2 Electrostatic Potential and Capacitance

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. The electric potential inside a conducting sphere
(a) increases from centre to surface
(b) decreases from centre to surface
(c) remains constant from centre to surface
(d) is zero at every point inside

2. In a region of constant potential
(a) the electric field is uniform
(b) the electric field is zero
(c) the electric field shall necessarily change if a charge is placed outside the region
(d) None of these

3. It becomes possible to define potential at a point in an electric field because electric field
(a) is a conservative field
(b) is a non-conservative field
(c) is a vector field
(d) obeys principle of superposition

4. Which of the following about potential at a point due to a given point charge is true ?
The potential at a point P due to a given point charge
(a) is a function of distance from the point charge.
(b) varies inversely as the square of distance from the point charge.
(c) is a vector quantity
(d) is directly proportional to the square of distance from the point charge.

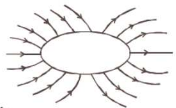
5. A cube of a metal is given a positive charge Q. For this system, which of the following statements is true?
(a) Electric potential at the surface of the cube is zero
(b) Electric potential within the cube is zero
(c) Electric field is normal to the surface of the cube
(d) Electric field varies within the cube

6. There are two metallic spheres of same radii but one is solid and the other is hollow, then
(a) solid sphere can be given more charge
(b) hollow sphere can be given more charge
(c) they can be charged equally (maximum)
(d) None of the above

7. The electric potential due to the pair of charges (+ 10μc and + 20 μc the middle of the line joing them is [if sepration is 2 cm]
(a) 27 MV (b) 35 MV (c) 37 MV (d) 40 MV

8. Potential due to electric dipole along equatorial line is.
(a) maximum (b) increasing
(c) zero (d) None of these

9. Figure below shows a hollow conducting body placed in an electric field. Which of the quantities are zero inside the body?



(a) Electric field and potential
(b) Electric field and charge density
(c) Electric potential and charge density.
(d) Electric field, potential and charge density.

10. The positive terminal of 12 V battery is connected to the ground. Then the negative terminal will be at
(a) – 6 V (b) + 12 V (c) zero (d) – 12 V

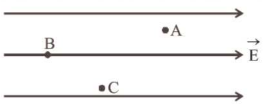
11. Let V be the electric potential at a given point. Then the electric field E_x along x-direction at that point is given by
(a) $\int_0^\infty V dx$ (b) $\frac{dV}{dx}$ (c) $-\frac{dV}{dx}$ (d) $-V\frac{dV}{dx}$

12. The electric field is along the direction in which the potential
(a) increases at max^m rate
(b) decreases at max^m rate
(c) increases at min^m rate
(d) None of these

13. Potential at any point inside a charged hollow sphere
(a) increases with distance
(b) is a constant
(c) decreases with distance from centre
(d) is zero

14. A solid sphere of radius R has uniform volume charge density. The electric potential at a points (r <R) is
(a) due to the charge inside a sphere of radius r only
(b) due to the entire charge of the sphere
(c) due to the charge in the spherical sheel of inner and outer radii r and R, only
(d) independent of r

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



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

16. Identify the false statement.
(a) Inside a charged or neutral conductor, electrostatic field is zero
(b) The electrostatic field at the surface of the charged conductor must be tangential to the surface at any point
(c) There is no net charge at any point inside the conductor
(d) Electrostatic potential is constant throughout the volume of the conductor

17. Three charges 2 q, – q and – q are located at the vertices of an equilateral triangle. At the centre of the triangle
(a) the field is zero but potential is non-zero
(b) the field is non-zero, but potential is zero
(c) both field and potential are zero
(d) both field and potential are non-zero

18. The electrostatic potential energy of a system of two charges is negative when
(a) both the charges are positive
(b) both the charges are negative
(c) one charge is positive and other is negative
(d) both the charges are separated by infinite distance

19. Two conducting spheres of radii R_1 and R_2 having charges Q_1 and Q_2 respectively are connected to each other. There is
(a) no change in the energy of the system
(b) an increase in the energy of the system
(c) always a decrease in the energy of the system
(d) a decrease in the energy of the system unless $Q_1R_2 = Q_2R_1$

20. A ball of mass 1 g carrying a charge 10^{-8} C moves from a point A at potential 600 V to a point B at zero potential. The change in its K.E. is
(a) -6×10^{-6} erg (b) -6×10^{-6} J
(c) 6×10^{-6} J (d) 6×10^{-6} erg

21. On moving a charge of 20 coulomb by 2 cm, 2 J of work is done, then the potential difference between the points is
(a) 0.1 V (b) 8 V (c) 2 V (d) 0.5 V.

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 to Q is:
(a) 9.60×10^{-17} J (b) -2.24×10^{-16} J
(c) 2.24×10^{-16} J (d) -9.60×10^{-17} J

23. A and B are two points in an electric field. If the work done in carrying 4.0C of electric charge from A to B is 16.0 J, the potential difference between A and B is
(a) zero (b) 2.0 V (c) 4.0 V (d) 16.0 V

24. A system of three positive charges placed at the vertices of an equilateral triangle. To decrease the potential energy of the system,
(a) a positive charge should be placed at centroid
(b) a negative charge should be placed at centroid.
(c) distance between the charges should be decreased.
(d) it should be rotated by an angle of $\frac{\pi}{2}$ radian.

25. The work done in carrying a charge q once around a circle of radius r with a charge Q placed at the centre will be
(a) $Qq(4\pi\varepsilon_0 r^2)$ (b) $Qq/(4\pi\varepsilon_0 r)$
(c) zero (d) $Qq^2/(4\pi\varepsilon_0 r)$

26. On decreasing the distance between the plates of a parallel plate capacitor, its capacitance
(a) remains unaffected
(b) decreases
(c) first increases then decreases.
(d) increases

27. 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

28. The potential gradient at which the dielectric of a condenser just gets punctured is called
(a) dielectric constant (b) dielectric strength
(c) dielectric resistance (d) dielectric number

29. When air in a capacitor is replaced by a medium of dielectric constant K, the capacity
(a) decreases K times (b) increases K times
(c) increases K^2 times (d) remains constant

30. Capacitors are used in electrical circuits where appliances need more
(a) voltage (b) current
(c) resistance (d) power

31. A parallel plate capacitor is charged by connecting it to a battery. Now the distance between the plates of the capacitor is increased. Which of the following remains constant ?
(a) Capacitance
(b) Charge on each plate of the capacitor.
(c) Potential difference between the plates of capacitor
(d) Energy stored in the capacitor.

32. A parallel plate condenser is immersed in an oil of dielectric constant 2. The field between the plates is
(a) increased, proportional to 2
(b) decreased, proportional to $\frac{1}{2}$
(c) increased, proportional to – 2
(d) decreased, proportional to $-\frac{1}{2}$

33. Capacitance (in F) of a spherical conductor with radius 1 m is
(a) 1.1×10^{-10} (b) 10^{6}
(c) 9×10^{-9} (d) 10^{-3}

34. A parallel plate capacitor is charged to a certain voltage. Now, if the dielectric material (with dielectric constant k) is removed then the
(a) capacitance increases by a factor of k
(b) electric field reduces by a factor k
(c) voltage across the capacitor decreases by a factor k
(d) None of these.

35. A dielectric slab is inserted between the plates of an isolated charged capacitor. Which of the following quantities remain unchanged ?
(a) The charge on the capacitor
(b) The stored energy in the Capacitor
(c) The potential difference between the plates
(d) The electric field in the capacitor

36. The capacitors of capacity C_1 and C_2 are connected in parallel, then the equivalent capacitance is
(a) $C_1 + C_2$ (b) $\frac{C_1C_2}{C_1 + C_2}$ (c) $\frac{C_1}{C_2}$ (d) $\frac{C_2}{C_1}$

37. A conductor carries a certain charge. When it is connected to another uncharged conductor of finite capacity, then the energy of the combined system is
(a) more than that of the first conductor
(b) less than that of the first conductor
(c) equal to that of the first conductor
(d) uncertain

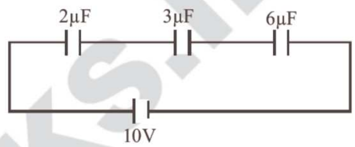
38. In a charged capacitor, the energy resides
(a) in the positive charges.
(b) in both the positive and negative charges.
(c) in the field between the plates.
(d) around the edges of the capacitor plates.

39. To obtain 3 μF capacity from three capacitors of 2 μF each, they will be arranged.
(a) all the three in series
(b) all the three in parallel
(c) two capacitors in series and the third in parallel with the combinatioin of first two
(d) two capacitors in parallel and the third in series with the combinatioin of first two

40. 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) $\frac{C}{3}, \frac{V}{3}$

41. A 5.0 μF capacitor is charged to a potential difference of 800 V and discharged through a conductor. The energy given to the conductor during the discharge is
(a) 1.6×10^{-2} joule (b) 3.2 joule
(c) 1.6 joule (d) 4.2 joule

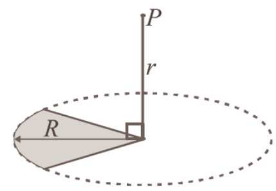
42. In the given figure, the charge on 3 μF capacitor is
(a) 10μC
(b) 15μ
(c) 30μC
(d) 5μC



43. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. The potential at a distance of 2 cm from the centre of the sphere is
(a) zero (b) 10 V (c) 4 V (d) 10/3 V

44. 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) $Q = -\frac{1}{q}$ (c) $Q = q$ (d) $Q = \frac{1}{q}$

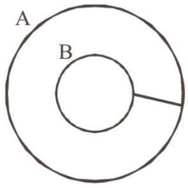
45. A plastic disc is charged on one side with a uniform surface charge density σ and then three quadrant of the disk are removed. The remaining quadrant is shown in figure, with $V = 0$ at infinity, the potential due to the remaining quadrant at point P is



(a) $\frac{\sigma}{2\epsilon_0}[(r^2 + R)^{1/2} - r]$ (b) $\frac{\sigma}{2\epsilon_0}[R - r]$
(c) $\frac{\sigma}{8\epsilon_0}[(r^2 + R^2)^{1/2} - r]$ (d) None of these

46. Consider the following statements and select the true/false.
I. Electric field lines are always perpendicular to equipotential surface.
II. No two equipotential surfaces can intersect each other.
III. Electric field lines are in the direction of tangent to an equipotential surface.
(a) T, F, F (b) F, T, F
(c) T, T, F (d) T, T, T

47. Figure shows two hollow charged conductors A and B having same positive surface charge densities. B is placed inside A and does not touches it. On connecting them with a conductor

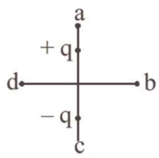


(a) charge will flow from A to B
(b) charge will flow from B to A
(c) charge oscillates between A and B
(d) no charge will flow.

48. Two equally charged spheres of radii a and b are connected together. What will be the ratio of electric field intensity on their surfaces?

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

49. Four points a, b, c and d are set at equal distance from the centre of a dipole as shown in figure. The electrostatic potential V_a, V_b, V_c, and V_d would satisfy the following relation:

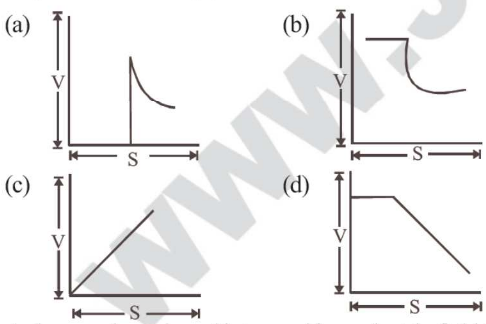


(a) $V_a > V_b > V_c > V_d$
(b) $V_a > V_b = V_d > V_c$
(c) $V_a > V_c = V_b = V_d$
(d) $V_b = V_d > V_a > V_c$

50. The electric potential at a point (x, y) in the x – y plane is given by V = –kxy. The field intensity at a distance r from the origin varies as

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

51. In a hollow spherical shell, potential (V) changes with respect to distance (s) from centre as



52. A charge q is projected into a uniform electric field E, work done when it moves a distance y is,

(a) q E y (b) q y/E (c) q E/ y (d) y/q E

53. Consider the following statements and select the true/ false statements

I. In an external electric field, the positive and negative charges of a non–polar molecule are displaced in opposite directions.
II. In non –polar molecules displacement stops when the external force on the constituent charges of the molecule is balanced by the restoring force.
III. The non–polar molecule develops an induced dipole moment.

(a) T, T, F (b) F, T, T (c) T, F, T (d) T, T, T

54. Which of the following about potential difference between any two points, are true/false.

I. It depends only on the initial and final position.
II. It is the work done per unit positive charge in moving from one point to other.
III. It is more for a positive charge of two units as compared to a positive charge of one unit.

(a) T, F, F (b) F, T, F (c) T, T, F (d) T, T, T

55. On decreasing the distance between the plates of a parallel plate capacitor, its capacitance

(a) remains unaffected
(b) decreases
(c) first increases then decreases.
(d) increases

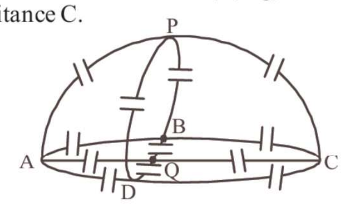
56. The potential energy of a charged parallel plate capacitor is U_0. If a slab of dielectric constant k is inserted between the plates, then the new potential energy will be

(a) U_0/k (b) U_0k^2 (c) U_0/k^2 (d) U_0^2

57. A capacitor is charged by using a battery which is then disconnected. A dielectric slab of dielectric k is then inserted between the plates, which results in

(a) Reduction of charge on the plates and increase of potential difference across the plates.
(b) Increase in the potential difference across the plate, reduction in stored energy, but no change in the charge on the plates.
(c) Decrease in the potential difference across the plates, reduction in the stored energy, but no change in the charge on the plates.
(d) None of these

58. Find the capacitance between P and Q (Fig). Each Capacitor has capacitance C.

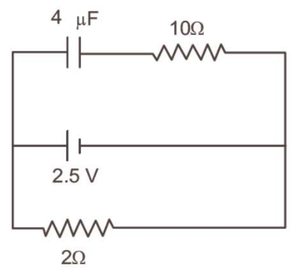


(a) 2C
(b) 3C
(c) 8C
(d) 6C

59. An electric dipole consisting of charges $+q$ and $-q$ separated by a distance L is in stable equilibrium in a uniform electric field $\vec{E}$. The electrostatic potential energy of the dipole is **[CBSE 2020]**

(a) qLE (b) zero (c) $-qLE$ (d) $-2\,qEL$

60. A capacitor of 4 μF is connected as shown in the circuit. The internal resistance of the battery is 0.5Ω. The amount of charge on the capacitor plates will be



(a) 0 μC (b) 4 μC (c) 16 μC (d) 8 μC

61. A positively charged particle is released from rest in an uniform electric field. The electric potential energy of the charge
(a) remains a constant because the electric field is uniform
(b) increases because the charge moves along the electric field
(c) decreases because the charge moves along the electric field
(d) decreases because the charge moves opposite to the electric field

62. Figure shows some equipotential lines distributed in space. A charged object is moved from point A to point B.
(a) The work done in Fig. (i) is the greatest
(b) The work done in Fig. (ii) is least
(c) The work done is the same in Fig. (i), Fig.(ii) and Fig. (iii)
(d) The work done in Fig. (iii) is greater than Fig. (ii) but equal to that in

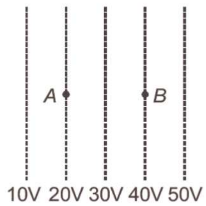


Fig. (i)

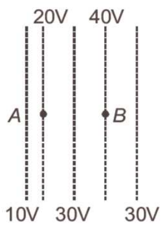


Fig. (ii)

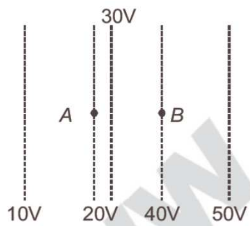
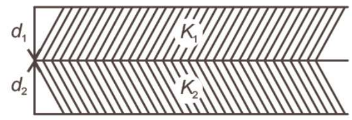


Fig. (iii)

63. The electrostatic potential on the surface of a charged conducting sphere is 100V. Two statements are made in this regard S_1 at any point inside the sphere, electric intensity is zero. S_2 at any point inside the sphere, the electrostatic potential is 100V. Which of the following is a correct statement?
(a) S_1 is true but S_2 is false
(b) Both S_1 and S_2 are false
(c) S_1 is true, S_2 is also true and S_1 is the cause of S_2
(d) S_1 is true, S_2 is also true but the statements are independant

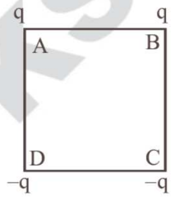
64. A parallel plate capacitor is made of two dielectric blocks in series. One of the blocks has thickness d_1 and dielectric constant K_1 and the other has thickness d_2 and dielectric constant K_2 as shown in figure. This arrangement can be thought as a dielectric slab of thickness d $(= d_1 + d_2)$ and effective dielectric constant K. The K is



(a) $\dfrac{K_1d_1 + K_2d_2}{d_1 + d_2}$ (b) $\dfrac{K_1d_1 + K_2d_2}{K_1 + K_2}$

(c) $\dfrac{K_1K_2(d_1 + d_2)}{(K_1d_2 + K_2d_1)}$ (d) $\dfrac{2K_1K_2}{K_1 + K_2}$

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



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

66. Two conducting spheres of radii R_1 and R_2 having charges Q_1 and Q_2 respectively are connected to each other. There is
(a) no change in the energy of the system
(b) an increase in the energy of the system
(c) always a decrease in the energy of the system
(d) a decrease in the energy of the system unless $Q_1R_2 = Q_2R_1$

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

Electrostatic potential energy of a system of point charges is the total amount of work done in bringing various charges to their respective positions from infinitely large mutual separations.

If two charges having charge q_1 and q_2 are placed at a distance r from each other, then the potential energy of the system is given by

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

The above potential energy is formed due to work done in bringing any one of the charge at the distance r of other charge from infinity so. $W = U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

67. The potential energy of a system of two charges is negative when
(a) both the charges are positive
(b) both the charges are negative
(c) one charge is positive and other is negative
(d) both the charges are separated by infinite distance

68. The electric potential at point A is 1 V and at another point B is 5V. A charge 3 μC is released from B. What will be the kinetic energy of the charge as it passes through A ?
(a) 8×10^{-6} J (b) 12×10^{-6} J
(c) 12×10^{-9} J (d) 4×10^{-6} J

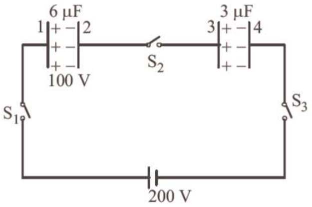
69. A square of side 'a' has charge Q at its centre and charge 'q' at one of the corners. The work required to be done in moving the charge 'q' from the corner to the diagonally opposite corner is
(a) zero (b) $\frac{Qq}{4\pi \in_0 a}$
(c) $\frac{Qq\sqrt{2}}{4\pi \in_0 a}$ (d) $\frac{Qq}{2\pi \in_0 a}$

70. When a positive charge q is taken from lower potential to a higher potential point, then its potential energy will
(a) increase (b) decrease
(c) remain unchanged (d) become zero

71. If a unit charge is taken from one point to another over an equipotential surface, then
(a) work is done on the charge
(b) work is done by the charge
(c) work done on the charge is constant
(d) no work is done

Case/Passage-II

Two capacitors of capacity 6 μF and 3 μF are charged to 100 V and 50 V separately and connected as shown in figure. Now all the three switches S_1, S_2 and S_3 are closed.



72. Which plates form an isolated system?
(a) plate 1 and plate 4 separately
(b) plate 2 and plate 3 separately
(c) plate 2 and plate 3 jointly
(d) none of these

73. Charge on the 6 μF capacitor in steady state will be
(a) 400 μC (b) 700 μC (c) 800 μC (d) 250 μC

74. Charge on the 3 μF capacitor in steady state will be
(a) 400 μC (b) 700 μC (c) 800 μC (d) 250 μC

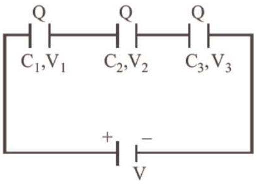
75. Suppose q_1, q_2 and q_3 be the magnitudes of charges flowing from charges S_1, S_2 and S_3 after they are closed. Then
(a) $q_1 = q_3$ and $q_2 = 0$ (b) $q_1 = q_3 = \frac{q_2}{2}$
(c) $q_1 = q_3 = 2q_2$ (d) $q_1 = q_2 = q_3$

76. A 2 μF capacitor is charged to 100 V and then its plates are connected by a conducting wire. The heat produced is
(a) 0.001 J (b) 0.01 J
(c) 0.1 J (d) 1J

Case/Passage-III

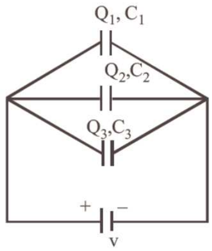
Combination of capacitors in series
Equivalent capacitance of capacitors

$$\frac{1}{C_5} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n}$$

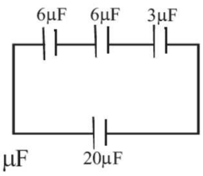


Combination of capacitors in parallel
Equivalent capacitance of capacitors,

$$C_P = C_1 + C_2 + C_3 + ... + C_n$$



77. The capacitor, whose capacitance is 6, 6 and 3μF respectively are connected in series with 20 volt line. Find the charge on 3μF.

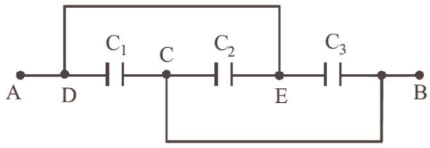


(a) 30 μc (b) 60 μF
(c) 15 μF (d) 90 μF

78. Three condensor each of capacitance 2F are put in series. The resultant capacitance is
(a) 6 F (b) 3/2 F
(c) 2/3 F (d) 5 F

79. To obtain 3 μF capacity from three capacitors of 2 μF each, they will be arranged.
(a) all the three in series
(b) all the three in parallel
(c) two capacitors in series and the third in parallel with the combinatioin of first two
(d) two capacitors in parallel and the third in series with the combinatioin of first two

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



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

(a) 3 (b) 4 (c) 5 (d) 6

81. Two capacitors of capacitances 3μF and 6μF are charged to a potential of 12V each. They are now connected to each other, with the positive plate of each joined to the negative plate of the other. The potential difference across each will be

(a) zero (b) 4 V (c) 6V (d) 12 V

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.

(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.

(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

82. **Assertion:** The potential difference between any two points in an electric field depends only on initial and final position.
Reason: Electric field is a conservative field so the work done per unit positive charge does not depend on path followed.

83. **Assertion :** Polar molecules have permanent dipole moment.
Reason : In polar molecules, the centres of positive and negative charges coincide even when there is no external field.

84. **Assertion :** Dielectric polarisation means formation of positive and negative charges inside the dielectric.
Reason: Free electrons are formed in this process.

85. **Assertion :** In the absence of an external electric field, the dipole moment per unit volume of a polar dielectric is zero.
Reason : The dipoles of a polar dielectric are randomly oriented.

86. **Assertion :** A parallel plate capacitor is connected across battery through a key. A dielectric slab of dielectric constant k is introduced between the plates. The energy stored becomes k times.

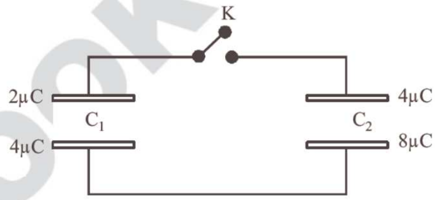
Reason : The surface density of charge on the plate remains constant.

87. **Assertion :** If two metal plates having charges $Q, -Q$ face each other at some separation are dipped into an oil tank, then electric field between the plates decreases.

Reason : Electric field between the plates, $E_{\text{med}} = \dfrac{E_{\text{air}}}{\kappa}$ due to polarization of dielectrical materials.

88. **Assertion :** A dielectric is inserted between the plates of a battery connected capacitor. The potential difference between the plates remains constant.
Reason : As the battery remains connected maintaining the same potential difference.

89. **Assertion :** Charges are given to plates of two plane parallel plate capacitors C_1 and C_2 (such that $C_2 = 2C_1$) as shown in figure. Then the key K is pressed to complete the circuit. Finally the net charge on upper plate and net charge on lower plate of capacitor C_1 is negative.



Reason : In a parallel plate capacitor both plates always carry equal and positive charge.

90. **Assertion :** Rate of change of potential is maximum at right angles to an equipotential surface.

Reason : There is no net force is acting on the dipole in a uniform electric field.

91. **Assertion :** A dielectric is inserted between the plates of a battery connected capacitor. The potential difference between the plates remains constant.

Reason : As the battery remains connected maintaining the same potential difference.

Match the Following

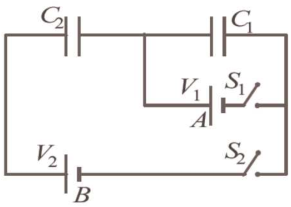
DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

92. Match the entries of Column I and Column II

Column I	**Column II**
(A) Inside a conductor placed in an external electric field.	(1) Potential energy = 0
(B) At the centre of a dipole	(2) Electric field = 0
(C) Dipole in stable equilibrium	(3) Electric potential = 0
(D) Electric dipole perpendicular to uniform electric field.	(4) Torque = 0

(a) (A)→(2); (B)→(4); (C)→(3); (D)→(1)
(b) (A)→(2); (B)→(3); (C)→(4); (D)→(1)
(c) (A)→(2); (B)→(3); (C)→(1); (D)→(4)
(d) (A)→(1); (B)→(3); (C)→(4); (D)→(2)

93. In the given circuit diagram, both capacitors are initially uncharged. The capacitance $C_1 = 2F$ and $C_2 = 4F$ emf of battery A and B are 2V and 4V respectively.



Column I	**Column II**
(A) On closing switch S_1 with S_2 open work done by battery A is	(1) $\frac{64}{3}$
(B) Switch S_1 is open and S_2 is closed, work done by battery B is	(2) 4
(C) Charge on capacitor C_2 is (after S_1 open and S_2 closed)	(3) 8
(D) Charge on C_1 when both are closed	(4) $\frac{16}{3}$

(a) (A)→(1); (B)→(2); (C)→(2); (D)→(4)
(b) (A)→(4); (B)→(3); (C)→(3); (D)→(1)
(c) (A)→(2); (B)→(3); (C)→(2); (D)→(1)
(d) (A)→(3); (B)→(1); (C)→(4); (D)→(2)

Fill in the Blanks

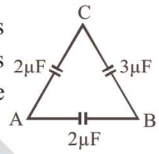
DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

94. The electric potential _______ inside a conducting sphere.

95. An electric dipole of moment $\vec{p}$ is placed normal to the lines of force of electric intensity $\vec{E}$, then the work done in deflecting it through an angle of 180° is _______.

96. Three capacitors each of capacitance C and break down voltage V are joined in series. The capacitance of the combination will be _______ and break down voltage of the combination will be _______.

97. Three capacitors are connected in the arms of a triangle ABC as shown in figure 5 V is applied between A and B. The voltage between B and C is _______.



98. The electric potential V is given as a function of distance × (metre) by
$V = (5x^2 + 10x - 4)$ volt. Value of electric field at x = 1 m is _______.

99. A dielectric of dielectric constant k is inserted in a capacitor after it is disconnected from the battery. As a result, the potential energy _______.

100. A parallel plate capacitor is made by stacking n equally spaced plates connected alternatively. If the capacitance between any two adjacent plates is 'C' then the resultant capacitance is _______.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

101. Electric potential and electric potential energy are different quantities.

102. For a system of positive test charge and point charge electric potential energy = electric potential.

103. When a dielectric slab is pulled out slowly from an isolated charged parallel plate capacitor, its energy increases.

104. Work done by external force is negative.

105. Electric potential due to dipole $\propto \frac{1}{r}$.

106. Electric potential due to a point charge $\propto \frac{1}{r^2}$.

107. For a non-uniformly charged thin circular ring with net charge is zero, the electric field at any point on axis of the ring is zero.

108. For a non-uniformly charged thin circular ring with net charge zero, the electric potential at each point on axis of the ring is maximum.

ANSWER KEY & SOLUTIONS

1. **(c)** Electric potential inside a conductor is constant and it is equal to that on the surface of the conductor.
2. **(b)** 3. **(a)**
4. **(a)** Since $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$, for a given point charge, q is constant, therefore V depends only on r. Hence V is a function of distance.
5. **(d)** Surface of metallic cube is an equipotential surface. Therefore, electric field is normal to the surface of the cube.
6. **(c)** Because in case of metallic spheres either solid or hollow, the charge will reside on the surface of the sphere. Since both spheres have same surface area, so they can hold equal maximum charge.
7. **(a)** 8. **(c)**
9. **(b)** Electric field is always zero inside a conductor. If there is any excess of charge on a hollow conductor it always resides on the outer surface of conductor. Therefore inside a hollow conductor there is no charge and hence charge density is zero.
10. **(d)** When negative terminal is grounded, positive terminal of battery is at +12 V. When positive terminal is grounded, the negative terminal will be at –12 V.
11. **(c)** The component of electric field in any direction is negative of the rate of change of electric potential with distance in that direction.

$$\therefore \quad E_x = -\frac{dV}{dx}$$

12. **(b)**
13. **(b)** As, $E = -\frac{dV}{dr}$ or, $0 = -\frac{dV}{dr}$

because electric field inside a charged hollow sphere is zero.

or, v = constant

14. **(a)**
15. **(a)** Potential at B, V_B is maximum

$V_B > V_C > V_A$

As in the direction of electric field potential decreases.

16. **(b)**
17. **(b)** Potential at the centre of the triangle,

$$V = \frac{\Sigma q}{4\pi\varepsilon_0 r} = \frac{2q - q - q}{4\pi\varepsilon_0 r} = 0$$

Obviously, $E \neq 0$

18. **(c)** The potential energy is negative whenever there is attraction. Since a positive and negative charge attract each other therefore their energy is negative. When both the charges are separated by infinite distance, they do not attract each other and their energy is zero.
19. **(d)** When $\frac{Q_1}{R_1} - \frac{Q_2}{R_2}$; current will flow in connecting wire so that energy decreases in the form of heat through the connecting wire.
20. **(c)** As work is done by the field, K.E. of the body increases by

$$K.E. = W = q(V_A - V_B)$$
$$= 10^{-8}(600 - 0) = 6 \times 10^{-6}\,J$$

21. **(a)** We know that $\frac{W_{AB}}{q} = V_B - V_A$

$$\therefore V_B - V_A = \frac{2\,J}{20\,C} = 0.1\,J/C = 0.1V$$

22. **(c)** $\frac{W_{PQ}}{q} = (V_Q - V_P)$

$$\Rightarrow W_{PQ} = q(V_Q - V_P)$$
$$= (-100 \times 1.6 \times 10^{-19})(-4 - 10)$$
$$= +2.24 \times 10^{-16} J$$

23. **(c)** Since $W_{A \to B} = q(V_B - V_A)$

$$\Rightarrow V_B - V_A = \frac{16}{4} = 4V$$

24. **(c)** Potential energy decreases whenever there is attraction. A negative charge placed at centroid causes attraction.
25. **(c)** In a round trip, displacement is zero. Hence, work done is zero.
26. **(d)** Since capacitance $C = \frac{\varepsilon_0 A}{d}$, as d decreases capacitance increases.
27. **(b)** 28. **(b)**
29. **(b)** $C_{\text{medium}} = K \times C_{\text{air}}$
30. **(b)**
31. **(c)** As the capacitor remains connected to the battery, the potential difference provided by the battery remains constant.
32. **(b)** In oil, C becomes twice, V becomes half. Therefore, E = V/d becomes half.
33. **(a)** Capacitance of spherical conductor = $4\pi\varepsilon_0 a$ where a is radius of conductor.

Therefore, $C = \frac{1}{9 \times 10^9} \times 1 = \frac{1}{9} \times 10^{-9}$

$$= 0.11 \times 10^{-9}\,F = 1.1 \times 10^{-10}\,F$$

34. **(d)**

35. **(a)** Due to insertion of a dielectric slab capacitance increase by K times. The potential difference, the electric field and the stored energy decreases by $\frac{1}{K}$ times.

36. **(a)** In parallel grouping of capacitors

$C_{eq} = C_1 + C_2 + \ldots\ldots\ldots\ldots C_n$

37. **(b)** Energy will be lost during transfer of charge (heating effect).

38. **(c)**

39. **(c)** $C = \frac{2\times 2}{2+2} + 2 = 3\ \mu F$

40. **(b)** In series combination of capacitors

$V_{eff} = V + V + V = 3V$

$\frac{1}{C_{eff}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} \Rightarrow C_{eff} = \frac{C}{3}$

Thus, the capacitance and breakdown voltage of the combination will be $\frac{C}{3}$ and 3V.

41. **(c)** Energy of given to conductor, $U = \frac{1}{2}CV^2$

or $U = \frac{1}{2}\times 5\times 10^{-6}\times (800)^2 = 1.6$ joule

42. **(a)** C = equivalent capacitance

$\therefore \frac{1}{C} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} \Rightarrow \therefore C = 1\mu F$

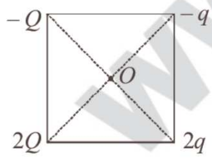
Charge in series circuit will be same.

$\therefore q = CV = (1\times 10^{-6})\times 10 = 10\mu C$

$\therefore$ Charge across '3μF' capacitor will be 10μC.

43. **(b)** Potential at any point inside the sphere = potential at the surface of the sphere = 10V.

44. **(a)** Let the side length of square be 'a' then potential at centre O is



$$V = \frac{k(-Q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{k(-q)}{\frac{a}{\sqrt{2}}} + \frac{k(2q)}{\frac{a}{\sqrt{2}}} + \frac{k(2Q)}{\frac{a}{\sqrt{2}}} = 0 \text{ (Given)}$$

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

45. **(c)** The potential at P due to whole disc is

$$V = \frac{\sigma}{2\epsilon_0}\left[\sqrt{R^2+r^2} - r\right]$$

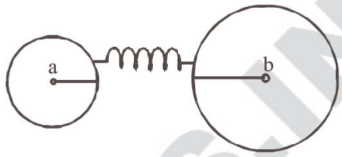
Now potential due to quarter disc,

$$V = \frac{V}{4} = \frac{\sigma}{8\epsilon_0}\left[\sqrt{R^2+r^2} - r\right]$$

46. **(c)** Electric field lines are always perpendicular to equipotential surface so, they cannot be in a direction of tangent to an equipotential surface.

47. **(b)** Irrespective of the charges on the inner and outer conductors, the inner conductor is always at a higher potential as long as the charge on inner conductor is not zero. Therefore charge flows from B to A. When the whole charge of B flows to A and charge on B becomes zero then A and B are at same potential.

48. **(c)**



Let charge on each sphere $= q$

when they are connected together their potential will be equal.

Now let charge on $a = q_1$ and on $b = 2q - q_1$

$\Rightarrow V_a = V_b$ or $\frac{1}{4\pi\varepsilon_o}\frac{q_1}{a} = \frac{1}{4\pi\varepsilon_o}\frac{2q-q_1}{b}$

$\Rightarrow \frac{q_1}{2q-q_1} = \frac{a}{b}$

$$\frac{E_a}{E_b} = \frac{\frac{1}{4\pi\varepsilon_o}\cdot\frac{q_1}{a^2}}{\frac{1}{4\pi\varepsilon_o}\frac{q_2}{b^2}} = \left(\frac{q_1}{2q-q_1}\right)\frac{b^2}{a^2}$$

$$= \frac{a}{b}\cdot\frac{b^2}{a^2} = \frac{b}{a} = b : a$$

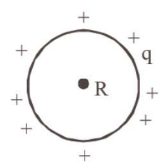
49. **(b)**

50. **(b)** $\vec{E} = \frac{\partial v}{\partial x}\hat{i} + \frac{\partial v}{\partial y}\hat{j}$ $\quad \therefore |\vec{E}| = k(\sqrt{x^2+y^2}) = kr$

Given $v = -kxy$ $\quad E \propto r$

$\therefore \vec{E} = ky\hat{i} + kx\hat{j}$

51. **(b)** In shell, q charge is uniformly distributed over its surface, it behaves as a conductor.



V = potential at surface $= \frac{q}{4\pi\varepsilon_0 R}$

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

Because of this it behaves as an equipotential surface.

52. **(a)** Force on a charge q in a uniform electric field E is, F = q E, work done = force × distance = qEy.

53. **(d)** In an external electric field, the positive and negative charges of a non-polar molecule are displaced in opposite directions. The displacement stops when the external force on the constituent charges of the molecule is balanced by the restoring force (due to internal fields in the molecule). The non-polar molecule thus develops an induced dipole moment. The dielectric is said to be polarised by the external field.

54. **(c)** Since $V = \frac{W}{Q}$, more work will be done for a positive charge of two units as compared to positive charge of one unit, but the ratio $\frac{W}{Q}$ is same. Therefore potential difference is same.

55. **(d)** Since capacitance $C = \frac{\varepsilon_0 A}{d}$, as d decreases capacitance increases.

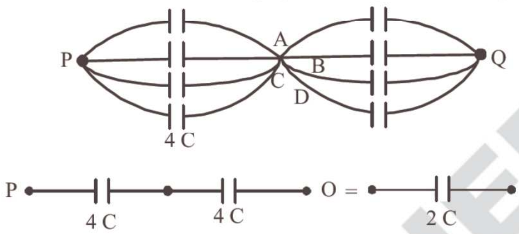
56. **(a)** PE, $U_0 = Q^2/2C$

When a slab of dielectric constant k is inserted, then $C' = Ck$

$$U' = \frac{Q^2}{2C'} = \frac{Q^2}{2Ck} = \frac{U_0}{k}$$

57. **(c)** Battery is disconnected so Q will be constant as $C \propto k$. So with introduction of dielectric slab capacitance will increase using $Q = CV$, V will decrease and using $U = \frac{Q^2}{2C}$, energy will decrease.

58. **(a)** A, B, C and D are equipotential points (see fig.)



59. **(c)** Potential energy of a dipole in external field U is

$$U = -\vec{P} \cdot \vec{E}$$

for stable equilibrium $\theta = 0°$

$$U = -pE\cos 0° = -pE$$

$$\therefore \quad U = -qLE$$

60. **(d)** As capacitor offers infinite resistance in dc-circuit. So, current flows through 2Ω resistance from left to right, given by

$$I = \frac{V}{R + r} = \frac{2.5V}{2 + 0.5} = \frac{2.5}{2.5} = 1\text{ A}$$

So, the potential difference across 2Ω resistance

$V = IR = 1 \times 2 = 2$ volt.

Since, capacitor is in parallel with 2Ω resistance, so it also has 2V potential difference across it.

As current does not flow through capacitor branch so no potential drop will be accross 10Ω resistance. The charge on capacitor

$q = CV = (4\ \mu F) \times 2V = 8\ \mu C$

61. **(c)** The direction of electric field is always perpendicular to the direction of electric field and equipotential surface maintained at high electrostatic potential to other equipotential surface maintained at low electrostatic potential.

The positively charged particle experiences the electrostatic force in the direction of electric field i.e., from high electrostatic potential to low electrostatic potential. Thus, the work done by the electric field on the positive charge, so electrostatic potential energy of the positive charge decreases because speed of charged particle moves in the direction of field due to force $q\vec{E}$.

62. **(c)** The work done (in displacing a charge particle) by a electric force is given by $W_{12} = q(V_2 - V_1)$. Here initial and final potentials are same in all three cases are equal (20V) and same charge is moving from A to B, so work done is (ΔVq) same in all three cases.

63. **(c)** As we know that the relation between electric field intensity E and electric potential V is

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

Electric field intensity $E = 0$ then $\frac{dV}{dr} = 0$

This imply that $V =$ constant

Thus, $E = 0$ inside the charged conducting sphere then the constant electrostatic potential 100V at every where inside the sphere and it verifies the shielding effect also.

64. **(c)** The capacitance of parallel plate capacitor filled with dielectric of thickness d_1 and dielectric constant K_1 is

$$C_1 = \frac{K_1 \varepsilon_o A}{d_1}$$

Similarly, capacitance of parallel plate capacitor filled with dielectric of thickness d_2 and dielectric constant K_2 is

$$C_2 = \frac{K_2 \varepsilon_o A}{d_2}$$

Since both capacitors are in series combination, then the equivalent capacitance is

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\text{or} \quad C = \frac{C_1 C_2}{C_1 + C_2} = \frac{\frac{K_1\varepsilon_0 A}{d_1} \frac{K_2 \varepsilon_0 A}{d_2}}{\frac{K_1 \varepsilon_0 A}{d_1} + \frac{K_2 \varepsilon_0 A}{d_2}}$$

$$C = \frac{K_1 K_2 \varepsilon_0 A}{K_1 d_2 + K_2 d_1} \quad \text{...(i)}$$

So multiply the numerator and denominator of equation (i) with $(d_1 + d_2)$

$$C = \frac{K_1 K_2 \varepsilon_0 A}{(K_1 d_2 + K_2 d_1)} \times \frac{(d_1 + d_2)}{(d_1 + d_2)}$$

$$= \frac{K_1 K_2 (d_1 + d_2)}{(K_1 d_2 + K_2 d_1)} \times \frac{\varepsilon_0 A}{(d_1 + d_2)} \quad \text{...(ii)}$$

So, the equivalent capacitances is

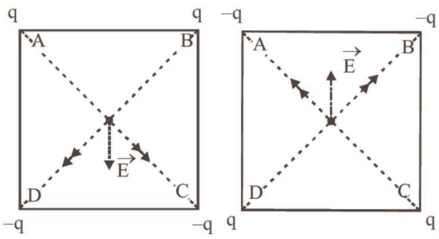
$$C = \frac{K \varepsilon_0 A}{(d_1 + d_2)} \quad \text{...(iii)}$$

Comparing, (ii) and (iii), the dielectric constant of new capacitor

$$K = \frac{K_1 K_2 (d_1 + d_2)}{K_1 d_2 + K_2 d_1}$$

65. **(a)** As shown in the figure, the resultant electric fields before and after interchanging the charges will have the same magnitude, but opposite directions.

Also, the potential will be same in both cases as it is a scalar quantity.



66. **(d)** When $\frac{Q_1}{R_1} - \frac{Q_2}{R_2}$; current will flow in connecting wire so that energy decreases in the form of heat through the connecting wire.

67. **(c)** The potential energy is negative whenever there is attraction. Since a positive and negative charge attract each other therefore their energy is negative. When both the charges are separated by infinite distance, they do not attract each other and their energy is zero.

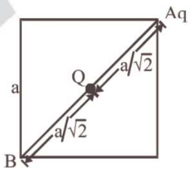
68. **(b)** When the charge is released to move freely, the work done by electric field is equal to change in kinetic energy

$\therefore \; W_{EF} = \Delta KE$

$-q\Delta V = \Delta KE$

$KE = -3 \times 10^{-6}(1-5) = 12 \times 10^{-6}$ J

69. **(a)** Here, $V_A = V_B = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{a/\sqrt{2}}$



Hence, $V_A - V_B = 0$

Work done, $W = q(V_A - V_B) = 0$

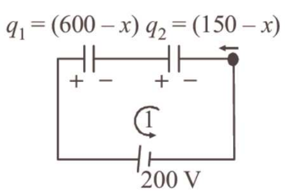
70. **(a)** **71.** **(d)**

72. **(c)** Plate 2 and plate 3 jointly.

$$\frac{(150-x)}{3} + \frac{(600-x)}{6} - 200 = 0$$

73. **(b)** Hence, find charge on 6 μF capacitor is $q_1 = 700\ \mu C$

74. **(d)** Charge on 3 μF is $q_2 = 250\ \mu C$



75. **(d)** Plates 2 and 3 and plates 1 and 4 form isolated system.

Hence $q_1 = q_2 = q_3 = x = -100\ \mu C$

76. **(b)** Energy stored in capacitor will convert into heat.

$$= \frac{1}{2}CV^2 = \frac{1}{2} \times 2 \times 10^{-6} \times (100)^2 = 0.01 \text{ J}$$

77. **(a)** In series $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ and charge on each capacitor is same.

78. **(c)** Capacitance are in series

$$\frac{1}{c} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} \Rightarrow c = \frac{2}{3}F$$

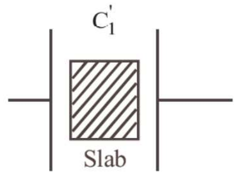
79. **(c)** $C = \frac{2 \times 2}{2+2} + 2 = 3\ \mu F$

80. **(c)** Before introducing a slab capacitance of plates

$$C_1 = \frac{\varepsilon_0 A}{3}$$

If a slab of dielectric constant K is introduced between plates then

$C = \frac{K\varepsilon_0 A}{d}$ then $C_1' = \frac{\varepsilon_0 A}{2.4}$



C_1 and C_1' are in series hence,

$$\frac{\varepsilon_0 A}{3} = \frac{k\frac{\varepsilon_0 A}{3} \cdot \frac{\varepsilon_0 A}{2.4}}{k\frac{\varepsilon_0 A}{3} + \frac{\varepsilon_0 A}{2.4}}$$

$3k = 2.4k + 3 \qquad 0.6k = 3$

Hence, the dielectric constant of slap is given by,

$$k = \frac{30}{6} = 5$$

81. **(b)**

82. **(a)** As $(V_B - V_A) = \frac{W_{AB}}{q} = -\int_A^B \vec{E}.\vec{d\ell}$

$$= kq\left[\frac{1}{r_A} - \frac{1}{r_B}\right]$$

Which depends on the initial and final position.

83. **(c)** **84.** **(c)** **85.** **(a)**

86. **(c)** $C' = kC$, and so, $U' = \frac{1}{2}(kC)V^2 = kU$. Also $q' = C'V = kCV = kq$, and so charge density increases.

87. **(a)**

88. **(a)** In the battery connected capacitor V remains constant while C increases with the introduction of dielectric.

89. **(d)**

90. **(b)** Since force on both the charges of a dipole is equal but opposite in direction, so net force = 0

91. **(a)** In the battery connected capacitor V remains constant while C increases with the introduction of dielectric

92. **(b)** $A \rightarrow (2); B \rightarrow (3); C \rightarrow (4); D \rightarrow (1)$

Electrice field is zero inside a conductor placed in an external field.

Electrice potential is zero at the centre of a dipole.

Torque is zero when a dipole in stable equilibrium.

Potential energy is zero if a electric dipole perpendicular to uniform electice field.

93. **(d)** $(A) \rightarrow (3); (B) \rightarrow (1); (C) \rightarrow (4); (D) \rightarrow (2)$

W.d. by battery A, $= 2\left(\frac{1}{2}C_1V_1^2\right) = 2 \times 2^2 = 8\text{J}$

W.d. by battery B, $= 2\left[\frac{1}{2}CV_2^2\right]$

$= 2\left[\frac{1}{2} \times \frac{4 \times 2}{4+2} \times 4^2\right] = \frac{64}{3}\text{J}$

$q_2 = CV_2 = \left(\frac{4 \times 2}{4+2}\right) \times 4 = \frac{16}{3}$

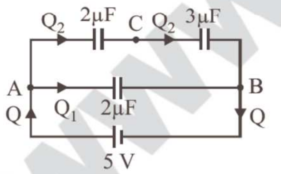
$q_1 = C_1V_1 = 2 \times 2 = 4$

94. Electric potential inside a conductor is constant and it is equal to that on the surface of the conductor.

95. Zero

96. $\frac{C}{3}$, 3V

97. (2v) The equivalent circuit diagram as shown in the figure.



The equivalent capacitance between A and B is

$$C_{eq} = \frac{2\mu F \times 3\mu F}{2\mu F + 3\mu F} + 2\mu F = \frac{16}{5}\mu F$$

Total charge of the given circuit is

$$Q = \frac{16}{5}\mu F \times 5V = 16\mu C$$

$$Q_1 = (2\mu F) \times 5V = 10\mu C$$

$\therefore$ $Q_2 = Q - Q_1 = 16\ \mu C - 10\ \mu C = 6\ \mu C$

$\therefore$ Voltage between B and C is

$$V_{BC} = \frac{Q_2}{3\mu F} = \frac{6\mu C}{3\mu F} = 2\text{ V}$$

98. (–20 V/m) $V = 5x^2 + 10x - 4$

$$E = \frac{-dV}{dx} = -(10x + 10).$$

At x = 1 m, E = –20 V/m.

99. (decreases)

100. $(n - 1)\ C$ As n plates are joined, it means $(n - 1)$ combination joined in parallel.

$\therefore$ resultant capacitance $= (n - 1)\ C$

101. (True) Potential and potential energy are different quantities and cannot be equated.

102. (False)

103. (True) For an isolated capacitor, q is constant $U = \frac{q^2}{2C}$

When C decreases, U will increase

External force is outwards, hence work done is positive.

104. (False)

105. (False) $V_{dipole} = \frac{KP}{r^2}$

106. (True) $V_{point\ charge} = \frac{Kq}{r}$

107. (False)

108. (True)