the dielectric constant of wax is

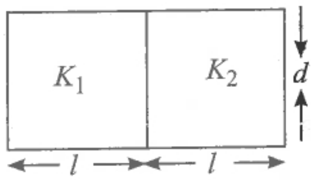
(a) 2 (b) 3 (c) 4 (d) 6

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

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



21. What is the equivalent capacitance of the arrangement as shown in figure, if A is the area?



(a) $\frac{A\varepsilon_o}{2} \cdot \frac{(K_1 + K_2)}{2}$

(b) $A\varepsilon_0 \frac{(K_1 + K_2)}{2d}$

(c) $\frac{A\varepsilon_0}{2d}\left(\frac{K_1 K_2}{K_1 + K_2}\right)$

(d) $\frac{A\varepsilon_0}{d}\left(\frac{K_1 K_2}{K_1 + K_2}\right)$

22. Two points P and Q are maintained at the potentials of 10 V and - 4 V respectively. The work done in moving 100 electrons from P and Q is

(a) -19×10^{-17} J

(b) 9.60×10^{-17} J

(c) -2.24×10^{-16} J

(d) 2.24×10^{-16} J

23. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre; a, b are constants. Then the charge density inside the ball is

(a) $-24\pi a\varepsilon_0 r$ (b) $-24\pi a\varepsilon_0$ (c) $-6\pi a\varepsilon_0 r$ (d) $-6\pi a\varepsilon_0$

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

$V(x) = \frac{20}{(x^2-4)}$ volts

The electric field E at $x = 4$μm is given by

(a) $\frac{10}{9}$ volt / μ m and in the +ve x-direction.

(b) $\frac{5}{3}$ volt / μ m and in the -ve x-direction.

(c) $\frac{5}{3}$ volt / μ m and in the +ve x-direction.

(d) $\frac{10}{9}$ volt / μ m and in the -ve x-direction.

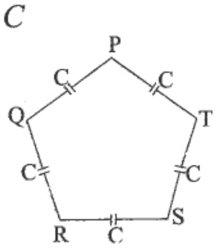
25. A sheet of aluminium foil of negligible thickness is introduced between the plates of a capacitor. The capacitance of the capacitor

(a) decreases (b) remains unchanged. (c) becomes infinite (d) increases

26. To demonstrate the conversion of electrical energy into heat energy a set up is created. A fully charged capacitor has a capacitance C. It is discharged through a small coil of resistance wire charge embedded in a thermally insulated block of specific heat capacity s and mass m. The temperature of the block is raised by ΔT, then the potential difference V across the capacitor will be:

(a) $\sqrt{\frac{2mC\Delta T}{s}}$ (b) $\frac{mC\Delta T}{s}$ (c) $\frac{ms\Delta T}{C}$ (d) $\sqrt{\frac{2ms\Delta T}{C}}$

27. Five capacitors, each of capacitance value C are connected as shown in the figure. The ratio of capacitance between P and R; and the capacitance between P and Q is



(a) 3:1 (b) 5:2

(c) 2:3 (d) 1:1

28. A conducting sphere of radius R carrying charge Q lies inside an uncharged conducting shell of radius 2 R. If they are joined by a metal wire, the amount of heat that will be produced is

(a) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{4R}$ (b) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{2R}$ (c) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{R}$ (d) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{3R}$

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

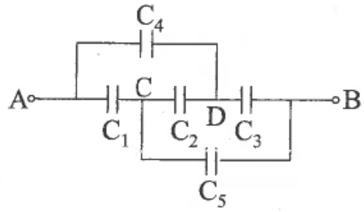
(a) is maximum at the surface.

(b) is maximum at the centre.

(c) remains the same throughout the conductor

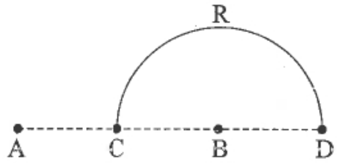
(d) is maximum somewhere between surface and centre.

30. In the given figure, the capacitors C_1, C_3, C_4, C_5 have a capacitance 4 μF each. If the capacitor C_2 has a capacitance 10 μF, then effective capacitance between A and B will be



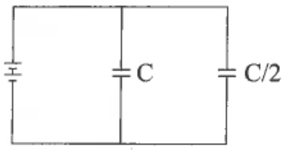
(a) 2 μF (b) 4 μF
(c) 6 μF (d) 8 μF

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



(a) $\frac{qQ}{2\pi\varepsilon_0 L}$ (b) $\frac{qQ}{6\pi\varepsilon_0 L}$
(c) $-\frac{qQ}{6\pi\varepsilon_0 L}$ (d) $\frac{qQ}{4\pi\varepsilon_0 L}$

32. A circuit for a refrigerator was designed by an engineer. It had two condensers, one of capacity C and the other of capacitor C/2 are connected to a V volt battery, as shown. What is the energy stored in the circuit?

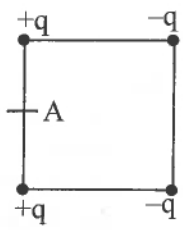


(a) $\frac{1}{4}$ CV^2 (b) $\frac{1}{2}$ CV^2
(c) $\frac{3}{4}$ CV^2 (d) $2CV^2$

33. The mean free path of electrons in a metal is 4×10^{-8} m. The electric field which can give on an average 2 eV energy to an electron in the metal will be in units of V/m
(a) 5×10^{11} (b) 8×10^{-11} (c) 5×10^{7} (d) 8×10^{7}

34. A series combination of n_1 capacitors, each of value C_1,is charged by a source of potential difference 4 V. An electrician wanted to make a parallel combination of capacitor for another device such that it stores the same amount of energy stored in the previous arrangement. He made the parallel combination of n_2 capacitors such that each capacitor has value C_2, is charged by a source of potential difference V. The value of C_2, in terms of C_1, is then
(a) $2C_1/n_1n_2$ (b) $16C_1n_2/n_1$ (c) $2C_1n_2/n_1$ (d) $16C_1/n_1n_2$

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

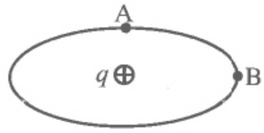


(a) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1+\sqrt{5}\right)$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1+\frac{1}{\sqrt{5}}\right)$
(c) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1-\frac{1}{\sqrt{5}}\right)$ (d) zero

36. Two identical thin rings, each of radius R metre are coaxially placed at distance R metre apart. If Q_1 and Q_2 coulomb are respectively the charges uniformly spread on two rings, the work done in moving a charge q from the centre of one ring to that of the other is
(a) zero (b) $\frac{q(Q_1-Q_2)\left(\sqrt{2}-1\right)}{4\sqrt{2}\,\pi\varepsilon_0 R}$ (c) $\frac{q\sqrt{2}(Q_1+Q_2)}{4\pi\varepsilon_0 R}$ (d) $\frac{q(Q_1+Q_2)\left(\sqrt{2}+1\right)}{4\sqrt{2}\,\pi\varepsilon_0 R}$

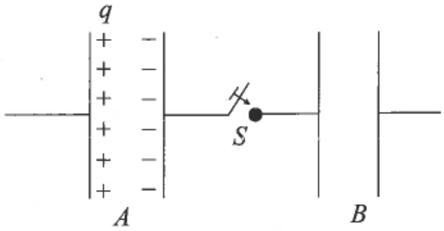
37. The magnitude of electric field $\vec{E}$ in the annular region of $\vec{E}$ a charged cylindrical capacitor
(a) is same throughout.
(b) is higher near the outer cylinder than near the inner cylinder.
(c) varies as $(1/r)$, where r is the distance from the axis.
(d) varies as $(1/r^2)$, where r is the distance from the axis.

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



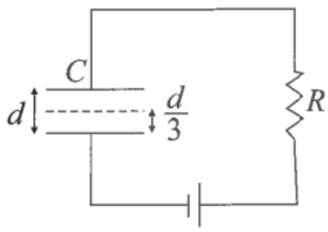
(a) electric field near A in the cavity = electric field near B in the cavity
(b) charge density at A = charge density at B
(c) potential at A = potential at B
(d) total electric field flux through the surface of the cavity is $-q/\varepsilon_0$

39. Consider the situation shown in the figure. The capacitor A has charge q on it, whereas B is uncharged.



The charge appearing on the capacitor B a long time after the switch S is closed, is
(a) zero (b) $q/2$ (c) q (d) $2q$

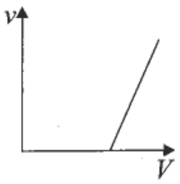
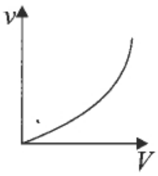
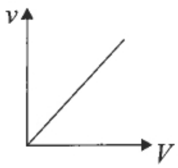
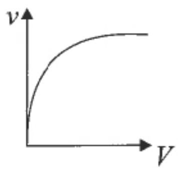
40. A parallel plate capacitor C with plates of unit area and separation d is filled with a liquid of dielectric constant K = 2. The level of liquid is $d/3$ initially. Suppose the liquid level decreases at a constant speed v, the time constant as a function of time t is



(a) $\dfrac{6\varepsilon_0 R}{5d+3vt}$ (b) $\dfrac{(15d+9vt)\varepsilon_0 R}{2d^2-3dvt-9v^2t^2}$

(c) $\dfrac{6\varepsilon_0 R}{5d-3vt}$ (d) $\dfrac{(15d-9vt)\varepsilon_0 R}{2d^2+3dvt-9v^2t^2}$

41. The velocity v acquired by an electron starting from rest and moving through potential difference V is shown by which of the following graphs?

(a)  (b)  (c)  (d) 

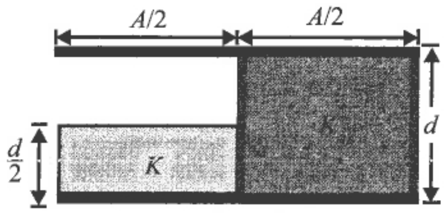
42. In a certain charge distribution, all points having zero potential can be joined by a circle S. Points inside S have positive potential and points outside S have negative potential. A positive charge, which is free to move, is placed inside S.
(a) It will remain in equilibrium
(b) It can move inside S, but it cannot cross S.
(c) It must cross S at some time.
(d) It may move, but will ultimately return to its starting point.

43. An electron initially at rest, is accelerated through a potential difference of 200 volt, so that it acquires a velocity 8.4×10^6 m/s. The value of e/m of electron will be
(a) 1.76×10^{11} C/kg (b) 2.76×10^{12} C/kg (c) 0.76×10^{11} C/kg (d) none of these

44. A certain region of space has a potential given by the function xy^2z^3 with respect to some reference point. Find the z–component of the electric field at (1, –3, 2).
(a) $108\ \hat{k}$ (b) $-108\ \hat{k}$ (c) $48\ \hat{k}$ (d) $-48\ \hat{k}$

45. A capacitor fabrication unit designed a parallel plate capacitor. It was charged to 200 V and then the battery was disconnected. Due to some fault, a dielectric slab of dielectric constant 5 and thickness 4 mm was inserted between them. So in order to achieve the original capacitance, what should be the increase in the separation of plates of capacitor?
(a) 0.8 mm (b) 3.2 mm (c) 4.0 mm (d) 1.6 mm

46. What will be the equivalent capacitance of a arrangement shown in figure?



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

(c) $\frac{(K+1)\varepsilon_0 A}{2d}$ (d) $\frac{(K+3)\varepsilon_0 A}{2(K+1)d}$

47. A condenser is charged and then the battery is removed. A dielectric plate is put between the plates of condenser, then correct statement is

(a) Q is constant, V and U decrease (b) Q is constant, V increases, U decreases

(c) Q increases, V decreases, U increases (d) Q,V and U increase

48. Two charges q and -q are kept apart. Then at any point on the perpendicular bisector of line joining the two charges:

(a) the electric field strength is zero

(b) the electric potential is zero

(c) both electric potential and electric field strength are zero

(d) both electric potential and electric field strength are non-zero

49. A new intern at the parallel plate capacitor manufacturing unit was making a parallel plate. He made the capacitor with one plate smaller than the other. Then the charge on the smaller plate:

(a) will be less than other (b) will be more than other

(c) will be equal to other (d) will depend upon the medium between the plates

50. The capacitance of a capacitor becomes $\frac{7}{6}$ times its original value if a dielectric slab of thickness, $t = \frac{2}{3}$ d is introduced in between the plates, d is the separation between the plates. The dielectric constant of the dielectric slab is:

(a) $\frac{14}{11}$ (b) $\frac{11}{14}$ (c) $\frac{7}{11}$ (d) $\frac{11}{7}$

51. In the capacitor of capacitance 20 μF, the distance between plates is 2 mm. If a material of dielectric constant 2 is inserted between the plates, then the capacitance of the system is:

(a) 20 μF (b) 30 μF (c) 22 × 5 μF (d) 40 μF

52. Two metal plates are separated by a distance d in a parallel plate condenser. A metal plate of thickness t and of the same area is inserted between the condenser plates.

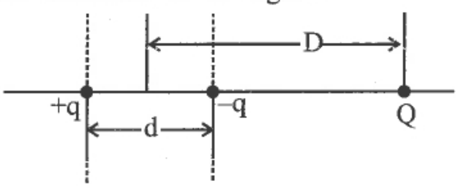
The value of capacitance increases by a factor of:

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

53. In free space, a particle A of charge 1μC is held fixed at a point P. Another particle B of the same charge and mass 4 μg is kept at a distance of 1 mm from P. If B is released, then its velocity at a distance of 9 mm from P is

(a) 1.0 m/s (b) 6.32×10^4 m/s (c) 2.0×10^3 m/s (d) 1.5×10^2 m/s

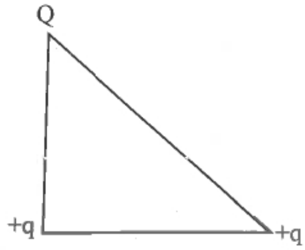
54. A system of three charges are placed as shown in the figure :



If D >> d, the potential energy of the system is best given by :

(a) $\frac{1}{4\pi\varepsilon_0}\left[\frac{q^2}{d}+\frac{qQd}{D^2}\right]$ (b) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{2D^2}\right]$ (c) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{D^2}\right]$ (d) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}+\frac{2qQd}{D^2}\right]$

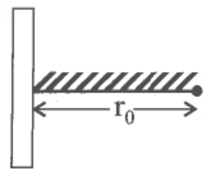
55. Three charges Q, + q and + q are placed at the vertices of a right-angle isosceles triangle as shown below. The net electrostatic energy of the configuration is zero, if the value of Q is :



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

(c) $-2q$ (d) $\frac{-\sqrt{2}q}{1+\sqrt{2}}$

56. A positive point charge is released from rest at a distance r_0 from a positive line charge with uniform density. The speed (v) of the point charge, as a function of instantaneous distance r from line charge, is proportional to :



(a) $\upsilon \propto \left(\frac{r}{r_o}\right)$ (b) $\upsilon \propto ln\left(\frac{r}{r_o}\right)$ (c) $\upsilon \propto e^{+r/r_0}$ (d) $\upsilon \propto \sqrt{ln\left(\frac{r}{r_0}\right)}$

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

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

58. A parallel plate capacitor of capacitance 90 pF is connected to a battery of emf 20 V. If a dielectric material of dielectric constant K = 5/3 is inserted between the plates, the magnitude of the induced charge will be :

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

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

(a) 20 mm (b) 32 mm (c) 28 mm (d) 16 mm

60. There is a uniform electrostatic field in a region. The potential at various points on a small sphere centred at P, in the region, is found to vary between the limits 589.0 V to 589.8 V. What is the potential at a point on the sphere whose radius vector makes an angle of 60° with the direction of the field?

(a) 589.5 V (b) 589.2 V (c) 589.4 V (d) 589.6 V

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

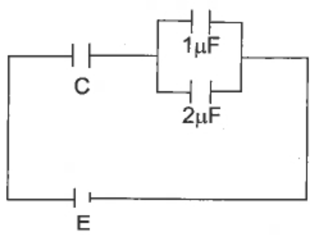
(a) 2 (b) 16 (c) 32 (d) 24

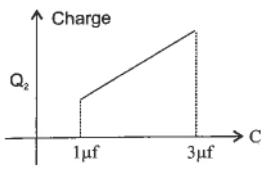
62. A student was given three capacitors each of 4 μF. For an experiment he needs a capacitor of 6μF. This can be done by connecting them :

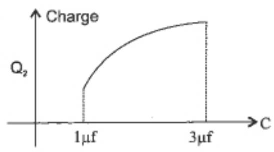
(a) all in series (b) two in series and one in parallel

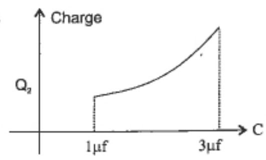
(c) all in parallel (d) two in parallel and one in series

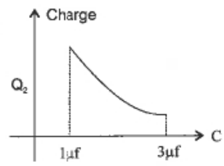
63. In the given circuit, charges Q_2 on the 2μF capacitor changes as C is varied from 1μF to 3μF. Q_2 as a function of 'C' is given by:



(a) 

(b) 

(c) 

(d) 

64. A parallel plate capacitor is made of two circular plates separated by a distance 5 mm and with a dielectric of dielectric constant 2.2 between them. When the electric field in the dielectric is 3×10^4V/m the charge density of the positive plate will be close to:

(a) 6×10^{-7} C/m^2 (b) 3×10^{-7} C/m^2 (c) 3×10^{4} C/m^2 (d) 6×10^{4} C/m^2

65. Two capacitors C_1 and C_2 are charged to 120 V and 200 V respectively. It is found that connecting them together the potential of each one can be made zero. Then

(a) $5C_1 = 3C_2$ (b) $3C_1 = 5C_2$ (c)$3C_1 + 5C_2 = 0$ (d) $9C_1 = 4C_2$

66. An electrician was asked to charge a parallel plate capacitor having separation between them as d and plate area A.The energy he will require to charge it such that the uniform electric field between the plate is E, is:

(a) $\varepsilon_0 E^2 Ad$ (b) $\frac{1}{2}\varepsilon_0 E^2 Ad$ (c) $\frac{1}{2}\varepsilon_0 E^2/Ad$ (d) $\varepsilon_0 E^2/Ad$

67. The electric field intensity produced by the radiations coming from 100 W bulb at 3 m distance is E. The electric field intensity produced by the radiations coming from 50 W bulb at the same distance is:

(a) E/2 (b) 2E (c) $E/\sqrt{2}$ (4) $\sqrt{2}E$

68. A charge Q is placed at the origin. The electric potential due to this charge at a given point in space is V. The work done by an external force in bringing another charge q from infinity up to the point is

(a) V/q (b) Vq (c) V + q (d) V

69. Which of the following is not true?

(a) For a point charge, the electrostatic potential varies as 1/r

(b) For a dipole, the potential depends on the position vector and dipole moment vector

(c) The electric dipole potential varies as 1/r at large distance

(d) For a point charge, the electrostatic field varies as $1/r^2$

70. A parallel plate capacitor has a uniform electric field E (V/m) in the space between the plates. If the distance between the plates is d(m) and area of each plate is A(m^2) the energy (joule) stored in the capacitor is

(a) $\varepsilon_0 E^2 Ad$ (b) $\frac{1}{2}\varepsilon_0 E^2 Ad$ (c) $\frac{1}{2}\varepsilon_0 E^2/Ad$ (d) $\varepsilon_0 E^2/Ad$

71. The ionisation potential of mercury is 10.39 V. How far an electron must travel in an electric field of 1.5×10^6 V / m to gain sufficient energy to ionise mercury?

(a) 10.39 / (1.6×10^{-19}) m (b) 10.39 / ($2 \times 1.6 \times 10^{-19}$) m

(c) $10.39 \times 1.6 \times 10^{-19}$ m (d) 10.39 / (1.5×10^{6}) m

72. If a charged spherical conductor of radius 10 cm has potential V at a point distant 5 cm from its centre, then the potential at a point distant 15 cm from the centre will be

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

73. A 500 μF capacitor is charged at the steady rate of 100 μC/s. How long will it take to raise the potential difference between the plates of the capacitor to 10 V?

(a) 5 s (b) 10 s (c) 50 s (d) 100 s

74. An 8 μF capacitor is connected across 220 V, 50 Hz line. What is the peak value of the charge through capacitor?

(a) 2.5×10^{-3} C (b) 2.5×10^{-4} C (c) 5×10^{-5} C (d) 7.5×10^{-2} C

75. The relation between electric field vector **E**, the displacement vector **D** and the polarization vector **P** for a dielectric placed in electric field E is given by

(a) P = ε_0 E + D (b) D = ε_0 E + P (c) P = E + D (d) E = P + D

76. What is the use of a Van de Graff generator?

(a) Van de Graff generator is used to create a large amount of current

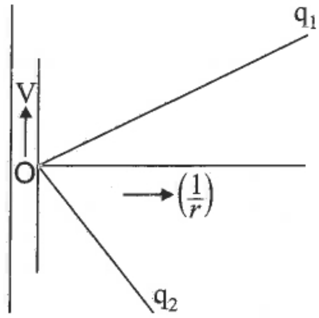
(b) Van de Graff generator is used to create a small amount of voltage

(c) Van de Graff generator is used to create a large amount of static electricity

(d) Van de Graff generator is used to create a small amount of resistance

(Data for question 77 and 78)

The two graphs drawn here, show the variation of electrostatic potential (V) with $1/r$ (r being distance of the field point from the point charge) for two point charges q_1 and q_2



77. What are the signs of the two charges?

(a) q_1 is negative and q_2 is positive

(b) both q_1 and q_2 are positive

(c) q_1 is positive and q_2 is negative

(d) both q_1 and q_2 are negative

78. Which of the two charges has a larger magnitude?

(a) magnitude of q_1 is larger than q_2

(b) magnitude of q_2 is larger than q_1

(c) magnitude of q_1 is equal to q_2

(d) can't say as data is not sufficient

79. Keeping the voltage of the charging source constant, what would be the fractional change in the energy stored in a parallel plate capacitor if the separation between its plates were to decreased by 10%?

(a) 19/81 (b) 1/9 (c) 1/81 (d) 10/9

80. Which of the following statement regarding equipotential surfaces is false?

Equipotential surfaces

(a) are closer in regions of large electric fields compared to regions of lower electric fields

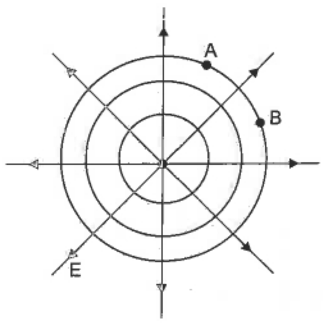
(b) will be more crowded near sharp edges of a conductor

(c) will be more crowded near regions of large charge densities

(d) will always be equally spaced.

INPUT TEXT BASED MCQs

1. *An equipotential surface is a surface with a constant value of potential at all points on the surface. For any charge configuration, equipotential surface through a point is normal to the electric field at that point. The equipotential surfaces of a single point charge are concentric spherical surfaces centred at the charge. The lines of force point radially outwards*



(i) Identify the wrong statement

(a) Equipotential surface due to a single point charge is spherical

(b) Equipotential surface can be constructed for dipoles too.

(c) The electric field is normal to the equipotential surface through the point

(d) The work done to move a test charge on the equipotential surface is positive.

(ii) Nature of equipotential surface for a point charge is

(a) Ellipsoid with charge at foci
(b) Sphere with charge at the centre of the sphere
(c) Sphere with charge on the surface of the sphere
(d) Plane with charge on the surface

(iii) A spherical equipotential surface is not possible

(a) inside a uniformly charged sphere
(b) for a dipole
(c) inside a spherical condenser
(d) for a point charge

(iv) The work done in carrying a charge q once round a circle of radius a with a charge Q at its centre is

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

(v) The work done to move a unit charge along an equipotential surface from P to Q

(a) must be defined as $-\int_P^Q \vec{E}.d\vec{l}$
(b) is zero
(c) can have a zero value
(d) both (a) and (b) are correct

2. A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance. The electric field in different regions is:

(a) Outer region I (region above the plate 1),

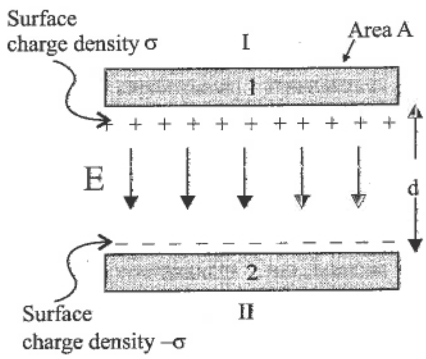
$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

(b) Outer region II (region below the plate 2),

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

(c) In the inner region between the plates 1 and 2, the electric fields due to the two charged plates add up, giving

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$



For uniform electric field, potential difference is simply the electric field times the distance between the plates. Capacitance of parallel plate capacitor is , the charge required supplied to either of the conductors of the capacitor so as to increase the potential difference by unit amount.

(i) A capacitor of capacitance C_1 is charged upto potential V and then connected in parallel to an uncharged capacitor of capacitance C_2. The final potential difference across each capacitor will be

(a) $\frac{C_2 V}{C_1 + C_2}$
(b) $\frac{C_1 V}{C_1 + C_2}$
(c) $\left(1+\frac{C_2}{C_1}\right)V$
(d) $\left(1-\frac{C_2}{C_1}\right)V$

(ii) In a parallel plate capacitor the capacity increases if

(a) area of the plate is decreases
(b) distance between the plate increases
(c) area of the plate is increases
(d) dielectric constant decreases

(iii) A parallel plate capacitor has two square plates with equal and opposite charges. The surface charge densities on the plate are $+\sigma$ and $-\sigma$ respectively. In the region between the plates the magnitude of the electric field is

(a) $\frac{\sigma}{2\varepsilon_0}$
(b) $\frac{\sigma}{\varepsilon_0}$
(c) 0
(d) none of these

(iv) If a parallel plate air capacitor consists of two circular plate of diameter 8 cm. As what distance should the plate be held so as to have the same capacitance as that of sphere of diameter 20 cm?

(a) 9mm
(b) 4 mm
(c) 8 mm
(d) 2mm

(v) If a charge of a $+2.0\times10^{-8}$ C is placed on the positive plate and a charge of 1.0×10^{8} C on the negative plate of a parallel plate capacitor of capacitance 1.2×10^{-3} μF, then the potential difference between the plate is

(a) 6.25 V
(b) 3.0 V
(c) 12.5 V
(d) 25 V

ANSWERS

1. (a)	**2.** (c)	**3.** (b)	**4.** (d)	**5.** (a)	**6.** (c)	**7.** (a)	**8.** (a)	**9.** (d)	**10.** (b)
11. (b)	**12.** (b)	**13.** (a)	**14.** (c)	**15.** (b)	**16.** (b)	**17.** (c)	**18.** (c)	**19.** (d)	**20.** (a)
21. (b)	**22.** (d)	**23.** (d)	**24.** (a)	**25.** (b)	**26.** (d)	**27.** (c)	**28.** (a)	**29.** (c)	**30.** (b)
31. (c)	**32.** (c)	**33.** (c)	**34.** (d)	**35.** (c)	**36.** (b)	**37.** (c)	**38.** (c)	**39.** (a)	**40.** (a)
41. (b)	**42.** (c)	**43.** (a)	**44.** (b)	**45.** (b)	**46.** (d)	**47.** (a)	**48.** (b)	**49.** (c)	**50.** (a)
51. (d)	**52.** (d)	**53.** (b)	**54.** (c)	**55.** (d)	**56.** (d)	**57.** (a)	**58.** (b)	**59.** (d)	**60.** (c)
61. (c)	**62.** (b)	**63.** (b)	**64.** (a)	**65.** (b)	**66.** (a)	**67.** (a)	**68.** (b)	**69.** (c)	**70.** (b)
71. (d)	**72.** (b)	**73.** (c)	**74.** (a)	**75.** (b)	**76.** (c)	**77.** (a)	**78.** (a)	**79.** (b)	**80.** (d)

Input Text Based MCQs

1. (i) (d), (ii) (b), (iii) (b), (iv) (d), (v) (d)   **2.** (i) (b), (ii) (c), (iii) (b), (iv) (b), (v) (c)