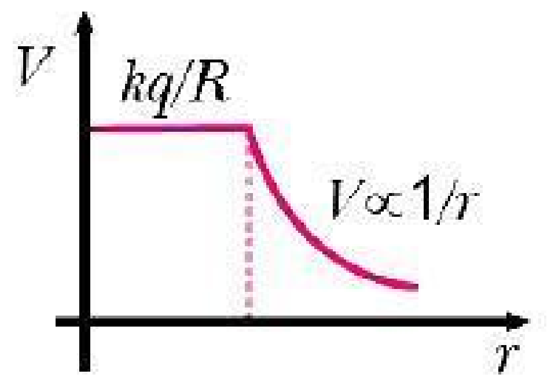
ELECTROSTATIC POTENTIAL AND CAPACITANCE

IMPORTANT FORMULAE

1. **Electric Potential:**



Due to a charged conducting sphere or charged spherical shell of radius R.

(*i*) Inside, $V_{inside} = \frac{1}{4\pi\varepsilon_0}\frac{q}{R} \; (r \le R)$ (*ii*) Outside, $V_{out} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} \; (r > R)$

2. **Relation between electric field and potential,**

$$E = -\frac{dV}{dr} = \frac{V}{r} \text{ (numerically)}$$

3. Work done in taking a charge q from one point to another in electric field.

$$W = q(V_2 - V_1) \text{ joule}$$

where V_1 = potential at initial point,

V_2 = potential at final point.

4. Work done in carrying a charge on equipotential surface is always zero.

5. **Electric potential due to dipole,**

(*i*) at axial point $V_{axis} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$,

(*ii*) at an equatorial point $V = 0$

6. Capacitance for isolated conductor, $C = \frac{Q}{V}$

7. Dielectric constant $K = \frac{\varepsilon}{\varepsilon_0} = \frac{C_{medium}}{C_{air}}$

8. **Capacitance of parallel plate capacitor**

(*i*) $C = \frac{\varepsilon_0 A}{d}$ in air

(*ii*) $C = \frac{K\varepsilon_0 A}{d}$ when medium of dielectric constant K fills the space between plates.

(*iii*) When the space between the plates is partly filled with a dielectric of thickness t, then capacitance $C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$

11. **Combination of Capacitors:**

(*a*) Capacitors in series:

(*i*) Net capacitance C is given by

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

(*ii*) In series charge is the same on all capacitors

$$q_1 = q_2 = q_3$$

(*iii*) Net potential difference $V = V_1 + V_2 + V_3$

(*b*) Capacitors in Parallel:

(*i*) Net capacitance, $C = C_1 + C_2 + C_3$

(*ii*) Potential difference is same across all capacitors

$$V_1 = V_2 = V_3 = \text{V (same for all)}$$

(*iii*) Charge, $q = q_1 + q_2 + q_3$

12. Energy stored in a capacitor,

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

13. Electrostatic energy density,

$$U_e = \frac{1}{2}\varepsilon_0 E^2 \text{(in air) and } \frac{1}{2}\varepsilon E^2 \text{ (in medium)}$$

Effect of Introducing a dielectric between plates of a charged parallel plate capacitor

S. No.	Physical Quantity	When battery remains connected	When battery is removed before introduction of dielectric
(1)	Capacitance (*C*)	increases *K*-times	increases *K*-times
(2)	Charge (*Q*)	increases *K*-times	remains constant
(3)	Electric Field	remains constant	decreases $\frac{1}{K}$ times
(4)	Electric Potential (*V*)	remains constant	decreases $\frac{1}{K}$ times
(5)	Electrostatic Energy Stored	increases *K*-times	decreases $\frac{1}{K}$ times

MULTIPLE CHOICE QUESTIONS

Choose and write the correct option in the following questions.

1. The ratio of charge to potential of a body is known as

(*a*) capacitance (*b*) inductance

(*c*) conductance (*d*) resistance

2. On moving a charge of 20 C 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

3. In brining an electron towards another electron, the electrostatic potential energy of the system

(*a*) increases (*b*) decreases

(*c*) remains unchanged (*d*) becomes zero

4. Electric potential of earth is taken to be zero, because earth is a good

(*a*) insulator (*b*) conductor

(*c*) semi-conductor (*d*) dielectric

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

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

6. Equipotential surface associated with an electric field, which is increasing in magnitude along the X-direction, are

(*a*) planes parallel to YZ-plane.
(*b*) planes parallel to XZ-plane.
(*c*) planes parallel to XY-plane.
(*d*) coaxial cylinder of increasing radii around the X-axis.

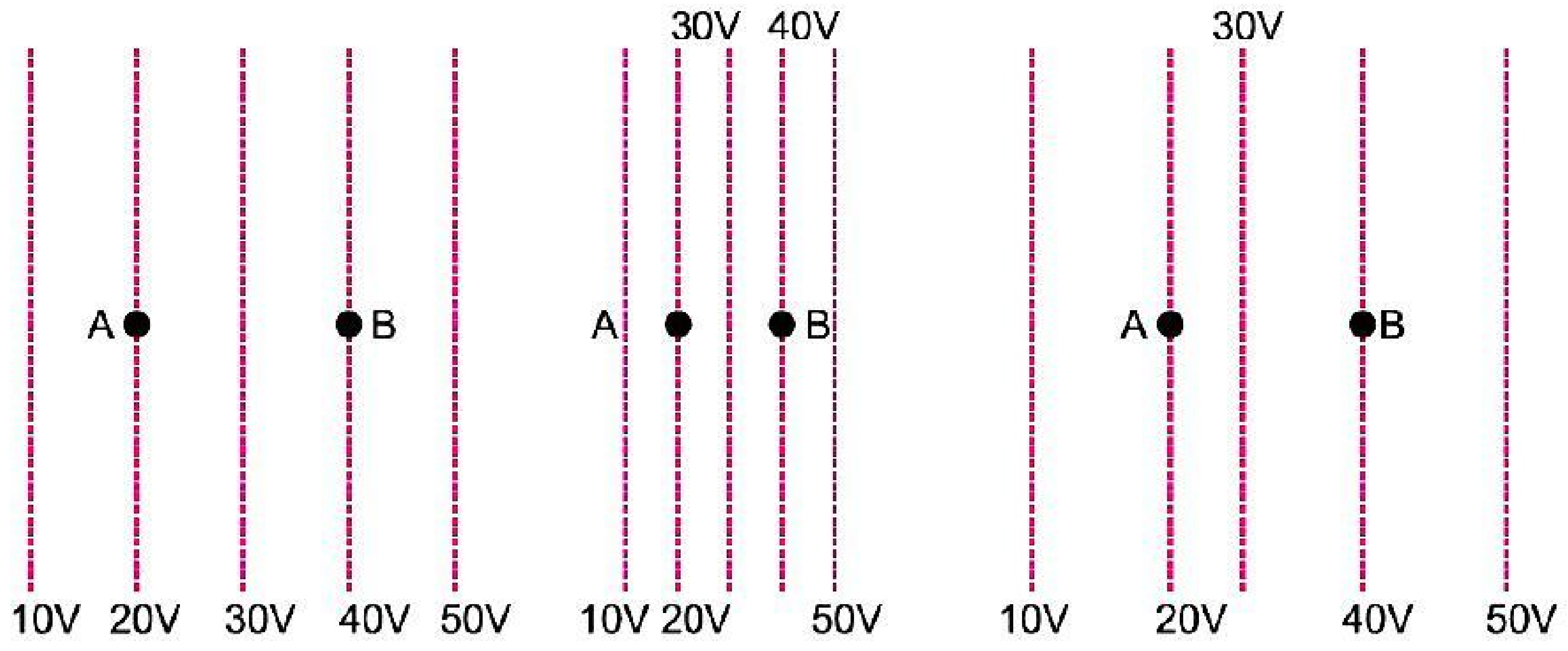
7. What is angle between electric field and equipotential surface?

(*a*) 90° always
(*b*) 0° always
(*c*) 0° to 90°
(*d*) 0° to 180°

8. A positively charged particle is released from rest in an uniform electric field. The electric potential energy of the charge **[*NCERT Exemplar*]**

(*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.

9. Figure shows some equipotential lines distributed in space. A charged object is moved from point A to point B. **[*NCERT Exemplar*]**



(i) (ii) (iii)

(*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*).

10. The electrostatic potential on the surface of a charged conducting sphere is 100 V. Two statements are made in this regard: **[*NCERT Exemplar*]**

S_1 : At any point inside the sphere, electric intensity is zero.

S_2 : At any point inside the sphere, the electrostatic potential is 100 V.

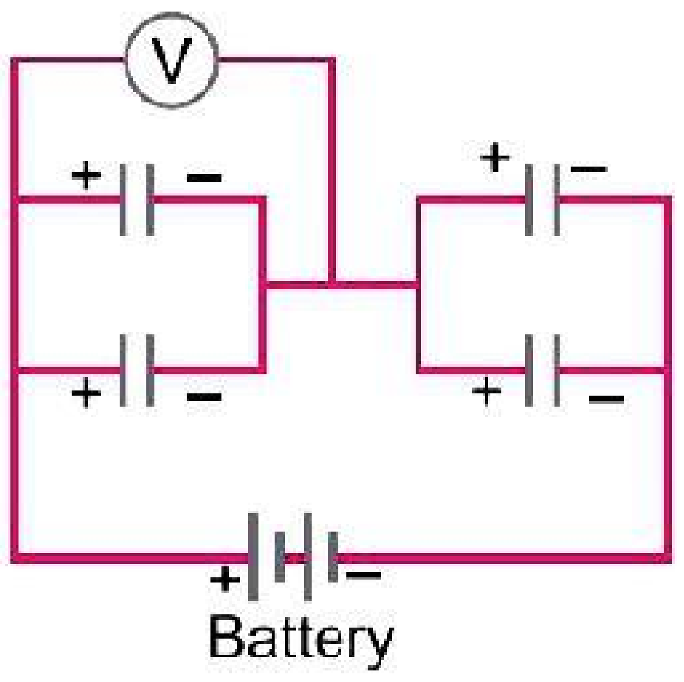
Which of the following is a correct statement?

(*a*) S_1 is true but S_2 is false.
(*b*) Both S_1 and S2 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 independent.

11. Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximately **[*NCERT Exemplar*]**

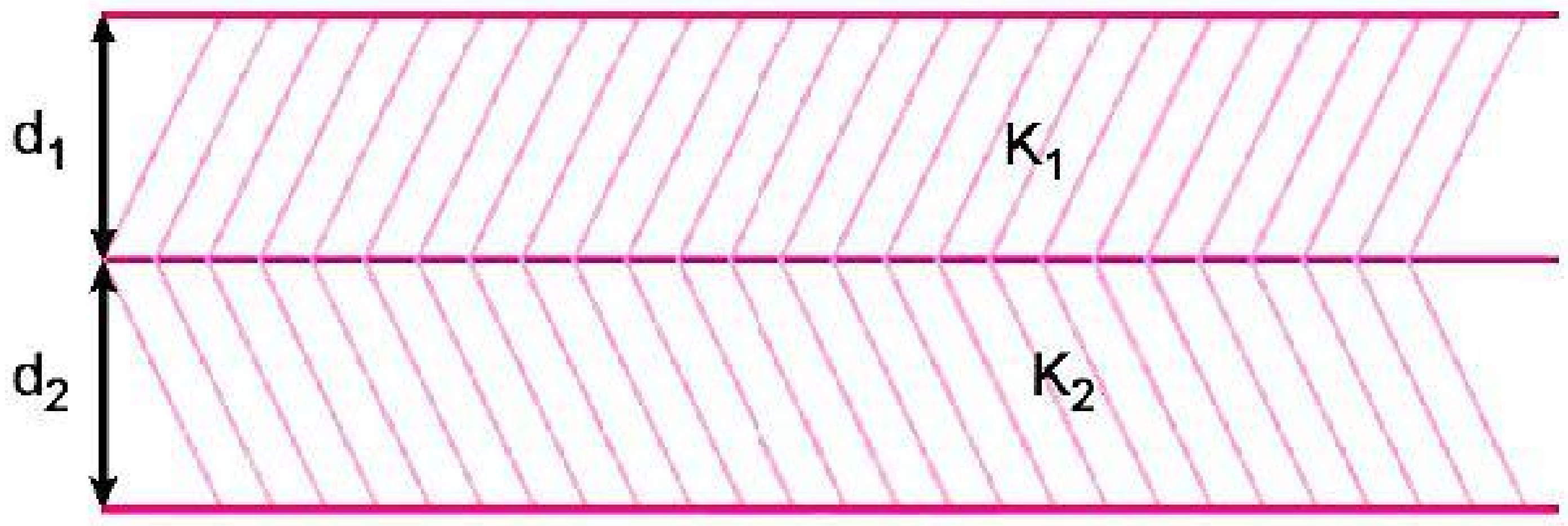
(*a*) spheres (*b*) planes (*c*) paraboloids (*d*) ellipsoids

12. Four capacitors, each 50 μF are connected as shown. The DC voltmeter V reads 100 V. The charge on each plate of each capacitor is



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

13. 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 **[*NCERT Exemplar*]**



(*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*) $\dfrac{k_1k_2(d_1+d_2)}{k_1d_1+k_2d_2}$ (*d*) $\dfrac{2k_1k_2}{k_1+k_2}$

14. Equipotential surfaces **[*NCERT Exemplar*]**

(*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*) all of the above

15. A 2 μF capacitor is charged to 200 volt and then the battery is disconnected. When it is connected in parallel to another uncharged capacitor, the potential difference between the plates of both is 40 volt. The capacitance of the other capacitor is

(*a*) 2 μF (*b*) 4 μF (*c*) 8 μF (*d*) 16 μF

16. Two identical metal plates, separated by a distance *d* form a parallel-plate capacitor. A metal sheet of thickness *d*/2 is inserted between the plates. The ratio of the capacitance after the insertion of the sheet to that before insertion is

(*a*) $\sqrt{2}:1$ (*b*) 2 : 1 (*c*) 1 : 1 (*d*) 1 : 2

17. *n* identical capacitors joined in parallel are charged to a common potential *V*. The battery is disconnected. Now, the capacitors are separated and joined in series. For the new combination:

(*a*) energy and potential difference both will remain unchanged

(*b*) energy will remain same, potential difference will become nV

(*c*) energy and potential both will become n times

(*d*) energy will become n times, potential difference will remain V.

18. 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, where d is the separation between the plates. The dielectric constant of the slab is

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

19. Two capacitors of capacitances 3 μF and 6 μF are charged to a potential of 12 V 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 3 μF will be

(*a*) 3 V (*b*) zero (*c*) 6 V (*d*) 4 V

20. The plates of a parallel plate capacitor are 4 cm apart, the first plate is at 300 V and the second plate at – 100 V. The voltage at 3 cm from the second plate is

(*a*) 200 V (*b*) 400 V (*c*) 250 V (*d*) 500 V

21. The potential of a charged spherical conductor of radius r is 10 V. The potential at a point $\frac{r}{2}$ from its centre is

(*a*) 20 V (*b*) 0 (*c*) 10 V (*d*) 40 V

22. Proton has a mass of 1840 times that of an electron. If a proton is accelerated from rest by a potential difference of 1 volt, its kinetic energy is

(*a*) 1840 eV (*b*) 1 eV (*c*) 1 meV (*d*) 0

23. When charge is supplied to a conductor, its potential depends upon

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

(*c*) both (*a*) and (*b*) (*d*) only on (*a*)

24. A dipole is placed parallel to electric field. If W is the work done in rotating the dipole from 0° to 60°, then work done in rotating it from 0° to 180° is

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

25. A charge Q is supplied to a metallic conductor. Which of the following statements is correct?

(*a*) Electric field inside it is same as on the surface.

(*b*) Electric potential inside is zero.

(*c*) Electric potential on the surface is zero.

(*d*) Electric potential inside it is constant.

26. Work done to bring a unit positive charge un-accelerated from infinity to a point inside electric field is called

(*a*) electric field (*b*) electric potential

(*c*) capacitance (*d*) electric flux

27. Electric potential due to a point charge $-q$ at distance x from it is given by

(*a*) $\frac{kq}{x^2}$ (*b*) $\frac{kq}{x}$

(*c*) $\frac{-kq}{x^2}$ (*d*) $\frac{-kq}{x}$

28. Electric field is always

(*a*) parallel to equipotential surface

(*b*) perpendicular to equipotential surface

(*c*) it can be perpendicular and parallel as well

(*d*) it does not depends on distribution of charge

29. The electric potential due to an electric dipole at an axial point, distant r from the dipole is related to r as

(*a*) r^1 (*b*) r^{-1} (*c*) r^2 (*d*) r^{-2}

30. A positive charge Q' is moved around another positive charge Q on circular path. If the radius of the circular path is r, the work done on the charge Q' in making one complete revolution is

(*a*) $\frac{Q}{4\pi\varepsilon r}$ (*b*) $\frac{QQ'}{4\pi\varepsilon r}$ (*c*) zero (*d*) $\frac{Q'}{4\pi\varepsilon r}$

31. The electric potential at a point in an electric field has the unit of

(*a*) Nm^2/C (*b*) Nm/C (*c*) NC/m (*d*) Cm/N

32. An electron is accelerated under a potential difference of 200 V. Energy gained by it in electron volt is

(*a*) 50 eV (*b*) 100 eV (*c*) 200 eV (*d*) 400 eV

33. There exists a potential difference of 5 V between two points in an electric field. Work done in moving a charge of 7 C from one point to the other is

(*a*) 5/7 J (*b*) 7/5 J (*c*) 35 J (*d*) 1/35 J

34. A charge q contain n electrons each of mass m. This charge is accelerated under the potential difference V. The speed acquired by the charge is

(*a*) $\sqrt{\frac{2eV}{m}}$ (*b*) $\sqrt{\frac{2qV}{m}}$ (*c*) $\sqrt{\frac{2e}{mV}}$ (*d*) $\sqrt{\frac{2q}{mnV}}$

35. A test charge q_0 is brought from infinity along the perpendicular bisector of an electric dipole. The work done on q_0 by the electric field of the dipole is

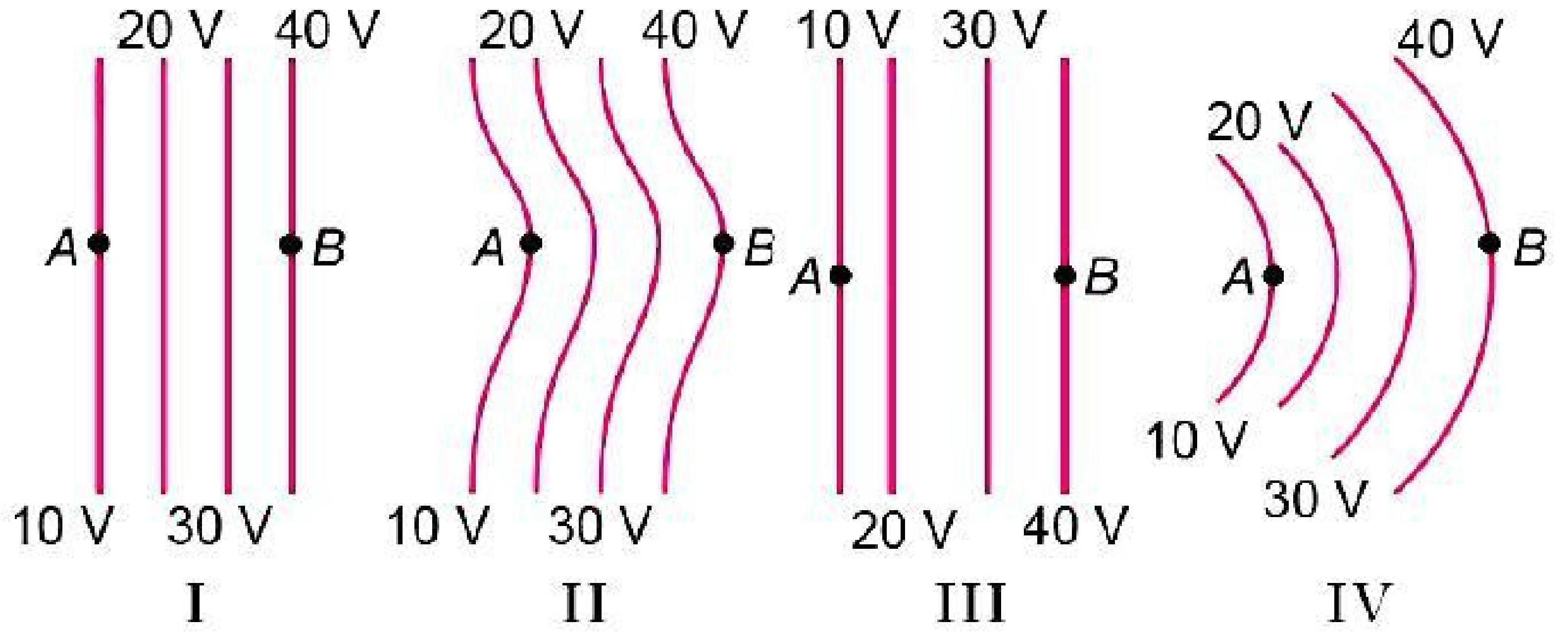
(*a*) zero (*b*) negative

(*c*) positive (*d*) proportional to q_0

36. If 1000 droplets each of charge q and radius r are combined to form a big drop, then the potential of big drop, as compared to small droplet will be

(*a*) 1000 times (*b*) 100 times (*c*) 10 times (*d*) 10^4 times

37. The diagrams below show regions of equipotentials.



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

(*a*) In all the four cases the work done is the same.

(*b*) Minimum work is required to move q in figure (I).

(*c*) Maximum work is required to move q in figure (II).

(*d*) Maximum work is required to move q in figure (III).

38. Capacitor is a device used to store

(*a*) charge (*b*) electrostatic energy

(*c*) electric field (*d*) none of these

39. Unit of capacitance is

(*a*) volt (*b*) coulomb

(*c*) ohm (*d*) farad

40. A parallel plate capacitor is charged by a battery. Once it is charged, the battery is removed. Now a dielectric material is inserted between the plates of the capacitor, which of the following does not change?

(*a*) Electric field between the plates (*b*) Potential difference across the plates

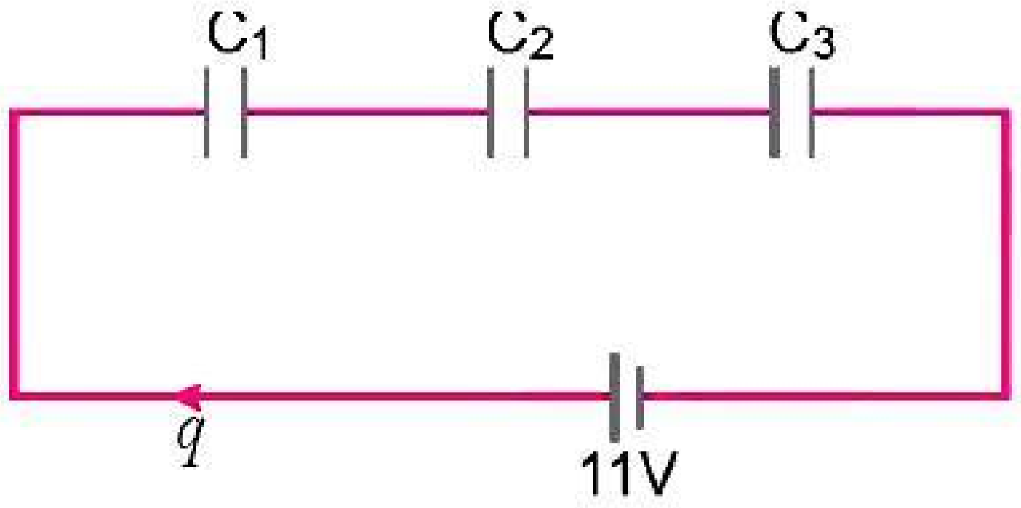
(*c*) Charge on the plates (*d*) Energy stored in the capacitor

41. A parallel plate capacitor C has a charge Q. The actual charges on the plates are

(*a*) Q, Q (*b*) $\frac{Q}{2}, \frac{Q}{2}$

(*c*) $Q, -Q$ (*d*) $\frac{Q}{2}, \frac{-Q}{2}$

42. Three capacitors of capacitances 1 μF, 2 μF & 3 μF are connected in series and a potential difference of 11V is applied across the combination then the potential difference across the plates of 1 μF capacitor is



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

43. On reducing potential across a capacitor, its capacitance

(*a*) decreases (*b*) increases

(*c*) remains constant (*d*) first increases then decreases

44. A charge Q is supplied to a metallic conductor. Which of the following is correct?

(*a*) More in case of sphere (*b*) More in case of cube

(*c*) Same in both cases (*d*) Information incomplete

45. Energy stored in a in a charged capacitor is given by:

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

46. If n number of equal capacitors each of capacitance C are connected in series then equivalent capacitance will be given as:

(*a*) $n \times C$ (*b*) $\frac{C}{n}$ (*c*) $n + C$ (*d*) n^2C

47. Capacitance of parallel plate capacitor when there is no medium between the plates is C_0. If capacitor is now completely filled with dielectric matter of constant K then capacitance is

(*a*) $\frac{C_0}{K}$ (*b*) KC_0 (*c*) K^2C_0 (*d*) $2KC_0$

48. A parallel plates capacitor is charged by connecting a battery across its plates. If the battery remains connected and a dielectric material is inserted in between the plates of the capacitor, then

(*a*) potential difference across the capacitor increases

(*b*) electric field remains the same

(*c*) capacitance increases

(*d*) all the above

49. The capacitance of spherical conductor of radius 10 m is

(*a*) 10 farad (*b*) 19×10^9 farad

(*c*) $\frac{1}{9\times10^9}$ farad (*d*) $\frac{1}{9\times10^8}$ farad

50. Four capacitors, each of capacitance 0.5 μF are connected in parallel. The resultant capacitance of the combination is

(*a*) 0.5 μF (*b*) 0.125 μF (*c*) 2 μF (*d*) 4 μF

51. Three capacitors, each of capacitance 1 μF are connected in series. The resultant capacitance of the combination is

(*a*) $\frac{1}{3}\mu$F (*b*) $\frac{2}{3}\mu$F (*c*) 3 μF (*d*) 0.5 μF

52. The relation between the capacitance of an isolated spherical conductor situated in air and its radius is:

(*a*) $C\ \alpha\ r$ (*b*) $C\ \alpha\ 1/r$ (*c*) $C\ \alpha\ r^2$ (*d*) $C\ \alpha\ r^{-2}$

53. Two points P and Q are maintained at the potential of 10 V and –4 V respectively. The work done in moving 100 electrons from P to Q is

(*a*) -10×10^{-17} J (*b*) 9.60×10^{-17} J

(*c*) -2.24×10^{-16} J (*d*) 2.24×10^{-16} J

54. A parallel-plate capacitor, with air between the plates has capacitance 3 μF. If the capacitor is immersed in liquid of dielectric constant 4.0, its capacitance will be

(*a*) 0.75 μF (*b*) 1.5 μF (*c*) 6 μF (*d*) 12 μF

55. The distance between the plates of a parallel plate capacitor of capacitance C is doubled. Its new capacitance will be

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

56. Which of the following is the correct relation among the capacitance, potential & charge?

(*a*) $q = CV$ (*b*) $q = C^{-1}V$ (*c*) $q = C^{-1}V^{-1}$ (*d*) $q = CV^{-1}$

57. What is the area of the plates of a 3F parallel plate capacitor, if the separation between the plates is 5 mm?

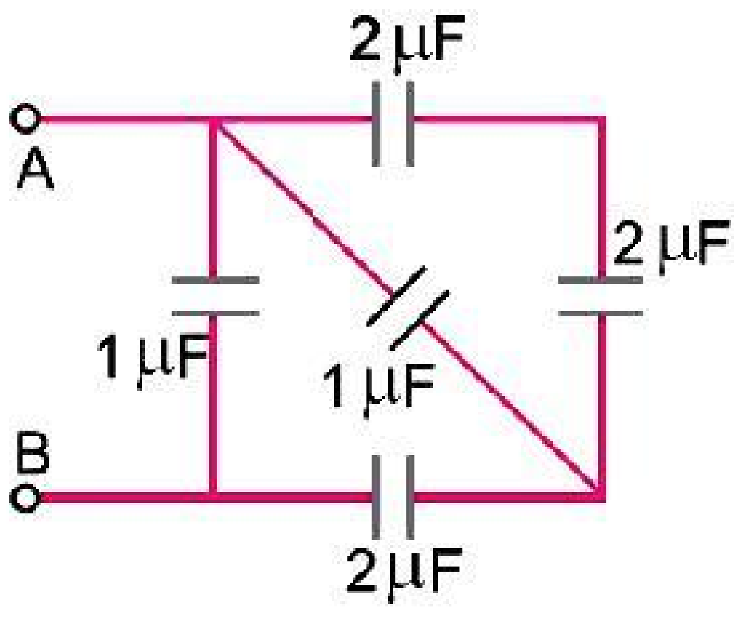
(*a*) 1.694×10^9 m^2 (*b*) 4.529×10^9 m^2

(*c*) 9.281×10^9 m^2 (*d*) 12.281×10^9 m^2

58. A parallel plate capacitor has plates with area A and separation d. A battery charges the plates to a potential difference V_0. The battery is then disconnected and a dielectric slab of dielectric constant K and thickness d is introduced. The ratio of energy stored in the capacitor before and after the slab is introduced is

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

59. Five capacitors are connected as shown in the figure. The equivalent capacitance between A and B is



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

60. A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system

(*a*) decreases by a factor of 2 (*b*) remains the same
(*c*) increases by a factor of 2 (*d*) increases by a factor of 4

61. 8 small droplets of water of same size and same charge form a large spherical drop. The potential of the large drop, in comparison to potential of a small drop, will be

(*a*) 2 times (*b*) 4 times (*c*) 8 times (*d*) same

62. A capacitor is charged through a p.d. of 200 volts and possesses charge of 0.1 coulomb. When discharged it would release an energy of

(*a*) 1 J (*b*) 2 J (*c*) 10 J (*d*) 20 J

63. A 500 μF capacitor is charged at a steady rate of 100 μC per second. A potential difference of 10 V will be developed between the capacitor plates after

(*a*) 5 s (*b*) 10 s (*c*) 20 s (*d*) 50 s

64. A parallel-plate capacitor has a plate area of 2 m^2 and a plate separation of 10 cm. It carries a charge of 8.85×10^{-10} C. The electric field is

(*a*) zero between the plates
(*b*) zero outside the plates
(*c*) different at different points between the plates
(*d*) 25 NC^{-1} between the plates

65. A capacitor of capacitance 2μF has been charged to 200 V. It is now discharged through a resistance, the heat produced in the wire is

(*a*) 400 J (*b*) 0.02 J (*c*) 0.04 J (*d*) 0.08 J

66. An air filled parallel plate capacitor has a capacitance 1 pF. The separation of the plates is doubled and wax inserted between them, which makes the capacitance 2 pF. This implies that dielectric constant of wax is

(*a*) 2.0 (*b*) 4/3 (*c*) 4.0 (*d*) 8.0

67. Three capacitors of capacitance 3 μF, 9 μF and 18 μF are connected first in series and then in parallel. The ratio of equivalent capacitance in two cases (C_s/C_p) will be

(*a*) 1 : 15 (*b*) 15 : 1 (*c*) 1 : 1 (*d*) 1 : 3

68. Two identical capacitors joined in parallel are charged to a common potential $V/2$. The battery is disconnected. Now, the capacitors are separated and joined in series. For the new combination:

(*a*) Energy and p.d. both will remain unchanged.
(*b*) Energy will remain same, p.d. will become V.
(*c*) Energy and potential both will become 2 times.
(*d*) Energy will become 2 times, p.d. will remain V.

69. A parallel plate capacitor with air between the plates has a capacitor of 9 pF. The separation between its plates is '*d*'. The space between its plates is now filled with two dielectric. One of the dielectrics has dielectric constant $K_1 = 3$ and thickness $\frac{d}{3}$ while the other one has dielectric constant $K_2 = 6$ and thickness $\frac{2d}{3}$. Capacitance of the capacitor is now

(*a*) 40.5 pF (*b*) 20.25 pF
(*c*) 1.8 pF (*d*) 4.5 pF

70. **The capacitance of a capacitor becomes $\frac{8}{9}$ times its original value if a dielectric slab of thickness $t = \frac{1}{3}d$ is introduced in between the plates, where d is the separation between the plates. The dielectric constant of the slab is**

(*a*) $\frac{14}{11}$ (*b*) $\frac{11}{14}$ (*c*) $\frac{8}{11}$ (*d*) $\frac{11}{8}$

71. **Two capacitors of capacitances 3 μF and 6 μF are charged to a potential of 12 V 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*) 3 V (*b*) zero (*c*) 6 V (*d*) 4 V

72. **The plates of a parallel plate capacitor are 4 cm apart, the first plate is at 300 V and the second plate at – 100 V. The voltage at 1 cm from the first plate is**

(*a*) 200 V (*b*) 400 V (*c*) 250 V (*d*) 500 V

73. **If the potential of a capacitor having capacitance 6 μF is increased from 10 V to 20 V, the increase in energy is**

(*a*) 9×10^{-4} J (*b*) 4.5×10^{-6} J

(*c*) 12×10^{-6} J (*d*) 2.25×10^{-6} J

74. **A battery is used to charge a parallel plate capacitor till the potential difference between the plates becomes equal to the emf of the battery. The ratio of the energy stored in the capacitor and the work done by the battery will be**

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

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

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

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

76. **The electric potential at a point (x, y, z) is given by $V = -x^2y - xz^3 + 4$. The electric field $\vec{E}$ at that point is**

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

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

77. **Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The equivalent capacitance and breakdown voltage of the combination will be**

(*a*) $3C, \frac{V}{3}$ (*b*) $\frac{C}{3}, 3V$ (*c*) $3C, 3V$ (*d*) $\frac{C}{3}, \frac{V}{3}$

78. **A particle A has charge $+ q$ and particle B has charge $+ 4q$ with each of them having the same mass m. When allowed to fall from rest through same electrical potential difference, the ratio of their speeds $v_A : v_B$ will become**

(*a*) 2 : 1 (*b*) 1 : 2 (*c*) 1 : 4 (*d*) 4 : 1

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

(*a*) 8 along negative X-axis (*b*) 8 along positive X-axis

(*c*) 16 along negative X-axis (*d*) 16 along positive Z-axis

80. Two identical thin rings, each of radius R metre are co-axially placed at distance R metre apart. If Q_1 and Q_2 coulomb are respectively the charges uniformly spread on the 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*) $\dfrac{q(Q_1 - Q_2)(\sqrt{2} - 1)}{\sqrt{2}.4\pi\varepsilon_0 R}$

(*c*) $\dfrac{q\sqrt{2}(Q_1 - Q_2)}{4\pi\varepsilon_0 R}$

(*d*) $\dfrac{q(Q_1 - Q_2)(\sqrt{2} + 1)}{\sqrt{2}.4\pi\varepsilon_0 R}$

81. A particle of mass 2 g and charge 1 μC is held at rest on a frictionless horizontal surface at a distance of 1 m from the fixed charge of 1 milli coulomb (mC). If the particle is released it will be repelled. The speed of the particle when it is at a distance of 10 m from the fixed charge is

(*a*) 100 m/s (*b*) 90 m/s (*c*) 60 m/s (*d*) 45 m/s

82. A hollow charged metal sphere has radius r. If the potential difference between its surface and a point at distance $3r$ from the centre is V, then the electric field intensity at a distance $3r$ from the centre is

(*a*) $\dfrac{V}{6r}$ (*b*) $\dfrac{V}{4r}$ (*c*) $\dfrac{V}{3r}$ (*d*) $\dfrac{V}{2r}$

83. When a charge of 3 C is placed in a uniform electric field it experiences a force of 3000 N. The potential difference between two points separated by a distance of 1 cm within this field is

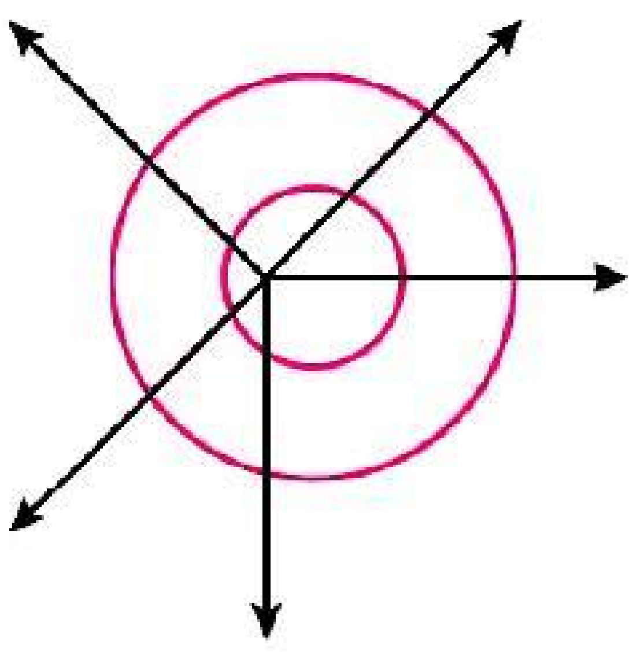
(*a*) 10 volt (*b*) 90 volt (*c*) 1000 volt (*d*) 3000 volt

84. A uniform electric field having magnitude and direction along positive X-axis exists. If the electric potential V is zero at $x = 0$, then its value at $x = +x$ will be

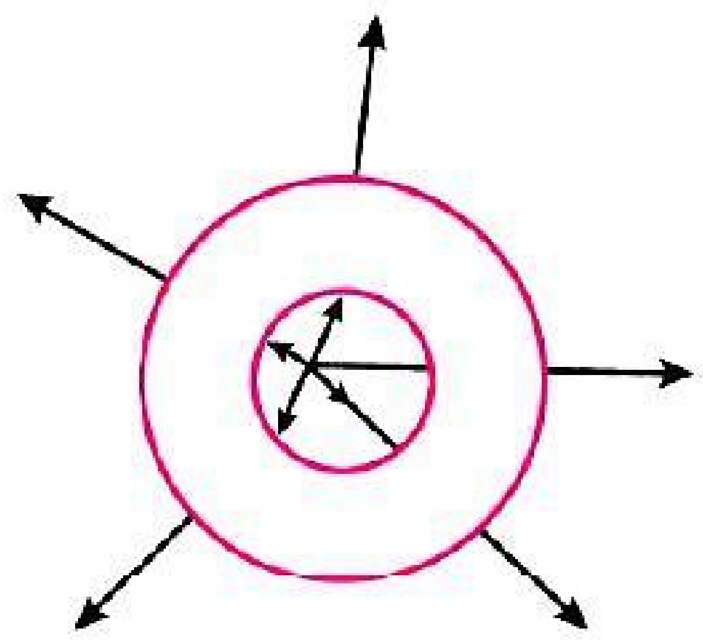
(*a*) $V_x = xE_0$ (*b*) $V_x = -xE_0$ (*c*) $V_x = -x^2E_0$ (*d*) $V_x = -x^2E_0$

85. A metallic shell has a point charge q kept inside a cavity. Which one of the following diagrams correctly represents the electric lines of force?

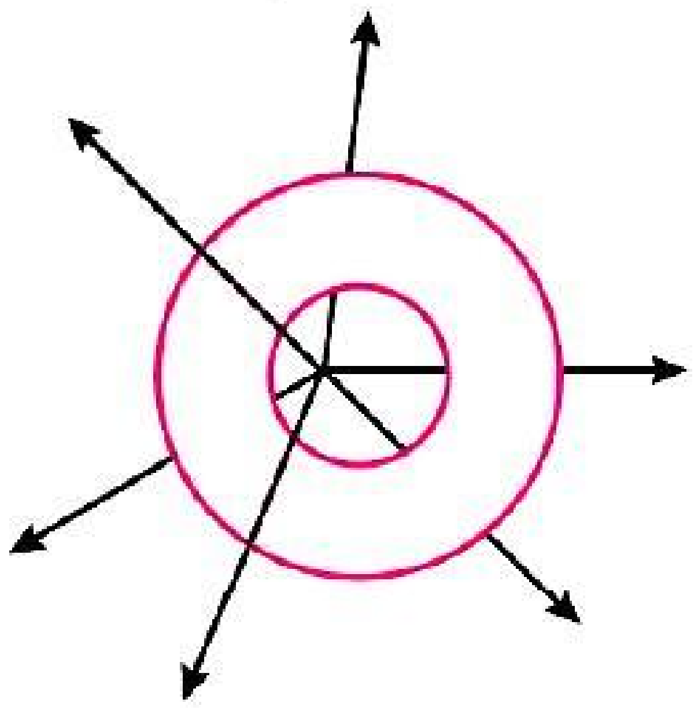
(*a*)



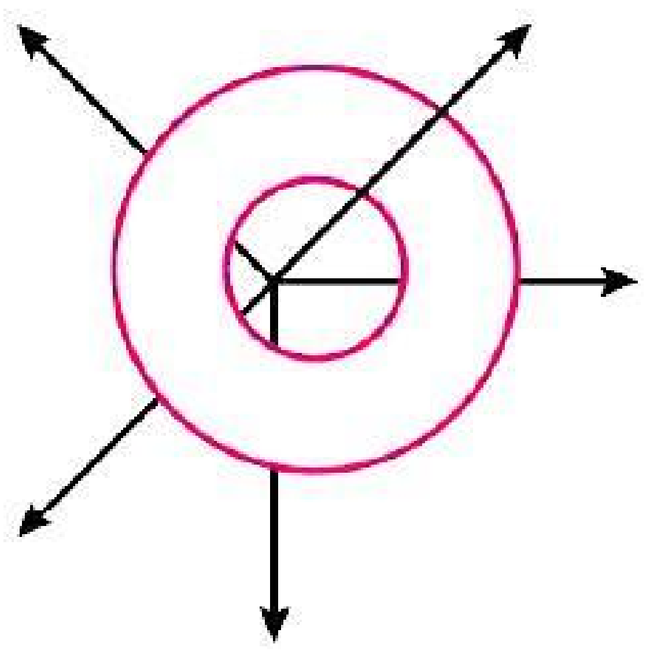
(*b*)



(*c*)



(*d*)



86. Two thin wire rings, each having a radius R are placed at a distance 'd' apart with their axes coinciding. The charge on the two rings are $+q$ and $-q$. The potential difference between the centres of the two rings is

(*a*) $\dfrac{q}{2\pi\varepsilon_0}\left[\dfrac{1}{R} - \dfrac{1}{\sqrt{R^2 + d^2}}\right]$

(*b*) $\dfrac{qR}{4\pi\varepsilon_0 d^2}$

(*c*) $\dfrac{q}{4\pi\varepsilon_0}\left[\dfrac{1}{R} - \dfrac{1}{\sqrt{R^2 + d^2}}\right]$

(*d*) zero

87. An electric charge of 10^{-3} μC is placed at the origin (0, 0) of XY coordinate system. Two points A and B are situated at ($\sqrt{2}$, $\sqrt{2}$) and (2, 0) respectively. The potential difference between the points A and B will be

(*a*) zero (*b*) 2 V (*c*) 4.5 V (*d*) 9 V

88. A parallel plate air capacitor is connected to a battery. The quantities charge, voltage, electric field and energy associated with the capacitor are given by Q_0, V_0, E_0 and U_0 respectively. A dielectric slab is now introduced to fill the space between the plates with a battery still in connection. The corresponding quantities now given by Q. V, E and U are related to previous ones as

(*a*) $Q = Q_0$ (*b*) $V > V_0$ (*c*) $E > E_0$ (*d*) $U > U_0$

89. A number of condensers, each of capacitance 1μF and each one of which gets punctured if a p.d. just exceeding 500 V is applied, are provided. Then an arrangement suitable for giving a capacitor of capacitance 1μF across which 3000 volts may be applied requires at least

(*a*) 6 component capacitors (*b*) 12 component capacitors

(*c*) 72 component capacitors (*d*) 36 component capacitors

90. A parallel-plate capacitor of plate area A and plate separation d is charged to a potential difference V and then the battery is disconnected. A slab of dielectric constant K is then inserted between the plates of the capacitor so as to fill the space between the plates. If q, E and W denote respectively the magnitude of charge on each plate, the electric field between the plates (after the slab is inserted) and work done by the system, in question, in the process of inserting the slab, then which of the following is false?

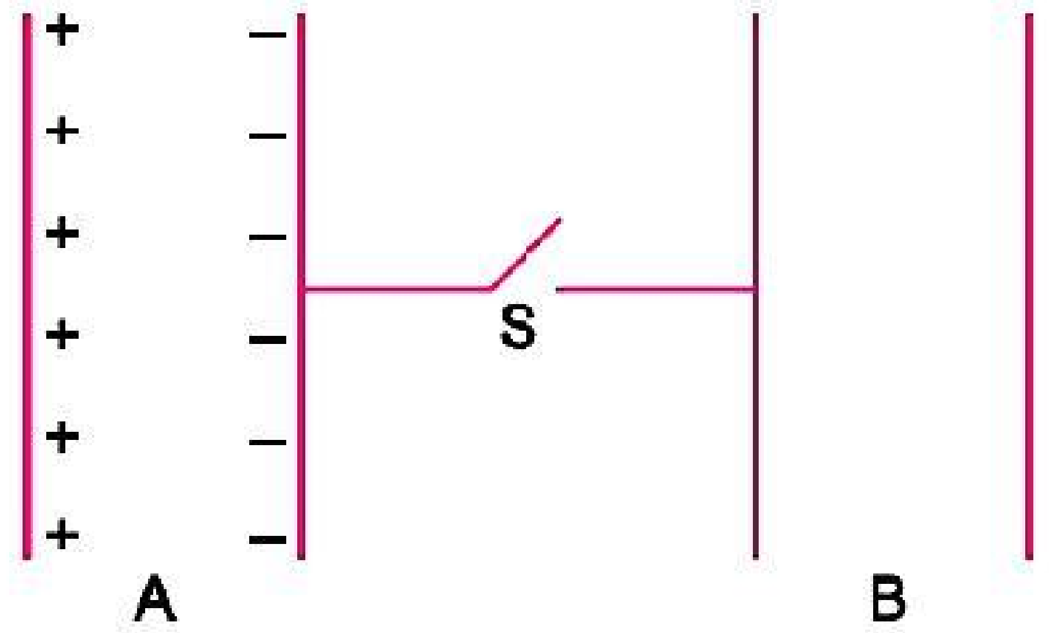
(*a*) $q = \frac{\varepsilon_0 AV}{d}$ (*b*) $q = \frac{\varepsilon_0 KAV}{d}$

(*c*) $E = \frac{V}{Kd}$ (*d*) $W = \frac{\varepsilon_0 AV^2}{2d}\left(1 - \frac{1}{K}\right)$

91. Two identical metallic plates are given positive charges Q_1 and Q_2 ($Q_2 < Q_1$). If these plates are brought together to form a parallel plate capacitor, then potential difference between them will be

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

92. Consider a situation shown in 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

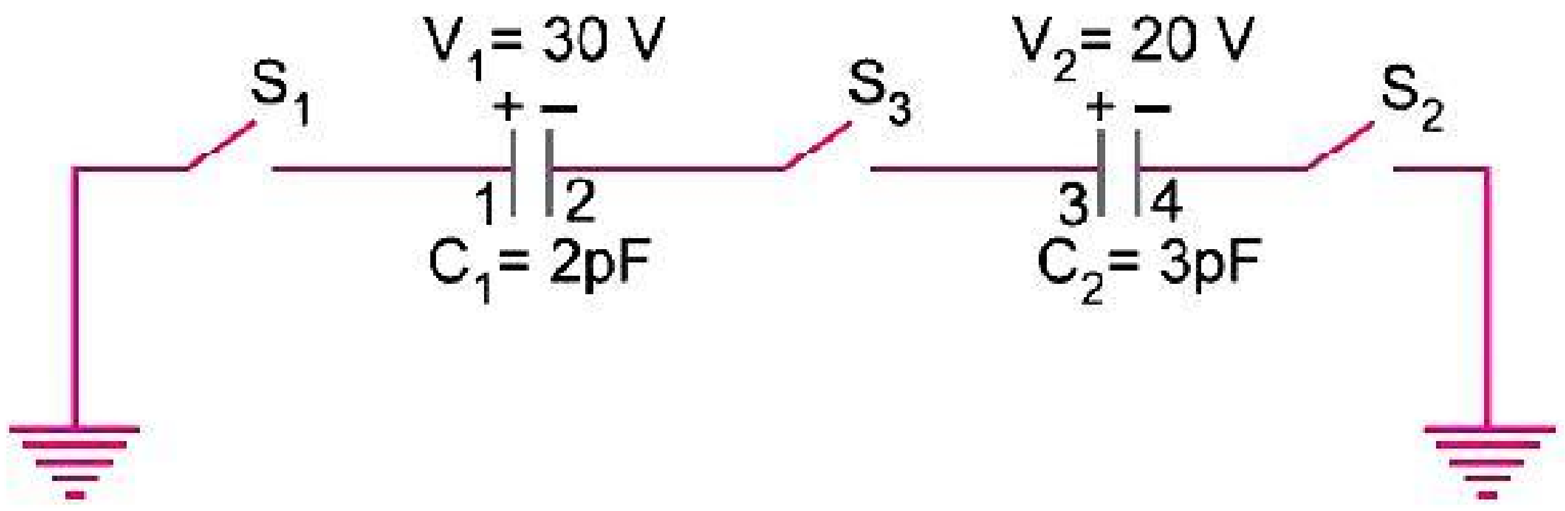


(*a*) zero (*b*) $\frac{q}{2}$ (*c*) q (*d*) $2q$

93. Each of two identical capacitors has capacitance C, one of them is charged to a potential V_1 and the other to a potential V_2. The negative terminals of capacitors are connected together. When their positive terminals are also connected together, then energy loss of whole system is

(*a*) $\frac{1}{4}C(V_1^2 - V_2^2)$ (*b*) $\frac{1}{4}C(V_1^2 + V_2^2)$ (*c*) $\frac{1}{4}C(V_1 - V_2)^2$ (*d*) $\frac{1}{4}C(V_1 + V_2)^2$

94. Which one of the following statements is true for the given circuit?



(*a*) With S_1 closed, $V_1 = 15$ V, $V_2 = 20$ V.

(*b*) With S_3 closed, $V_1 = V_2 = 25$ V.

(*c*) With S_1 and S_2 closed, $V_1 = V_2 = 0$.

(*d*) With S_1 and S_3 closed, $V_1 = 30$ V, $V_2 = 20$ V.

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

(*a*) $(n + 1)\,C$ (*b*) $(n - 1)\,C$ (*c*) nC (*d*) C

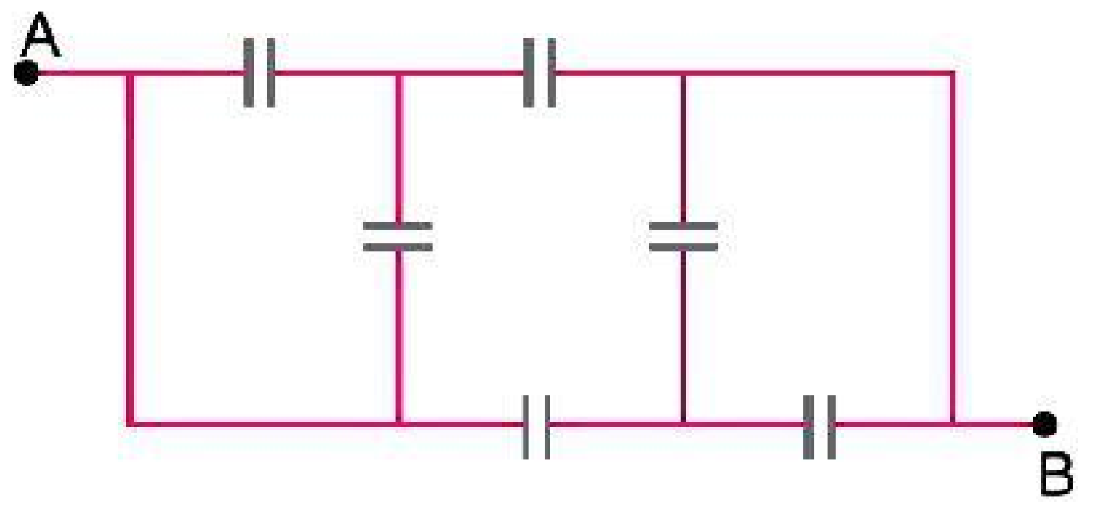
96. A fully charged capacitor has a capacitance *C*. It is discharged through a small coil of resistance wire embedded in a thermally insulated block of specific heat capacity '*s*' and mass '*m*'. If the temperature of the block is raised by ΔT the potential difference *V* across the capacitance is

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

97. Two spherical conductors *A* and *B* of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire, then in equilibrium condition, the ratio of the magnitudes of the electric fields at the surfaces of spheres *A* and *B* is:

(*a*) 4: 1 (*b*) 1: 2 (*c*) 2: 1 (*d*) 1: 4

98. A network of six identical capacitors, each of value *C* is made as shown in fig. The equivalent capacitance between points *A* and *B* is



(*a*) $\dfrac{C}{4}$ (*b*) $\dfrac{3C}{4}$ (*c*) $\dfrac{3}{2}C$ (*d*) $\dfrac{4}{3}C$

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

(*a*) $\dfrac{CV^2\,(K-1)}{K}$ (*b*) $(K - 1)\,CV^2$ (*c*) zero (*d*) $\dfrac{1}{2}(K - 1)\,CV^2$

100. If 343 droplets each of charge *q* and radius *r* are combined to form a big drop, then the potential of big drop, as compared to small droplet will be

(*a*) 343 times (*b*) 49 times (*c*) 7 times (*d*) none of the above

101. 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 (55/1/1)]

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

102. If a positive charge in displaced against the electric field in which it was situated, then *[CBSE 2020 (55/3/1)]*

(*a*) work will be done by the electric field on the charge.
(*b*) the intensity of the electric field decreases.
(*c*) energy of the system will decrease.
(*d*) energy will be provided by external source displacing the charge.

103. The capacitors of capacitances C_1 and C_2 are connected in parallel. If a charge Q is given to the combination, the ratio of the charge on the capacitor C_1 to the charge on C_2 will be *[CBSE 2020 (55/3/1)]*

(*a*) $\frac{C_1}{C_2}$ (*b*) $\sqrt{\frac{C_1}{C_2}}$ (*c*) $\sqrt{\frac{C_2}{C_1}}$ (*d*) $\frac{C_2}{C_1}$

104. A charge Q is kept at the centre of a circle of radius r. A test charge q_0, is carried from a point X to the point Y on this circle such that are XY subtends an angle of 60° at the centre of the circle. The amount s of work done in this process will be *[CBSE 2020 (55/3/2)]*

(*a*) $\frac{1}{4\pi\varepsilon_0}\frac{Qq_0}{2r}$ (*b*) $\frac{1}{4\pi\varepsilon_0}\frac{\sqrt{3}\,Qq_0}{2r}$
(*c*) zero (*d*) $\frac{1}{4\pi\varepsilon_0}\frac{\sqrt{3}\,Qq_0}{r}$

105. A parallel plate capacitor is charged to V volt by a battery. The battery is disconnected and the separation between the plates is halved. The new potential difference across the capacitor will be *[CBSE 2020 (55/3/2)]*

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

106. A charge Q is uniformly distributed over the surface of a spherical shell of radius R. The work done in bringing a test charge Q_0 from its centre to its surface is *[CBSE 2020 (55/3/3)]*

(*a*) $\frac{1}{4\pi\varepsilon_0}\frac{QQ_0}{R}$ (*b*) $\frac{1}{4\pi\varepsilon_0}\frac{QQ_0}{2R}$
(*c*) $\frac{QQ_0}{\varepsilon_0 R}$ (*d*) zero

Answers

1. (*a*)	**2.** (*a*)	**3.** (*a*)	**4.** (*b*)	**5.** (*c*)	**6.** (*a*)	**7.** (*a*)	**8.** (*c*)
9. (*c*)	**10.** (*c*)	**11.** (*a*)	**12.** (*b*)	**13.** (*c*)	**14.** (*d*)	**15.** (*c*)	**16.** (*b*)
17. (*b*)	**18.** (*a*)	**19.** (*d*)	**20.** (*a*)	**21.** (*c*)	**22.** (*b*)	**23.** (*c*)	**24.** (*c*)
25. (*d*)	**26.** (*b*)	**27.** (*d*)	**28.** (*b*)	**29.** (*d*)	**30.** (*c*)	**31.** (*b*)	**32.** (*c*)
33. (*c*)	**34.** (*b*)	**35.** (*a*)	**36.** (*b*)	**37.** (*a*)	**38.** (*b*)	**39.** (*d*)	**40.** (*c*)
41. (*c*)	**42.** (*d*)	**43.** (*c*)	**44.** (*c*)	**45.** (*b*)	**46.** (*b*)	**47.** (*b*)	**48.** (*c*)
49. (*d*)	**50.** (*c*)	**51.** (*a*)	**52.** (*a*)	**53.** (*d*)	**54.** (*d*)	**55.** (*b*)	**56.** (*a*)
57. (*a*)	**58.** (*b*)	**59.** (*b*)	**60.** (*a*)	**61.** (*b*)	**62.** (*c*)	**63.** (*d*)	**64.** (*b*)
65. (*c*)	**66.** (*c*)	**67.** (*a*)	**68.** (*b*)	**69.** (*a*)	**70.** (*c*)	**71.** (*b*)	**72.** (*a*)
73. (*a*)	**74.** (*c*)	**75.** (*d*)	**76.** (*d*)	**77.** (*b*)	**78.** (*b*)	**79.** (*a*)	**80.** (*b*)
81. (*b*)	**82.** (*a*)	**83.** (*a*)	**84.** (*b*)	**85.** (*c*)	**86.** (*a*)	**87.** (*a*)	**88.** (*d*)
89. (*d*)	**90.** (*b*)	**91.** (*c*)	**92.** (*c*)	**93.** (*c*)	**94.** (*d*)	**95.** (*b*)	**96.** (*c*)
97. (*c*)	**98.** (*d*)	**99.** (*c*)	**100.** (*b*)	**101.** (*c*)	**102.** (*d*)	**103.** (*a*)	**104.** (*c*)
105. (*a*)	**106.** (*d*)						

CASE-BASED QUESTIONS

Attempt any 4 sub-parts from each question. Each question carries 1 mark.

1. **FARADAY CAGE:**

A Faraday cage or Faraday shield is an enclosure made of a conducting material. The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero. These Faraday cages act as big hollow conductors you can put things in to shield them from electrical fields. Any electrical shocks the cage receives, pass harmlessly around the outside of the cage. *[CBSE Sample Paper 2021]*

(*i*) Which of the following material can be used to make a Faraday cage?

(*a*) Plastic (*b*) Glass

(*c*) Copper (*d*) Wood

(*ii*) Example of a real-world Faraday cage is

(*a*) car (*b*) plastic box

(*c*) lightning rod (*d*) metal rod

(*iii*) What is the electrical force inside a Faraday cage when it is struck by lightning?

(*a*) The same as the lightning (*b*) Half that of the lightning

(*c*) Zero (*d*) A quarter of the lightning

(*iv*) An isolated point charge $+q$ is placed inside the Faraday cage. Its surface must have charge equal to

(*a*) zero (*b*) $+q$

(*c*) $-q$ (*d*) $+2q$

(*v*) A point charge of 2 μC is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be

(*a*) 1.9×10^5 Nm^2/C entering the surface

(*b*) 1.9×10^5 Nm^2/C leaving the surface

(*c*) 2.0×10^5 Nm^2/C leaving the surface

(*d*) 2.0×10^5 Nm^2/C entering the surface

Answers

1. (*i*) (*c*) Copper (Electric field inside a conductor is zero.)

(*ii*) (*a*) car (Body of the car is made up of conductor.)\

(*iii*) (*c*) Zero (As electric field inside it is zero.)

(*iv*) (*c*) $-q$ (As from Gauss's law q_{in} must be zero for electric field inside it is zero.)

(*v*) (*c*) $q = 2\ \mu\text{C} = 2 \times 10^{-6}$ C

$$\varepsilon_0 = 8.85 \times 10^{-12} \frac{\text{Nm}^2}{\text{C}^2}$$

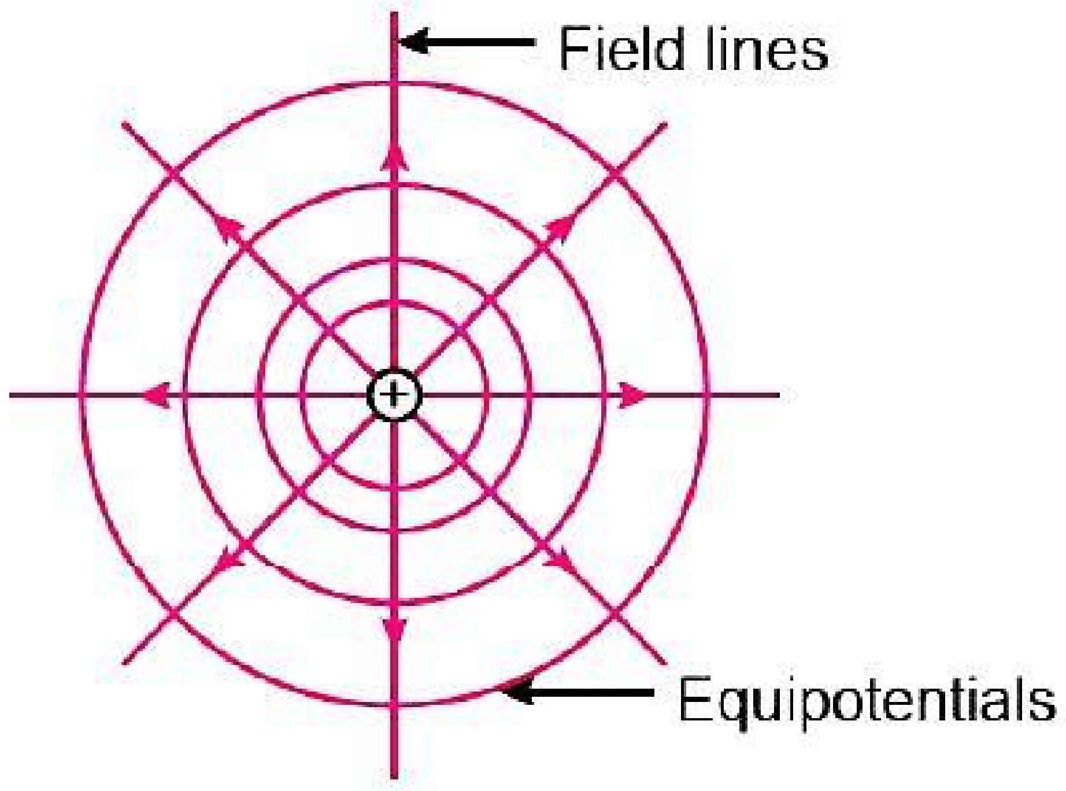
Now, total number of electric field lines $= \dfrac{q_{in}}{\varepsilon_0} = \dfrac{2 \times 10^{-6}}{8.85 \times 10^{-12}}$

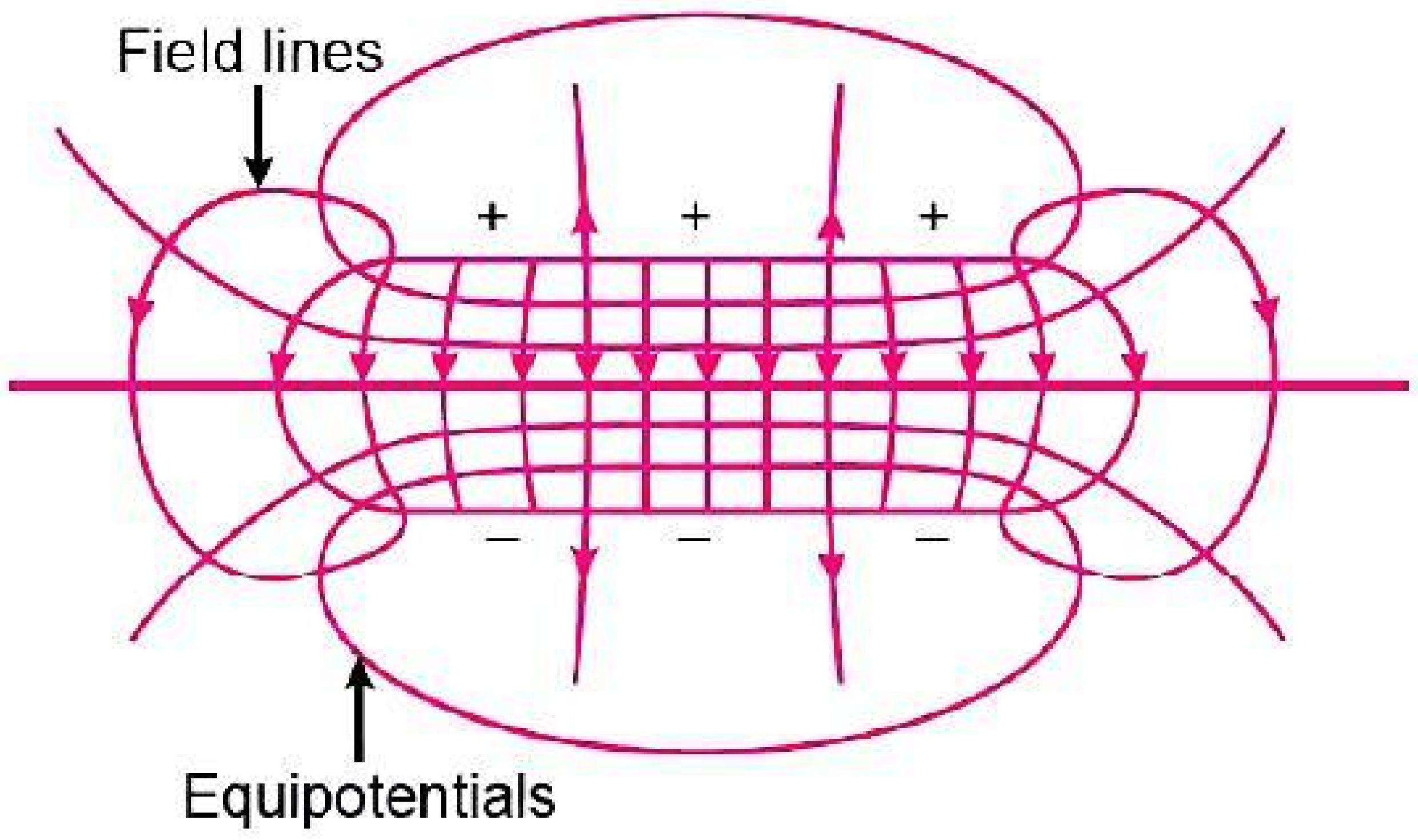
$$= 2.2 \times 10^5 \frac{\text{Nm}^2}{\text{C}} \text{ leaving the surface}$$

2. EQUIPOTENTIAL SURFACES:

All points in a field that have the same potential can be imagined as lying on a surface called an equipotential surface. When a charge moves on such a surface no energy transfer occurs and no work is done. The force due to the field must therefore act at right angles to the equipotential surfaces and field lines always intersect at right angles.

Equipotential surfaces for a point charge are concentric spheres; there is a spherical symmetry. If the equipotential are drawn so that the change of potential from one to the next is constant, then the spacing will be closer where the field is stronger. The closer the equipotentials, the shorter the distance that need be travelled to transfer a particular amount of energy. The surface of a conductor in electrostatics (*i.e.*, one in which no current is flowing) must be an equipotential surface since any difference of potential would cause a redistribution of charge in the conductor until no field exist in it.





(*i*) Equipotential surface 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

(*ii*) Two equipotential surfaces have a potential of – 20 V and 80 V respectively, the difference in potential between these surfaces is

(*a*) 100 V
(*b*) 90 V
(*c*) 80 V
(*d*) 0 V

(*iii*) Equipotential surfaces

(*a*) are closer in regions of higher electric fields compared to the 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*) all of the above

(*iv*) The work done to move a charge along an equipotential from *A* to *B*

(*a*) cannot be defined as $-\int_A^B E.dl$
(*b*) must be defined as $-\int_A^B E.dl$
(*c*) is zero
(*d*) can have a non-zero value

(*v*) The shape of equipotential surface for an infinite line charge is

(*a*) parallel plane surface
(*b*) parallel plane surface perpendicular to lines of force
(*c*) coaxial cylindrical surface
(*d*) none of these

Answers

2. (*i*) (*a*) A collection of charge located at a very large distance may be considered as a point charge. Also, the equipotential surfaces for a point charge are spherical. Therefore, the equipotential surfaces for a collection of charge form spheres.

(*ii*) (*a*) Equipotential surface has same voltage (potential) at every point on the surface.

i.e., $V_1 = -20$ V, $V_2 = 80$ V

$\Delta V = V_2 - V_1 = 80 - (-20) = 100$ V

So, $\Delta V = 100$ V

(*iii*) (*d*)

(*I*) Relation between electric field E and potential gradient is $E = -\dfrac{dV}{dr}$. So, electric field intensity is inversely proportional to the separation between equipotential surfaces.

(*II*) The electric field is larger near the sharp edges, due to larger charge density as A is very small.

$\because\ \sigma = \dfrac{q}{A}$, so, equipotential surfaces are closer or crowded.

(*III*) As the electric field $E = \dfrac{Kq}{r^2}$ and potential or field decreases as size of body increases or (vice-versa). So, equipotential surfaces are more crowded if the charge density $\left(\sigma = \dfrac{q}{A}\right)$ increases.

(*iv*) (*c*); As the potential on equipotential surface does not change so $(V_2 - V_1) = 0$

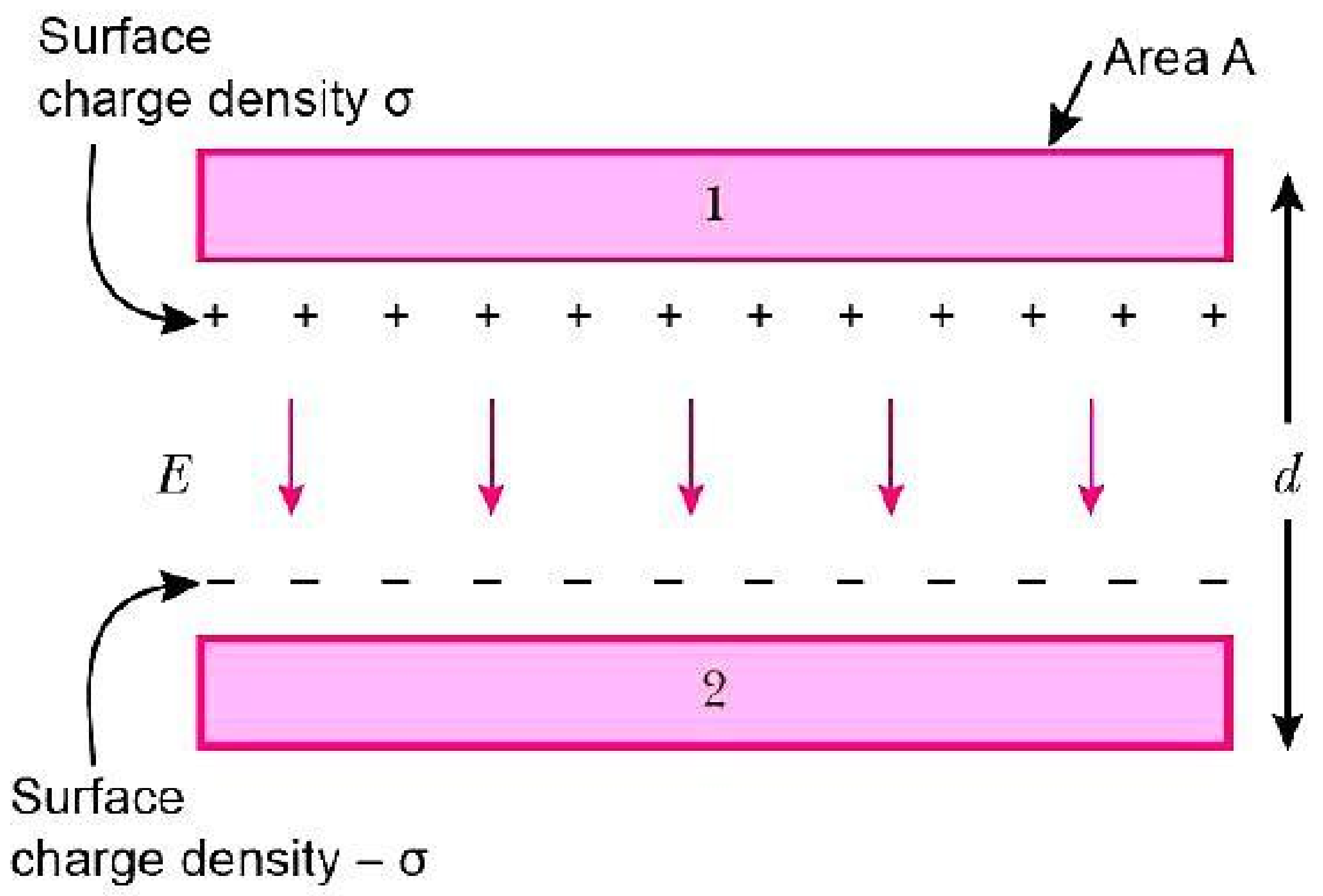
and $W = (V_2 - V_1)\,q = 0$

So, work done in moving a charge on equipotential surface is zero.

(*v*) (*c*); The shape of equipotential surface for infinite line charge is coaxial cylindrical surface.

3. THE PARALLEL-PLATE CONDENSATOR:

A condensator is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. Condenser or condensator are commercial names of capacitor. The effect of a capacitor is known as capacitance.



Today capacitors (condensator) are widely used in electronic circuits for blocking *dc* current while allowing *ac* current to pass. In electric power transmission system, they stablize voltage and power flow. The property of energy storage in capacitor was exploited as dynamic memory in early digital computers, and still in modern DRAM.

The simplest model of capacitor consist of two thin parallel conductive plates each with an area filled with a dielectric with permittivity ε. It is assumed that the gap d is much smaller than the dimensions of the plates. Since, the separations between the plates is uniform over the plate area, the electric field between the plates E is constant and directed perpendicularly to the plate surface, except for an area near the edges of the plate where field decreases because the electric field lines bulge out of the sides of capacitor.

(*i*) If a parallel plate capacitor has *n* number of interleaved plates, area of plates is *A* and separation between them is *d*, then the total capacitance would be

(*a*) $\frac{\varepsilon_0 A}{d}$

(*b*) $\frac{\varepsilon_0 n A}{d}$

(*c*) $\frac{\varepsilon_0 (n-1) A}{d}$

(*d*) $\frac{\varepsilon_0 n^2 A}{d}$

(*ii*) A capacitor's dielectric material has dielectric strength U_d which sets the capacitor's breakdown voltage at $V = U_d d$. The maximum energy stored in the capacitor is

(*a*) $\frac{1}{2}\varepsilon A d U_d$

(*b*) $\varepsilon A d U_d$

(*c*) $\frac{1}{2}\varepsilon A d U_d^2$

(*d*) $\varepsilon A d U_d^2$

(*iii*) A capacitor is constructed from two conductive metal plates having 30 cm × 50 cm dimension which are spaced 6 mm apart from each other and use dry air as its only dielectric material, then the capacitance of the capacitor is

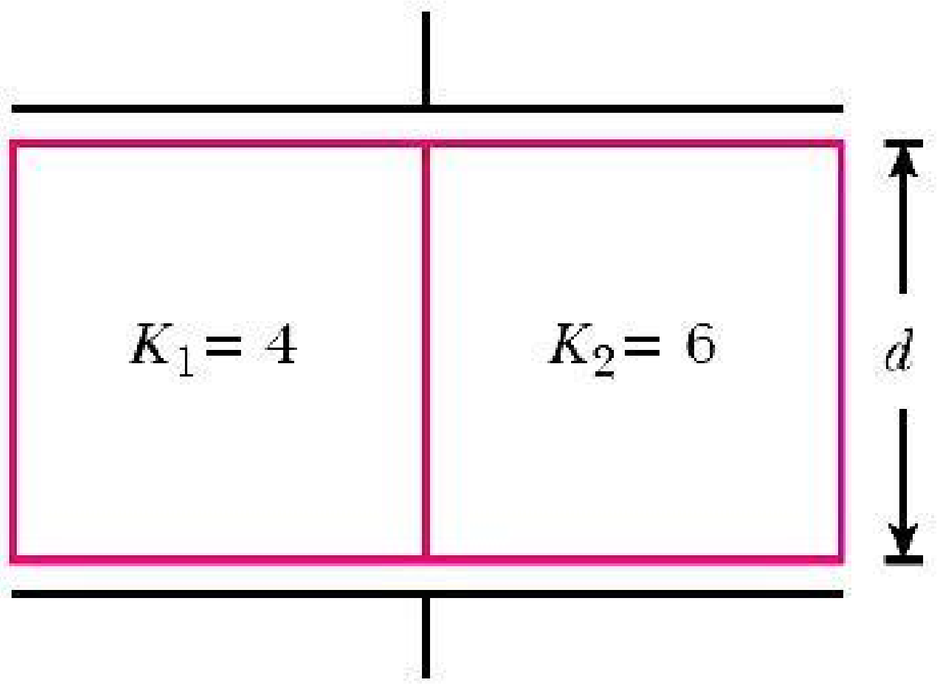
(*a*) 0.22 μF

(*b*) 0.221 nF

(*c*) 2.21 μF

(*d*) 2.21 nF

(*iv*) A capacitor of capacitance 1 μF is filled with two dielectric of dielectric constant 4 and 6. The new capacitance would be



(*a*) 10 μF

(*b*) 7 μF

(*c*) 5 μF

(*d*) 4 μF

(*v*) A parallel plate capacitor is charged. If the plates are pulled apart

(*a*) the charge and potential difference remain the same

(*b*) the total charge increases

(*c*) the potential difference increases

(*d*) the capacitance increases

Answers

3. (*i*) (*c*); For *n* number of plates in an interleaved capacitor, the total capacitance would be

$$C = \frac{\varepsilon_0 A}{d}(n-1) = (n-1)\,C_0$$

where $C_o = \varepsilon_0 A/d$ is the capacitance for a single plate and *n* is the number of interleaved plates.

(*ii*) (*c*); A parallel plate capacitor can only store a finite amount of energy before dielectric breakdown occurs. The maximum energy that the capacitor can store is therefore,

$$E = \frac{1}{2}CV^2$$

$$E = \frac{1}{2}\frac{\varepsilon A}{d}(U_d d)^2 = \frac{1}{2}\varepsilon A d U_d^2 \qquad \left[\because C = \frac{\varepsilon A}{d}\right]$$

(*iii*) (*b*); The capacitance of parallel plate capacitor is given as

$$C = \frac{\varepsilon_0 A}{d} = \frac{8.85\times10^{-12}\times30\times50\times10^{-4}}{6\times10^{-3}} = 0.221\times10^{-9}\text{ F}$$

$\therefore$ C = 0.221 nF

(iv) *(c)*; The arrangement is equivalent to a parallel combination of two capacitors, each with plate area $A/2$ and separation d,

$$C = C_1 + C_2 = \frac{\varepsilon_0 A}{2d}(K_1 + K_2)$$

$$= \frac{1}{2}(K_1 + K_2) \qquad \left[\because C_0 = \frac{\varepsilon_0 A}{d} = 1\mu\text{F (given)}\right]$$

$$\therefore \qquad C = \frac{1}{2}(4 + 6) = 5\,\mu\text{F}$$

(v) *(c)* $\because V = Ed$,

As E remains the same, so V increases as distance increases.

ASSERTION-REASON QUESTIONS

In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

1. **Assertion (A) :** A capacitor can be given only a limited amount of charge.

Reason (R) : After a limited value of charge, the dielectric strength of dielectric between the capacitor plates breaks down.

2. **Assertion (A) :** An applied electric field polarises a polar dielectric.

Reason (R) : The molecules of a polar dielectric possess a permanent dipole moment, but in the absence of electric field, these dipoles are randomly oriented and when electric field is applied these dipoles align along the direction of electric field.

3. **Assertion (A) :** The capacitance of a parallel plate capacitor increases with increase of distance between the plates.

Reason (R) : Capacitance of a parallel plate capacitor *i.e.*, $C \propto d$

4. **Assertion (A) :** The capacitance of a parallel plate capacitor increases when a dielectric constant of medium between the plates.

Reason (R) : Capacitance of a parallel plate capacitor is directly proportional to dielectric constant of medium between the plates.

5. **Assertion (A) :** When a charged capacitor is filled completely with a metallic slab, its capacitance is increased by a large amount.

Reason (R) : The dielectric constant for metal is infinite.

6. **Assertion (A) :** When charged capacitors are connected in parallel, the algebraic sum of charges remains constant but there is a loss of energy.

Reason (R) : During sharing a charges, the energy conservation law does not hold.

7. **Assertion (A) :** Change never flows from a condenser of higher capacity to the condenser of lower capacity. *[AIIMS 2018]*

Reason (R) : Flow of charge between two bodies connected by a thin wire is determined by the charges on them.

8. **Assertion (A) :** The force between the plates of a parallel plane capacitor is proportional to charge on it. *[AIIMS 2018]*

Reason (R) : Electric force is equal to charge per unit area.

9. **Assertion (A) :** In the absence of an externally applied electric field, the displacement per unit volume of a polar dielectric material is always zero. *[AIIMS 2018]*

Reason (R) : In polar dielectrics, each molecule has a permanent dipole moment but these are randomly oriented in the absence of an externally applied electric field.

10. **Assertion (A) :** Lines of force are perpendicular to conductor surface. *[AIIMS 2016]*

Reason (R) : Generally electric field is perpendicular to equipotential surface.

Answers

1. (*a*) **2.** (*a*) **3.** (*d*) **4.** (*a*) **5.** (*a*) **6.** (*c*) **7.** (*d*) **8.** (*c*)
9. (*a*) **10.** (*a*)

HINTS/SOLUTIONS OF SELECTED MCQs

1. (*a*) $C = \dfrac{Q}{V}$

2. (*a*) $W = q(\Delta V) \Rightarrow \Delta V = \dfrac{qV}{q} = \dfrac{2}{20} = 0.1\text{ V}$

3. (*a*) Due to repulsion between two electrons. The potential energy of the system increases.

4. (*b*) Because earth is a good conductor.

5. (*c*) Charge are reside on the surface of conductor. So, $E = 0$ inside the conductor then, $W = q(\Delta V) = 0 \Rightarrow \Delta V = 0$, so, $V =$ Constant.

6. (*a*) Electric field lines are always perpendicular to the equipotential surface.

7. (*a*) Electric field lines are always perpendicular to the equipotential surface.

8. (*c*) The positively charged particle experience electrostatic force along 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, hence potential energy of positive charge decreases.

9. (*c*) The work done by an electrostatic force is given by $W = q(\Delta V)$. Here initial and final potentials are same in all three cases and same charge is moved, so work done is same in all three cases.

10. (*c*) $E = -\dfrac{dV}{dr} \quad \Rightarrow \quad E = 0$ then, $\dfrac{dV}{dr} = 0 \Rightarrow V = \text{constant}$

Thus, $E = 0$ inside the charged conducting sphere causes, the same electrostatic potential 100 V at any point inside the sphere.

11. (*a*) The equipotential due to point charge are spherical in shape as electric potential due to point charge q is given by, $V = \dfrac{Kq}{r}$

12. (*b*) $C_{eq} = \dfrac{100 \times 100}{100 + 100} = 50\ \mu\text{F}$

$V_{\text{voltmeter}} = V_{AB} = \dfrac{Q}{C} = 100\text{ V}$

In parallels, $V =$ same.

Then, $Q = CV = 50 \times 10^{-6} \times 100 = 5 \times 10^{-3}$ C.

13. (*c*) In series combination,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

$$C_{eq} = \frac{\dfrac{K_1 \varepsilon_0 A}{d} \times \dfrac{K_2 \varepsilon_0 A}{d_2}}{\dfrac{K_1 \varepsilon_0 A}{d_1} + \dfrac{K_2 \varepsilon_0 A}{d_2}} = \frac{K_1 K_2 \varepsilon_0 A}{K_1 d_2 + K_2 d_1}$$

By comparing with $C_{eq} = \dfrac{K\varepsilon_0 A}{d_1 + d_2}$ then $K = \dfrac{K_1 K_2 (d_1 + d_2)}{K_1 d_2 + K_2 d_1}$

14. (*d*) $E = \dfrac{-dv}{dr}$, since the electric field (E) is inversely proportional to the separation between equipotential surface. So, equipotential surface are closer in regions of large E.

15. (*c*) $V_{\text{common}} = \dfrac{C_1 V_1 + C_2 V_2}{C_1 C_2} \Rightarrow 40 = \dfrac{2 \times 200 + 0}{2 + C_2}$

$$\Rightarrow C_2 = \frac{320}{40} = 8\,\mu\text{F}$$

16. (*b*) $C = \dfrac{\varepsilon_0 A}{d}$, $C' = \dfrac{\varepsilon_0 A}{d - t(1 - \frac{1}{K})} = \dfrac{\varepsilon_0 A}{d - \frac{d}{2}\left(1 - \frac{1}{\infty}\right)} = \dfrac{2\varepsilon_0 A}{d}$

$$\Rightarrow C' = 2C \Rightarrow \frac{C'}{C} = \frac{2}{1} = 2:1$$

17. (*b*) In series potential difference are additive, $V' = nV$.

$$V_i = \frac{1}{2}(nC_0)V^2 \text{, where } C_0 = \text{Capacitance of each capacitor}$$

$$V_f = \frac{1}{2}\left(\frac{C_0}{n}\right)(nV)^2 = V_i$$

18. (*a*) $C' = \dfrac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$, $C = \dfrac{\varepsilon_0 A}{d}$

$$\Rightarrow \frac{C'}{C} = \frac{d}{d - t\left(1 - \frac{1}{K}\right)} = \frac{d}{d - \frac{2}{3}d\left[1 - \frac{1}{K}\right]} = \frac{3K}{K+2}$$

$$\Rightarrow \frac{7}{6} = \frac{3K}{K+2} \Rightarrow K = \frac{14}{11}$$

19. (*d*) $V = \dfrac{C_2 V_2 - C_1 V_1}{C_1 + C_2} = \dfrac{6 \times 12 - 3 \times 12}{6 + 3} = \dfrac{36}{9} = 4\text{ V}$

then, $V_{3\mu F} = \dfrac{Q}{C} = \dfrac{4 \times 3 \times 10^{-6}}{3 \times 10^{-6}} = 4\text{ V}$

20. (*a*) $E = \dfrac{\Delta V}{d} = \dfrac{300 - (-100)}{4} = 100\text{ V/cm}$

∴ Voltage at 3 cm from second plate = 300 – (1 × 100) = 200 V.

21. (*c*) The given point lies inside the conductor and electric field intensity inside the conductor is zero. So, no work is done in bringing the charge from the surface to the given point. Therefore, the potential is same *i.e.*, 10 V.

22. (*b*) $\text{K.E} = W = q \,.\, V$

$= 1\, e \times V = 1 \text{ eV}$

23. (*c*) Amount of change, geometry and size of conductor

24. (*c*) $W = PE\,(\cos\theta_1 - \cos\theta_2)$

$= PE\,(\cos 0° - \cos 60°)$

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

$W' = PE\,(\cos 0° - \cos 180°)$

$= PE\,\{1 - (-1)\} = 2PE$

$$\frac{W}{W'} = \frac{\frac{1}{2}PE}{2PE} = \frac{1}{4}$$

$W' = 4\,W$

28. (*b*) As work done to move a charge on equipotential surface is zero.

29. (*d*) $V_{axial} = \frac{kp}{r^2}$

30. (*c*) As the charge returned to the initial position.

32. (*c*) $E = W = qV$

$= e \times 200 \text{ V} = 200 \text{ eV}$

33. (*c*) $W = qV = 7 \times 5 = 35 \text{ J}$

34. (*b*) $\frac{1}{2}mv^2 = W = qV$

36. (*b*) Let radius of bigger drop $= R$, radius of smaller droplet $= r$

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

$\Rightarrow R = 10r.$

$\therefore$ Potential of big drop $= \frac{k(1000\,q)}{10r} = \frac{100\,kq}{r}$

Potential of small drop $= \frac{kq}{r}$

$$\therefore \qquad \frac{V_{\text{big drop}}}{V_{\text{small drop}}} = 100$$

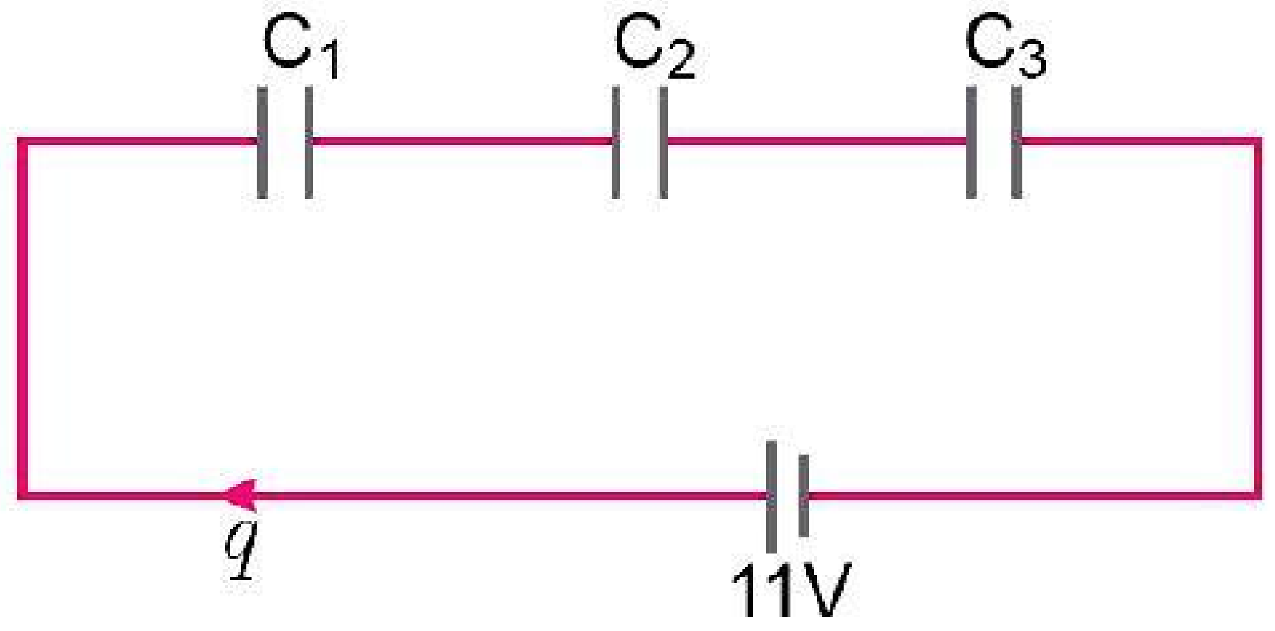
37. (*a*) Work done is given as $W = q\Delta V$

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

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

39. (*d*) $\frac{\text{C}}{\text{V}}$ called farad (F)

42. (*d*)



$$\frac{1}{C_{eq}} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$$

$$= \frac{11}{6} \Rightarrow C_{eq} = \frac{6}{11}\,\mu\text{F}$$

$$q = C_{eq}\,V = \frac{6}{11} \times 11 = 6\,\mu\text{C}$$

Also, $q = C_1 V_1 \Rightarrow 6 = 1 \times V_1$

$V_1 = 6$ V

43. (*c*) As $Q = CV$

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

It is a ratio so doesn't depends on either Q or V and thus remains constant.

44. (*c*) In all conductors charge is same.

46. (*b*) $\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C} + \text{...........}\ n \text{ times}$

$$= \frac{1+1+\text{.........}n \text{ times}}{C}$$

$$\frac{1}{C_{eq}} = \frac{n}{C}$$

$$C_{eq} = \frac{C}{n}$$

47. (*b*) As we know by inserting dielectric material capacitance increases K times.

$$C = KC_0$$

49. (*d*) $C_{\text{Sphere}} = 4\pi\varepsilon_0 r = \frac{1}{9 \times 10^9} \times 10 = \frac{1}{9 \times 10^8}$ farad

50. (*c*) $C_{eq} = nC = 4 \times 0.5 = 2\,\mu\text{F}$

51. (*a*) $C_{eq} = \frac{C}{n} = \frac{1}{3}\mu\text{F}$

52. (*a*) $C = 4\pi\varepsilon_0 r$

53. (*d*) $W = Q(V_Q - V_P)$

$= -100e(-4 - 10)$

$= -100 \times 1.6 \times 10^{-19} \times (-14)$

$= 2.24 \times 10^{-16}$ J

54. (*d*) As $C = KC_0 = 4 \times 3 = 12\,\mu\text{F}$

55. (*b*) As $C = \frac{A\varepsilon_0}{d}$

$$C \propto \frac{1}{d}$$

Now if distance be double capacitance will be half.

57. (*a*) As $C = \frac{A\varepsilon_0}{d}$

$$A = \frac{C \times d}{\varepsilon_0} = \frac{3 \times 5 \times 10^{-3}}{8.85 \times 10^{-12}} = 1.694 \times 10^9\,\text{m}^2$$

58. (*b*) We know that

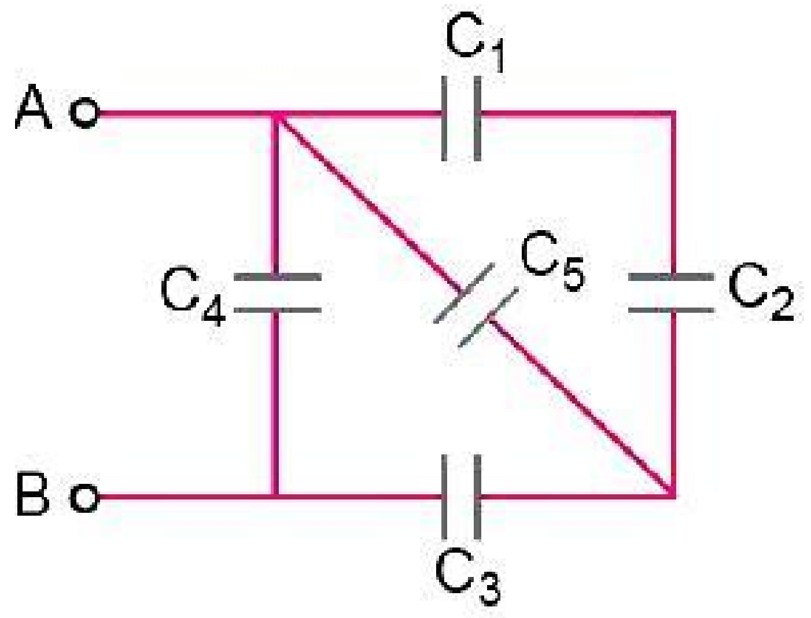
$U_0 = \frac{1}{2} C_0 V_0^2$ (Initial energy)

Also capacitance after introducing dielectric = KC_0 and potential $\frac{1}{K}$ times

So $U_f = \frac{1}{2}CV^2$

$$= \frac{1}{2}(KC_0)\left(\frac{1}{K}V_0\right)^2 = \frac{1}{K}.U_0$$

59. (*b*) C_1 and C_2 are connected in series, their equivalent capacitance is



$$C_{12} = \frac{C_1\,C_2}{C_1 + C_2}$$

$$= \frac{2\times 2}{2+2} = 1\,\mu\text{F}$$

Similarly, capacitance of C_3 and C_4

$C_{34} = 1\ \mu$F

The circuit represents Wheatstone's bridge and capacitor C_5 is neglected.

Equivalent capacitance of circuit

$C_{eq} = C_{12} + C_{34} = 1 + 1 = 2\ \mu$F.

60. (*a*) $U_i = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$

After connecting another capacitor in parallel,

$$\frac{q_1}{C} = \frac{q_2}{C} \quad \Rightarrow \quad q_1 = q_2$$

$$q_1 + q_2 = Q \quad \Rightarrow \quad q_1 = \frac{Q}{2}$$

⇒ Battery is disconnected,

Therefore, charge is constant $\Rightarrow \ U_f = \frac{\left(\frac{Q}{2}\right)^2}{2C} + \frac{\left(\frac{Q}{2}\right)^2}{2C} = \frac{Q^2}{4C} = \frac{U_i}{2}$

Hence, total electrostatic energy of resulting system is decreased by a factor of 2.

61. (*b*) Charge is invariant $Q = 8q$ and mass is invariant

$$M = 8m \quad \Rightarrow \quad \frac{4}{3}\pi R^3\rho = 8.\frac{4}{3}\pi r^3\rho \Rightarrow R = 2r$$

$$V' = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R} \text{ and } V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$\frac{V'}{V} = \frac{Q}{q}.\frac{r}{R} = 8\times\frac{1}{2} = 4 \qquad \Rightarrow \quad V' = 4V$$

62. (*c*) $U = \frac{1}{2}QV = \frac{1}{2}\times 0.1\times 200 = 10$ J

63. (*d*) $V = \frac{Q}{C} = \frac{qt}{C}$

$$\Rightarrow \quad t = \frac{VC}{q} = \frac{10\times 500}{100} = 50\text{ s}$$

64. (*b*) Electric field outside the plates $= \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$

Electric field inside the plates $= \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$

$$= \frac{\sigma}{\varepsilon_0} = \frac{q/A}{\varepsilon_0} = \frac{q}{A\varepsilon_0} = 50\text{ N/C}$$

65. (*c*) $W = \frac{1}{2}CV^2 = \frac{1}{2} \times 2 \times 10^{-6} \times (200)^2 = 4 \times 10^{-2}\text{ J} = 0.04\text{ J}$

66. (*c*) $C = \frac{\varepsilon_0 A}{d} = 1\text{pF}$

$$C' = \frac{K\varepsilon_0 A}{d'} = \frac{K\varepsilon_0 A}{2d} = \frac{K}{2} \times \left(\frac{\varepsilon_0 A}{d}\right)$$

$$\frac{C'}{C} = \frac{2\text{ pF}}{1\text{ pF}} = \frac{K}{2} \Rightarrow K = 4$$

67. (*a*) $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{3} + \frac{1}{9} + \frac{1}{18} = \frac{9}{18}$

$C_s = 2\,\mu\text{F}$

$\Rightarrow C_p = 3 + 9 + 18 = 30\,\mu\text{F} \qquad \therefore \frac{C_s}{C_p} = \frac{2}{30} = \frac{1}{15}$

68. (*b*) In series potential differences are additive, $V' = \frac{2V}{2} = V$

Initial energy $U_i = \frac{1}{2}(2C_0)\left(\frac{V}{2}\right)^2$, where C_0 is capacitance of each capacitor

Final energy, $U_f = \frac{1}{2}\left(\frac{C_0}{2}\right)(V)^2 = U_i$

69. (*a*) $C = \frac{\varepsilon_0 A}{d} = 9\text{ pF}$

$$C' = \frac{\varepsilon_0 A}{d - \left[t_1\left(1 - \frac{1}{K_1}\right) + t_2\left(1 - \frac{1}{K_2}\right)\right]}$$

$t_1 = \frac{d}{3}, t_2 = \frac{2d}{3}, K_1 = 3, K_2 = 6$

$\Rightarrow C' = \frac{9}{2}\frac{\varepsilon_0 A}{d} = \frac{9}{2} \times 9\text{ pF} = 40.5\text{ pF}$

70. (*c*) $C = \frac{\varepsilon_0 A}{d}, \quad C' = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$

$$\frac{C'}{C} = \frac{d}{d - t\left(1 - \frac{1}{K}\right)} = \frac{d}{d - \frac{2}{3}d\left[1 - \frac{1}{K}\right]} = \frac{3K}{2K+1}$$

$\Rightarrow \frac{8}{9} = \frac{3K}{2K+1} \Rightarrow K = \frac{8}{11}$

71. (*b*) $V = \frac{Q_2 - Q_1}{C_2 + C_1} = \frac{(4-1) \times 10}{4+1} = 6\text{ V}$

72. (*a*) $E = \frac{V}{d} = \frac{300 - (-100)V}{4\text{ cm}} = 100\text{ V/ cm}$

$\therefore$ Voltage at 1 cm from first plate = 300 – (1 × 100) = 200 V

73. (*a*) $U = \frac{1}{2}CV_2^2 - \frac{1}{2}CV_1^2 = \frac{1}{2}C(V_2^2 - V_1^2) = \frac{1}{2} \times 6 \times 10^{-6}[(20)^2 - (10)^2] = 9 \times 10^{-4}\text{ J}$

74. (*c*) Energy stored in capacitor, $U_1 = \frac{1}{2}CV^2$

Energy supplied by battery, $U_2\ (= qV) = CV^2$

$$\frac{U_1}{U_2} = \frac{1}{2}$$

75. (*d*) Potential (V) due to a charged sphere at internal point is same as on its surface and at external point, $V \propto \frac{1}{r}$.

$$\therefore \quad V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{4\pi a^2\sigma}{a} - \frac{4\pi b^2\sigma}{b} + \frac{4\pi c^2\sigma}{c}\right]$$

$$V_B = \frac{1}{4\pi\varepsilon_0}\left[\frac{4\pi a^2\sigma - 4\pi b^2\sigma}{b} + \frac{4\pi c^2\sigma}{c}\right]$$

$$V_C = \frac{1}{4\pi\varepsilon_0}\left[\frac{4\pi a^2\sigma - 4\pi b^2\sigma + 4\pi c^2\sigma}{c}\right]$$

with $c = a + b$, we note $V_A = V_C \neq V_B$

76. (*d*) $E = -\left(\hat{i}\,\frac{\partial V}{\partial x} + \hat{j}\,\frac{\partial V}{\partial y} + \hat{k}\,\frac{\partial V}{\partial z}\right)$

Here $V = -x^2y - xz^2 + 4$

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

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

77. (*b*) In series $C_{\text{eq}} = \frac{C}{3}$

and $V_{max} = V_1 + V_2 + V_3 = 3V$

78. (*b*) Work done = Gain in K.E.

$$\Rightarrow \qquad QV = \frac{1}{2}mv^2 \ \Rightarrow \ v = \sqrt{\frac{2QV}{m}}$$

$$\therefore \qquad v_A = \sqrt{\frac{2qV}{m}},\ v_B = \sqrt{\frac{2(4q)V}{m}}$$

$$\frac{v_A}{v_B} = \frac{1}{2}$$

79. (*a*) $E_x = -\frac{dV}{dx} = -\frac{d}{dx}(4x^2)$

$= -8x = -8 \times 1 = -8$

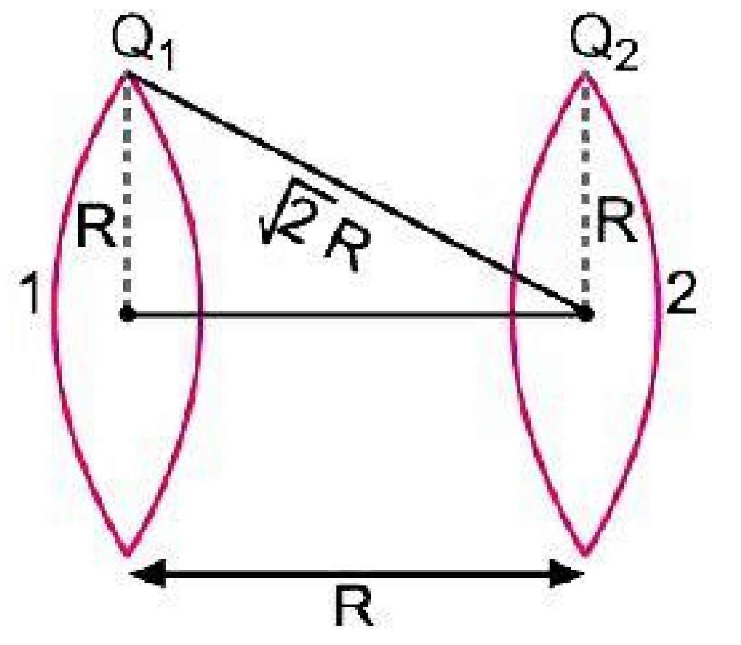
$\vec{E} = -8\,\hat{x}$ or 8 V/m along negative *x*-axis

80. (*b*) Potential at centre of ring 1

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

Potential at centre of ring 2

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



$\therefore$ Potential difference,

$$V_1 - V_2 = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1 - Q_2}{R} - \frac{Q_1 - Q_2}{\sqrt{2}R}\right)$$

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

Work done, $W = q(V_1 - V_2)$

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

81. (*b*) Initial energy = Final energy

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_1} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_2} + \frac{1}{2}mv^2$$

$$\frac{1}{2}mv^2 = \frac{q_1\, q_2}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$v^2 = \frac{2q_1 q_2}{4\pi\varepsilon_0 m}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$= \frac{2\times 1\times 10^{-6}\times 1\times 10^{-3}\times 9\times 10^{9}}{2\times 10^{-3}}\left(\frac{1}{1} - \frac{1}{10}\right)$$

$$= 9 \times 10^2 \times 9$$

$$v = 90 \text{ m/s}$$

82. (*a*) $$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r} - \frac{q}{3r}\right) = \frac{1}{4\pi\varepsilon_0}\frac{2}{3}\frac{q}{r}$$

$$\Rightarrow \quad \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = \frac{3}{2}V$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{(3r)^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{9r^2} = \frac{V}{6r}$$

83. (*a*) $V = \frac{W}{q} = \frac{Fd}{q} = \frac{3000\times 1\times 10^{-2}}{3} = 10 \text{ V}$

84. (*b*) $E_x = -\frac{dV}{dx} \quad \Rightarrow \quad E_0 = -\frac{V_x - 0}{x - 0} \quad \Rightarrow \quad V_x = -xE_0$

85. (*c*) Electric field is zero within the metal, so there should be no line of force within metal and lines are always normal to equipotential surface.

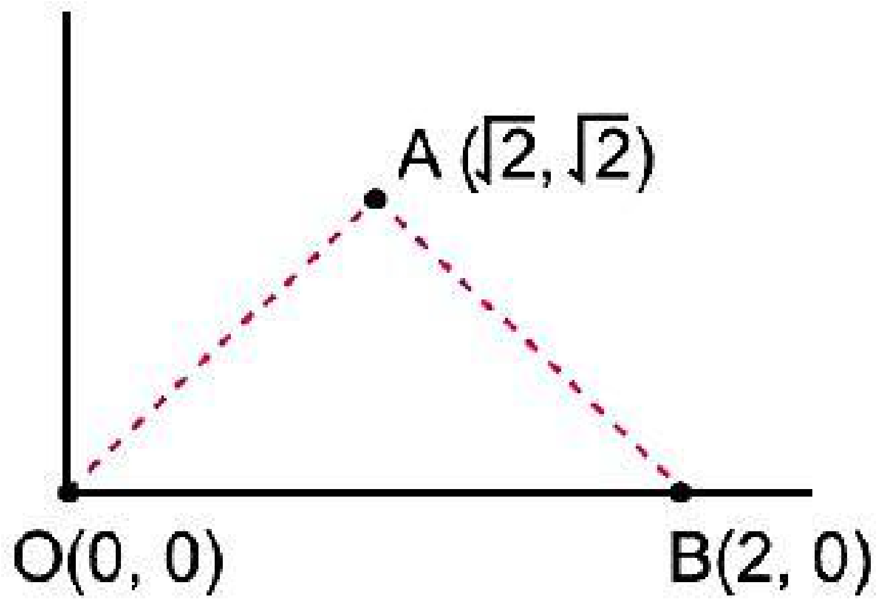
86. (*a*) $$V_1 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{R} - \frac{q}{\sqrt{R^2 + d^2}}\right]$$

$$V_2 = \frac{1}{4\pi\varepsilon_0}\left(-\frac{q}{R} + \frac{q}{\sqrt{R^2 + d^2}}\right)$$

$$V_1 - V_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{R} - \frac{q}{\sqrt{R^2 + d^2}} + \frac{q}{R} - \frac{q}{\sqrt{R^2 + d^2}}\right]$$

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

87. (*a*) Potential difference between A and B



$$V_A - V_B = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{OA} - \frac{q}{OB}\right)$$

$$OA = \sqrt{(\sqrt{2})^2 + (\sqrt{2})^2} = 2\text{ m}$$

$$OB = 2\text{ m}$$

$$\therefore V_A - V_B = 0$$

88. (*d*) $U_0 = \frac{1}{2}CV^2,\ U = \frac{1}{2}(KC)V^2 \Rightarrow U = KU_0 > U_0$

89. (*d*) Potentials are added in series. Number of capacitors in series arrangement,

$$n = \frac{3,000}{500} = 6$$

If m identical rows are connected in parallel, then

$$m = \frac{1}{(1/6)} = 6$$

Least number of capacitors $mn = 6 \times 6 = 36$

90. (*b*) When battery is disconnected charge remains same

$$Q = CV = \frac{\varepsilon_0 AV}{d}$$

$$E = \frac{\sigma}{K\varepsilon_0} = \frac{Q}{AK\varepsilon_0} = \frac{\varepsilon_0 AV}{dAK\varepsilon_0} = \frac{V}{Kd}$$

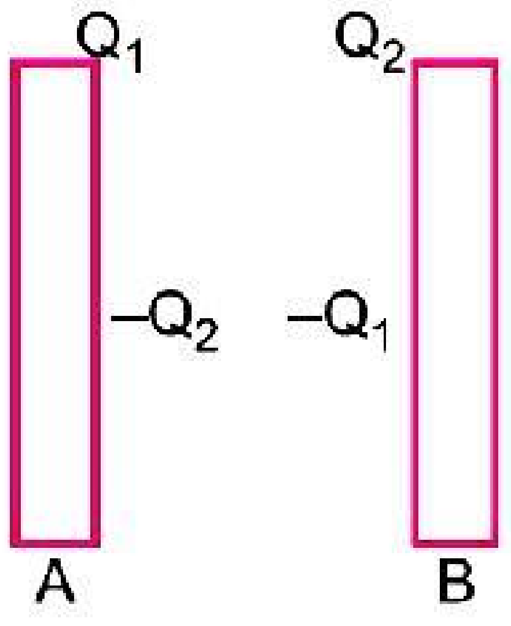
Initial energy, $U_i = \frac{1}{2}CV^2 = \frac{1}{2}\frac{\varepsilon_0 A}{d}V^2$

Final energy, $U_f = \frac{Q^2}{2C} = \frac{(\varepsilon_0 AV/d^2)}{2(\varepsilon_0 KA/d)} = \frac{\varepsilon_0 AV^2}{2dK}$

$\therefore$ Work done by system, $W = U_i - U_f = \frac{\varepsilon_0 AV^2}{2d}\left[1 - \frac{1}{K}\right]$

So, '*b*' is false

91. (*c*) Charge induced on plate A due to charge Q_2 on plate B is $-Q_2$, charge induced on plate B due to charge Q_1 on plate A is $-Q_1$.



Net charge on plate A

$$A = Q_1 - Q_2$$

Net charge on plate B

$$B = Q_2 - Q_1 = -(Q_1 - Q_2)$$

So charge on capacitor $= Q_1 - Q_2$

P.d. between the plates, $V = \frac{Q_1 - Q_2}{C}$

92. (*a*) The charges on the plates of the capacitor A are bound to each other, so no charge will flow to B, so there will be only equal and opposite induced charges on second plate of capacitor A are held by strong electrostatic force. Hence, charge on capacitor B is zero..

93. (*c*) Common potential, $V = \frac{CV_1 + CV_2}{C + C} = \frac{V_1 + V_2}{2}$

$$\therefore \text{ Energy loss, } \Delta U = \frac{1}{2}C(V_1^2 + V_2^2) - \frac{1}{2}(2C)\left(\frac{V_1 + V_2}{2}\right)^2$$

$$= \frac{1}{4}C(V_1 - V_2)^2$$

94. (*d*) Initial charge on $C_1 = 30 \times 2 = 60$ pC

Initial charge on $C_2 = 20 \times 3 = 60$ pC

Clearly initial charges on C_1 and C_2 are same; so when S_1 and S_3 are closed; the capacitors are connected in series, so charges do not redistribute and potential differences across C_1 and C_2 remain as before $V_1 = 30$ V, $V_2 = 20$ V.

95. (*b*) n-plates form $(n - 1)$ capacitors in parallel.

$\therefore$ Net capacitance $= (n - 1)\, C$

96. (*c*) Electrostatic energy = Thermal energy

$$\frac{1}{2}CV^2 = ms\,\Delta T$$

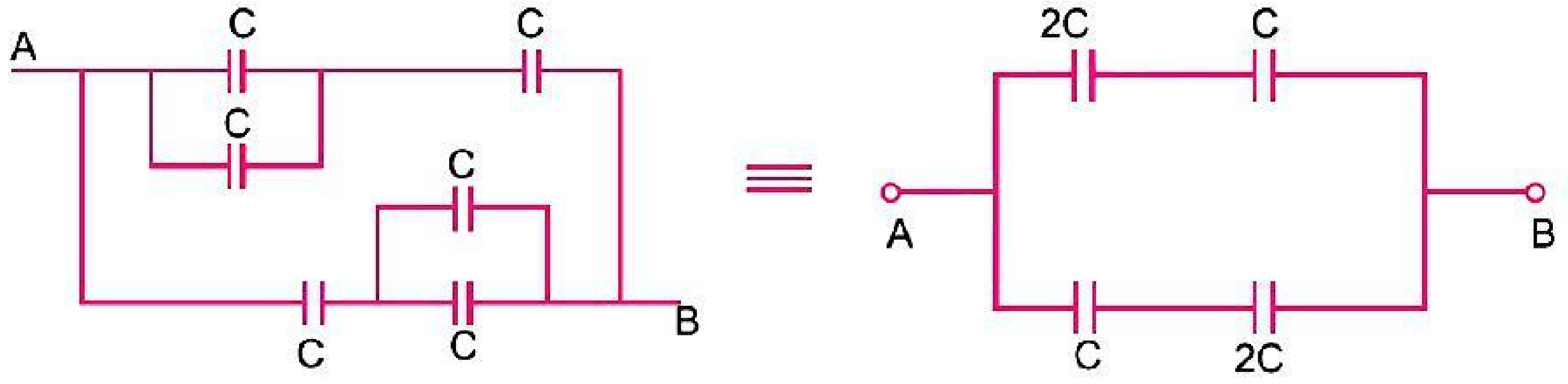
$$\Rightarrow \qquad V = \sqrt{\frac{2ms\,\Delta T}{C}}$$

97. (*c*) In equilibrium potentials of spheres are equal, *i.e.*,

$$V_1 = V_2$$

$$\frac{E_1}{E_2} = \frac{V/R_1}{V/R_2} = \frac{R_2}{R_1} = \frac{2\text{ mm}}{1\text{ mm}} = \frac{2}{1}$$

98. (*d*) Equivalent circuit is shown in figure



Effective capacitance of each row,

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

$$\therefore \quad C_{eff} = \frac{2}{3}C + \frac{2}{3}C = \frac{4}{3}C$$

99. (*c*) Initially work is done on the system and while reinserting the slab equal work is done by the system. So, net work done by the system is zero.

100. (*b*) Let radius of bigger drop = R.

i.e., $$\frac{4}{3}\pi R^3 = 343 \times \frac{4}{3}\pi r^3$$

$\Rightarrow \quad R = 7r$

$\therefore$ Potential of big drop $= \dfrac{k(343q)}{10r} = \dfrac{49kq}{r}$

Potential of small drop $= \dfrac{kq}{r}$

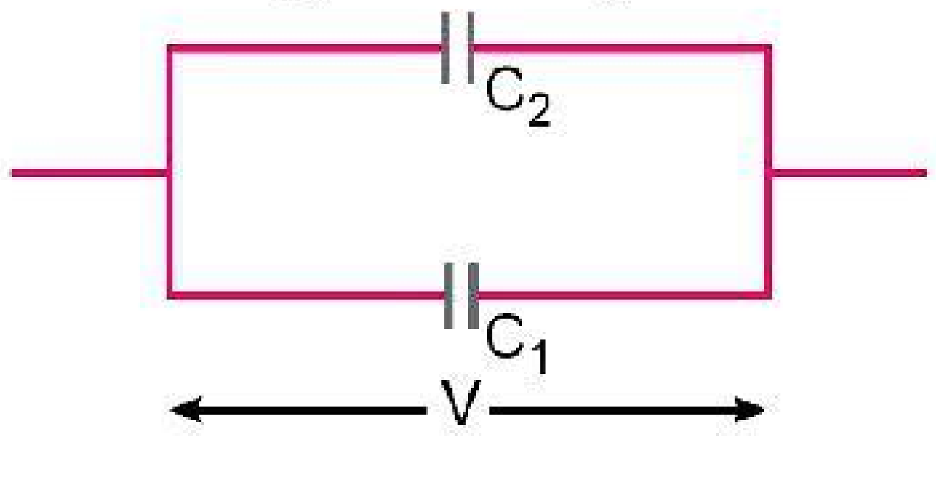
$$\therefore \quad \frac{V_{\text{big drop}}}{V_{\text{small drop}}} = 49 \Rightarrow V_{\text{big drop}} = 49V_{\text{small drop}}$$

101. (*c*) $-qLE$

102. (*d*) Since the positive charge is displaced against the electric field so the energy will be provided by external source in displacing the charge.

103. (*a*) Potential difference across C_1 = V

Potential difference across C_2 = V



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

$$\frac{Q_1}{C_1} = \frac{Q_2}{C_2} \Rightarrow \frac{Q_1}{Q_2} = \frac{C_1}{C_2}$$

105. (*a*) $V/2$

When the battery is disconnected the charge on the capacitor, $Q = CV$

Capacitance of parallel plate capacitor, $C = \frac{\varepsilon_0 A}{d}$

When the separation between the plates is halved, $C' = \frac{\varepsilon_0 A}{d/2} = 2C$

New potential difference $V = \frac{Q}{C'} = \frac{CV}{2C} = \frac{V}{2}$

106. (*d*) Zero

Potential at the center is equal to the potential at the surface so the work done in moving the test charge from its centre to its surface is zero.