15 Capacitor

QUICK LOOK

Capacitance

We know that charge given to a conductor increases it's potential *i.e.*, $Q \propto V \Rightarrow Q = CV$

Where C is a proportionality constant, called capacity or capacitance of conductor. Hence capacitance is the ability of conductor to hold the charge.

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

Unit and Dimensional Formula: S.I. unit is $\frac{\text{Coulomb}}{Volt}$ = Farad (F)

Smaller S.I. units are mF, μF, nF and pF ($1mF = 10^{-3}F$, $\mu F = 10^{-6}F$, $1nF = 10^{-9}F$, $1pF = 1\mu\mu F = 10^{-12}F$)

C.G.S. unit is *Stat Farad* $1F = 9 \times 10^{11}$ *Stat Farad*..

Dimension: $[C] = [M^{-1}L^{-2}T^{4}A^{2}]$..

Capacitance of earth is 711 μF = 711 × 10^{-6} F. Capacitance of a conductor/capacitor increases due to presence of neighbouring conductors. Energy stored in a capacitor lies in the medium between the plates. A capacitor is a device that stores electric energy. or A capacitor is a pair of two conductors of any shape, which are close to each other and have equal and opposite charge.

Energy of a Charged Conductor: When a conductor is charged it's potential increases from 0 to V as shown in the graph; and work is done against repulsion, between charge stored in the conductor and charge coming from the source (battery). This work is stored as "electrostatic potential energy"

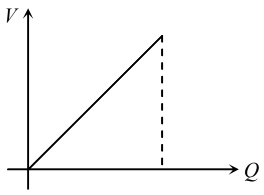


Figure: 15.1 Potential vs. Charge

- Energy of a charged conductor $U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{1}{2}QV$
- Capacitance of an isolated sphere $C = 4\pi\varepsilon_0 r$
- Sharing of charges: when two charged conductors are connected by a conducting wire, common potential

$$V = \frac{q_1 + q_2}{C_1 + C2} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

- Ratio of charges after sharing (i.e., after connection) $\frac{q_1}{q_2} = \frac{C_1}{C_2}$
- Energy loss during sharing $\Delta U = \frac{C_1C_2}{2(C_1 + C_2)}(V_1 - V_2)^2$
- In n small charged drops each of charge q. potential υ capacitance c and surface energy u; coalesce to form a single big drop, then charge on big drop $Q = nq$ Capacitance $C = n^{1/3}$, potential $V = n^{2/3}$, surface energy $U = n^{5/3}u$.

Parallel Plate Capacitor: Capacitance of a parallel plate capacitor, $C \propto A$ and $C \propto \frac{1}{d}$. If a parallel plate capacitor is charged by a battery to a charge Q, and the charging battery is disconnected, then the charge (Q) on capacitor remains constant though its capacitance is changed by introducing dielectric or altering the distance between the plates. A dielectric is introduced in the space between the plates of a parallel plate capacitor, its capacitance increases.

Capacitance $C = \frac{\varepsilon_0 A}{d}$ (for air as dielectric)

$C = \frac{K\varepsilon_0 A}{d}$ (for medium as dielectric)

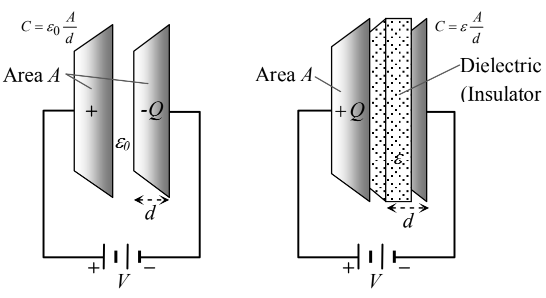


Figure: 15.2

When space between plates is partly filled with medium (dielectric constant K, thickness t) Dielectrics are insulating (non-conducting) materials which transmits electric effect without conducting.

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

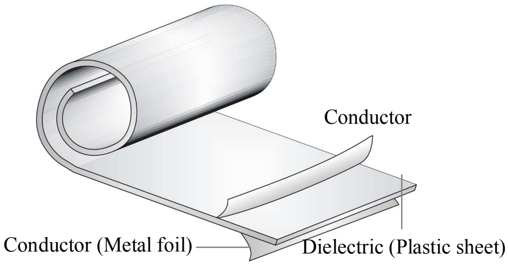


Figure: 15.3

- If a number of dielectric slabs are inserted between the plate as shown

$$C' = \frac{\varepsilon_0 A}{d - (t_1 + t_2 + t_3 + ...) + \left(\frac{t_1}{K_1} + \frac{t_2}{K_2} + \frac{t_3}{K_3} + ...\right)}$$

- When a metallic slab is inserted between the plates $C' = \frac{\varepsilon_0 A}{(d - t)}$. If metallic slab fills the complete space between the plates (*i.e.* $t = d$) or both plates are joined through a metallic wire then capacitance becomes infinite.
- Force between the plates of a parallel plate capacitor. $|F| = \frac{\sigma^2 A}{2\varepsilon_0} = \frac{Q^2}{2\varepsilon_0 A} = \frac{CV^2}{2d}$
- Energy density between the plates of a parallel plate capacitor.

  $\text{Energy density} = \frac{\text{Energy}}{\text{Volume}} = \frac{1}{2}\varepsilon_0 E^2.$

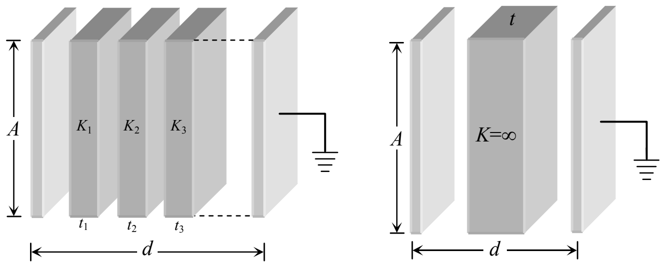


Figure: 15.4

Spherical Capacitor: It consists of two concentric conducting spheres of radii a and b ($a < b$). Inner sphere is given charge $+Q$, while outer sphere is earthed.

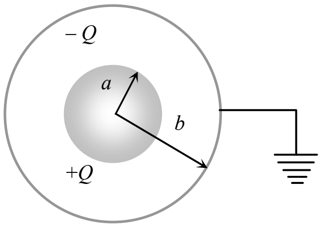


Figure: 15.5

Potential difference

Between the spheres is $V = \frac{Q}{4\pi\varepsilon_0 a} - \frac{Q}{4\pi\varepsilon_0 b}$

Capacitance: $C = 4\pi\varepsilon_0 . \frac{ab}{b-a}$.

In the presence of dielectric medium (dielectric constant K) between the spheres $C' = 4\pi\varepsilon_0 K \frac{ab}{b-a}$. If outer sphere is given a charge $+Q$ while inner sphere is earthed

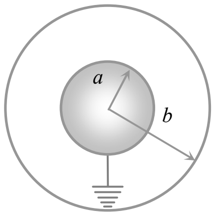


Figure: 15.6

Induced charge on the inner sphere $Q' = -\frac{a}{b}.Q$ and capacitance of the system $C' = 4\pi\varepsilon_0 . \frac{b^2}{b-a}$

This arrangement is not a capacitor. But it's capacitance is equivalent to the sum of capacitance of spherical capacitor and spherical conductor *i.e.* $4\pi\varepsilon_0 \cdot \frac{b^2}{b-a}$

$$= 4\pi\varepsilon_0 \frac{ab}{b-a} + 4\pi\varepsilon_0 b$$

Cylindrical Capacitor: It consists of two concentric conducting cylinders of radii a and b ($a < b$). Inner cylinder is given charge $+Q$, while outer cylinder is earthed

$$C = \frac{2\pi\varepsilon_0 Kl}{\log_e \frac{b}{a}} = \frac{2\pi\varepsilon_0 Kl}{2.3 \log_{10} \frac{b}{a}}$$

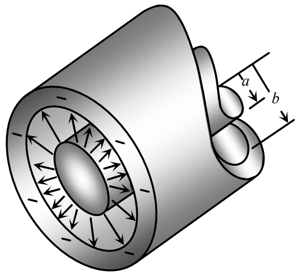


Figure: 15.7 Cylindrical Capacitor

Combinations of Capacitors

- **Capacitor in series** $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$q_1 - q_2 = q_3 = q$ (same for all)

$V - V_1 + V_2 + V_3$

If n identical capacitors each having capacitances C are connected in series with supply voltage V then Equivalent capacitance $C_{eq} = \frac{C}{n}$ and Potential difference across each capacitor $V' = \frac{V}{n}$.

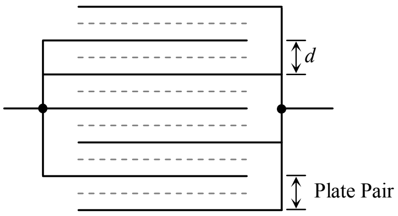


Figure: 15.8

- **Capacitors in parallel** $C = C_1 + C_2 + C_3$

  $q - q_1 + q_2 + q_3$

  $V_1 - V_2 = V_3 = V$ (same for all).

  If n identical plates are arranged as shown below, they constitute (n – 1) capacitors in series. If each capacitors having capacitance $\frac{\varepsilon_0 A}{d}$ then $C_{eq} = \frac{\varepsilon_0 A}{(n-1)d}$

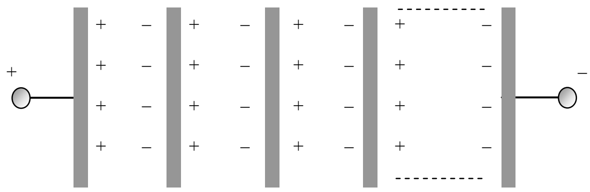


Figure: 15.9

Dielectrics: The ratio of force of interaction between two point charges separated by a certain distance in air/ vacuum to the force of attraction / repulsion between the same two point charges, held the same distance apart in the medium; can also be defined as the ratio of capacitances with medium to air.

Dielectric constant $K = \frac{C_{\text{medium}}}{C_{\text{air}}}$

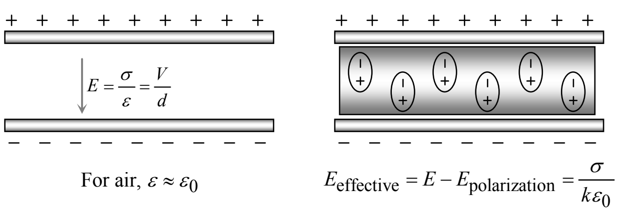


Figure: 15.10

Polarisation: The measure of Polarisation 'P' of a material is for a given electric field 'E' is called Electric susceptibility χ_e

$P = \varepsilon_0 \chi E$ where ε_0 is the permittivity of free space

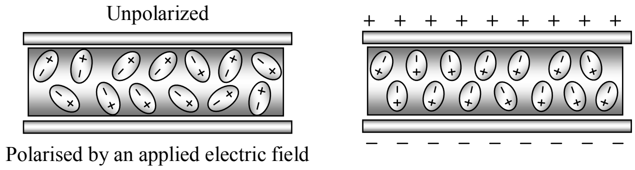


Figure: 15.11

Kirchhoff's Law for Capacitor Circuits: According to Kirchhoff's junction law $\Sigma q = 0$ and Kirchhoff's second law (Loop law) states that in a close loop of an electric circuit; Use following sign convention while solving the problems.

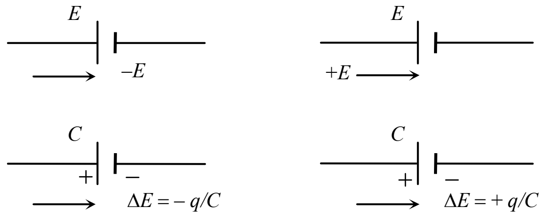


Figure: 15.12

When an arrangement of capacitors cannot be simplified by the method of successive reduction, then we need to apply the Kirchhoff's laws to solve the circuit.

Variation of Different Variables (*Q*, *C*, *V*, *E* and *U*) of Parallel Plate Capacitor

Suppose we have an air filled charged parallel plate capacitor having variables are as follows:

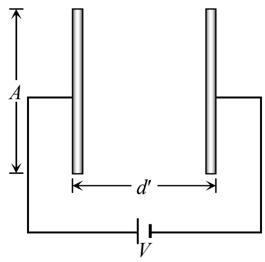


Figure: 15.13 Parallel Plate Capacitor

Charge – Q, Surface charge density – $\sigma = \frac{Q}{A}$,

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

Potential difference across the plates – $V = E.d$

Electric field between the plates – $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$

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

MULTIPLE CHOICE QUESTIONS

Capacitance

1. Eight drops of mercury of same radius and having same charge coalesce to form a big drop. Capacitance of big drop relative to that of small drop will be

a. 16 times **b.** 8 times
c. 4 times **d.** 2 times

2. Two spheres A and B of radius 4 cm and 6 cm are given charges of $80\,\mu C$ and $40\,\mu C$ respectively. If they are connected by a fine wire, the amount of charge flowing from one to the other is

a. $20\,\mu C$ from A to B **b.** $16\,\mu C$ from A to B
c. $32\mu C$ from B to A **d.** $32\,\mu C$ from A to B

3. Two insulated metallic spheres of $3\mu F$ and $5\mu F$ capacitances are charged to 300 V and $500V$ respectively. The energy loss, when they are connected by a wire, is

a. $0.012\,J$ **b.** $0.0218\,J$
c. $0.0375J$ **d.** $3.75\,J$

4. 64 small drops of mercury, each of radius r and charge q coalesce to form a big drop. The ratio of the surface density of charge of each small drop with that of the big drop is

a. 1 : 64 **b.** 64 : 1
c. 4 : 1 **d.** 1 : 4

5. Two hollow spheres are charged positively. The smaller one is at 50 V and the bigger one is at 100 V. How should they be arranged so that the charge flows from the smaller to the bigger sphere when they are connected by a wire

a. By placing them close to each other
b. By placing them at very large distance from each other
c. By placing the smaller sphere inside the bigger one
d. Information is insufficient

6. A condenser of capacity $50\,\mu F$ is charged to 10 volts. Its energy is equal to

a. $2.5\times10^{-3}\,joule$ **b.** $2.5\times10^{-4}\,joule$
c. $5\times10^{-2}\,joule$ **d.** $1.2\times10^{-8}\,joule$

7. The respective radii of the two spheres of a spherical condenser are $12\,cm$ and $9\,cm$. The dielectric constant of the medium between them is 6. The capacity of the condenser will be

a. 240 pF **b.** $240\mu F$
c. $240F$ **d.** None of the above

8. The distance between the plates of a parallel plate condenser is 4 mm and potential difference is 60 volts. If the distance between the plates is increased to 12 mm, then

a. The potential difference of the condenser will become 180 volts
b. The P.D. will become 20 volts
c. The P.D. will remain unchanged
d. The charge on condenser will reduce to one third

9. There is an air filled $1pF$ parallel plate capacitor. When the plate separation is doubled and the space is filled with wax, the capacitance increases to $2pF$. The dielectric constant of wax is

a. 2 **b.** 4
c. 6 **d.** 8

10. A $6\mu F$ capacitor is charged from 10 volts to 20 volts. Increase in energy will be

a. $18\times10^{-4}\,J$ **b.** $9\times10^{-4}\,J$
c. $4.5\times10^{-4}\,J$ **d.** $9\times10^{-6}\,J$

11. The plates of parallel plate capacitor are charged upto $100V$. A $2mm$ thick plate is inserted between the plates. Then to maintain the same potential difference, the distance between the plates is increased by 1.6 mm. The dielectric constant of the plate is

a. 5 **b.** 1.25
c. 4 **d.** 2.5

12. A capacitor with air as the dielectric is charged to a potential of 100 volts. If the space between the plates is now filled with a dielectric of dielectric constant 10, the potential difference between the plates will be

a. 1000 volts **b.** 100 volts
c. 10 volts **d.** Zero

13. The capacitance of a metallic sphere will be $1\mu F$, if its radius is nearly

a. 9 km **b.** 10 m
c. 1.11 m **d.** 1.11 cm

14. A capacitor is charged by using a battery which is then disconnected. A dielectric slab is then slipped 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 the above

15. The insulated 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 $Q_1R_2 = Q_2R_1$

16. Separation between the plates of a parallel plate capacitor is d and the area of each plate is A. When a slab of material of dielectric constant k and thickness t ($t < d$) is introduced between the plates, its capacitance becomes

a. $\dfrac{\varepsilon_0 A}{d + t\left(1 - \dfrac{1}{k}\right)}$ **b.** $\dfrac{\varepsilon_0 A}{d + t\left(1 + \dfrac{1}{k}\right)}$

c. $\dfrac{\varepsilon_0 A}{d - t\left(1 - \dfrac{1}{k}\right)}$ **d.** $\dfrac{\varepsilon_0 A}{d - t\left(1 + \dfrac{1}{k}\right)}$

17. If the dielectric constant and dielectric strength be denoted by k and x respectively, then a material suitable for use as a dielectric in a capacitor must have

a. High k and high x **b.** High k and low x

c. Low k and low x **d.** Low k and high x

18. The area of each plate of a parallel plate capacitor is $100\,cm^2$ and the distance between the plates is $1nm$. It is filled with mica of dielectric 6. The radius of the equivalent capacity of the sphere will be

a. 47.7 m **b.** 4.77 m

c. 477 m **d.** None of the above

19. The capacity of a parallel plate condenser is $10\mu F$ without dielectric. Dielectric of constant 2 is used to fill half the distance between the plates, the new capacitance in μF is

a. 10 **b.** 20

c. 15 **d.** 13.33

Combinations of Capacitors

20. The capacity of pure capacitor is 1 *farad*. In D.C. circuit, its effective resistance will be

a. Zero **b.** Infinite

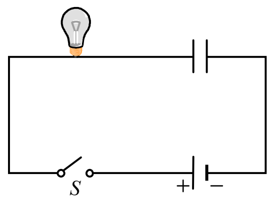
c. 1 *ohm* **d.** $\dfrac{1}{2}$ *ohm*

21. Two capacitances of capacity C_1 and C_2 are connected in series and potential difference V is applied across it. Then the potential difference across C_1 will be

a. $V\dfrac{C_2}{C_1}$ **b.** $V\dfrac{C_1 + C_2}{C_1}$

c. $V\dfrac{C_2}{C_1 + C_2}$ **d.** $V\dfrac{C_1}{C_1 + C_2}$

22. A light bulb, a capacitor and a battery are connected together as shown here, with switch S initially open. When the switch S is closed, which one of the following is true?



a. The bulb will light up for an instant when the capacitor starts charging

b. The bulb will light up when the capacitor is fully charged

c. The bulb will not light up at all

d. The bulb will light up and go off at regular intervals

23. Capacity of a parallel plate condenser is $10\mu F$ when the distance between its plates is 8 cm. If the distance between the plates is reduced to $4cm$, its capacity will be:

a. $10\mu F$ **b.** $15\mu F$

c. $20\mu F$ **d.** $40\mu F$

24. Three condensers each of capacitance $2F$ are put in series. The resultant capacitance is:

a. $6\,F$ **b.** $\dfrac{3}{2}F$

c. $\dfrac{2}{3}F$ **d.** $5F$

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

a. $1.694 \times 10^9\,m^2$ **b.** $4.529 \times 10^9\,m^2$

c. $9.281 \times 10^9\,m^2$ **d.** $12.981 \times 10^9\,m^2$

26. Two capacitors of $10\mu F$ and $20\mu F$ are connected in series with a $30V$ battery. The charge on the capacitors will be, respectively

a. $100\,\mu C$, $200\mu C$ **b.** $200\,\mu C$, $100\mu C$

c. $100\,\mu C$, $100\mu C$ **d.** $200\,\mu C$, $200\mu C$

27. If potential difference of a condenser $(6\ \mu F)$ is changed from 10 V to 20 V then increase in energy is

a. $2\times10^{-4} J$ **b.** $4\times10^{-4} J$
c. $3\times10^{-4} J$ **d.** $9\times10^{-4} J$

28. The diameter of each plate of an air capacitor is 4 *cm*. To make the capacity of this plate capacitor equal to that of 20 *cm* diameter sphere, the distance between the plates will be

a. $4\times10^{-3}\ m$ **b.** $1\times10^{-3}\ m$
c. 1 *cm* **d.** $1\times10^{-3}\ cm$

29. A spherical condenser has inner and outer spheres of radii a and b respectively. The space between the two is filled with air. The difference between the capacities of two condensers formed when outer sphere is earthed and when inner sphere is earthed will be

a. Zero **b.** $4\pi\varepsilon_0 a$
c. $4\pi\varepsilon_0 b$ **d.** $4\pi\varepsilon_0 a\left(\frac{b}{b-a}\right)$

30. After charging a capacitor of capacitance $4\ \mu F$ upto a potential 400 V, its plates are connected with a resistance of $1\ k\Omega$. The heat produced in the resistance will be

a. 0.16 J **b.** 1.28 J
c. 0.64 J **d.** 0.32 J

31. The amount of work done in increasing the voltage across the plates of a capacitor from $5\ V$ to $10\ V$ is W. The work done in increasing it from $10\ V$ to $15\ V$ will be

a. 0.6 W **b.** W
c. 1.25 W **d.** 1.67 W

32. Three capacitors each of capacitance $1\mu F$ are connected in parallel. To this combination, a fourth capacitor of capacitance $1\mu F$ is connected in series. The resultant capacitance of the system is

a. $4\mu F$ **b.** $2\mu F$
c. $\frac{4}{3}\mu F$ **d.** $\frac{3}{4}\mu F$

33. A capacitor $4\mu F$ charged to 50 V is connected to another capacitor of $2\mu F$ charged to 100 V with plates of like charges connected together. The total energy before and after connection in multiples of $(10^{-2} J)$ is

a. 1.5 and 1.33 **b.** 1.33 and 1.5
c. 3.0 and 2.67 **d.** 2.67 and 3.0

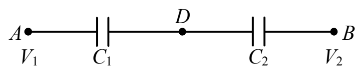
34. Two capacitors of $3pF$ and $6pF$ are connected in series and a potential difference of 5000 V is applied across the combination. They are then disconnected and reconnected in parallel. The potential between the plates is

a. 2250 V **b.** 2222 V
c. $2.25\times10^{6}\ V$ **d.** $1.1\times10^{6}\ V$

35. A condenser of capacity C_1 is charged to a potential V_0. The electrostatic energy stored in it is U_0. It is connected to another uncharged condenser of capacity C_2 in parallel. The energy dissipated in the process is

a. $\frac{C_2}{C_1+C_2}U_0$ **b.** $\frac{C_1}{C_1+C_2}U_0$
c. $\left(\frac{C_1-C_2}{C_1+C_2}\right)U_0$ **d.** $\frac{C_1C_2}{2(C_1+C_2)}U_0$

36. Two condensers C_1 and C_2 in a circuit are joined as shown in figure. The potential of point A is V_1 and that of B is V_2. The potential of point D will be



a. $\frac{1}{2}(V_1+V_2)$ **b.** $\frac{C_2V_1+C_1V_2}{C_1+C_2}$
c. $\frac{C_1V_1+C_2V_2}{C_1+C_2}$ **d.** $\frac{C_2V_1-C_1V_2}{C_1+C_2}$

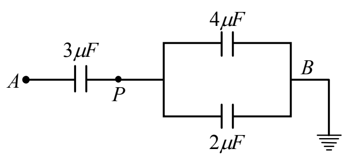
37. Two identical capacitors, have the same capacitance C. One of them is charged to potential V_1 and the other to V_2. The negative ends of the capacitors are connected together. When the positive ends are also connected, the decrease in energy of the combined system is

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.** $\frac{1}{4}C(V_1+V_2)^2$

38. Two capacitors of capacitance $2\mu F$ and $3\mu F$ are joined in series. Outer plate first capacitor is at 1000 *volt* and outer plate of second capacitor is earthed (grounded). Now the potential on inner plate of each capacitor will be

a. 700 *Volt* **b.** 200 *Volt*
c. 600 *Volt* **d.** 400 *Volt*

39. In the figure a potential of + 1200 V is given to point A and point B is earthed, what is the potential at the point P



a. 100 V **b.** 200 V **c.** 400 V **d.** 600 V

40. Two identical capacitors are joined in parallel, charged to a potential V and then separated and then connected in series $i.e.$ the positive plate of one is connected to negative of the other

a. The charges on the free plates connected together are destroyed

b. The charges on the free plates are enhanced

c. The energy stored in the system increases

d. The potential difference in the free plates becomes $2V$

41. The capacitor of capacitance $4\mu F$ and $6\mu F$ are connected in series. A potential difference of $500\,volts$ applied to the outer plates of the two capacitor system. Then the charge on each capacitor is numerically

a. 6000 C **b.** 1200 C

c. 1200 μC **d.** 6000 μC

42. Three capacitors of capacitances $3\mu F, 9\mu F$ and $18\mu F$ are connected once in series and another time in parallel. The ratio of equivalent capacitance in the two cases $\left(\frac{C_s}{C_p}\right)$ will be

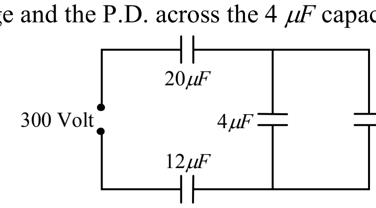
a. 1 : 15 **b.** 15 : 1

c. 1 : 1 **d.** 1 : 3

43. Two condensers of capacity 0.3 μF and 0.6 μF respectively are connected in series. The combination is connected across a potential of 6 volts. The ratio of energies stored by the condensers will be

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

44. In the adjoining figure, four capacitors are shown with their respective capacities and the P.D. applied. The charge and the P.D. across the 4 μF capacitor will be



a. $600\mu C$; 150 $volts$ **b.** $300\mu C$; 75 $volts$

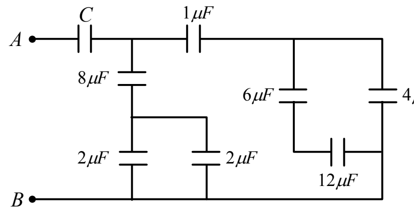
c. $800\mu C$; 200 $volts$ **d.** $580\mu C$; 145 $volts$

45. A $4\mu F$ condenser is connected in parallel to another condenser of $8\mu F$ Both the condensers are then connected in series with a 12 μF condenser and charged to 20 volts. The charge on the plate of $4\mu F$ condenser is

a. 3.3 μC **b.** 40 μC

c. 80 μC **d.** 240 μC

46. In the following circuit, the resultant capacitance between A and B is 1 μF. Then value of C is



a. $\frac{32}{11}\mu F$ **b.** $\frac{11}{32}\mu F$

c. $\frac{23}{32}\mu F$ **d.** $\frac{32}{23}\mu F$

Variation of Different Variables (Q, C, V, E and U) of Parallel Plate Capacitor

47. The mean electric energy density between the plates of a charged capacitor is (here Q = Charge on the capacitor and A = Area of the capacitor plate)

a. $\frac{Q^2}{2\varepsilon_0 A^2}$ **b.** $\frac{Q}{2\varepsilon_0 A^2}$

c. $\frac{Q^2}{2\varepsilon_0 A}$ **d.** None of these

48. Plate separation of a $15\mu F$ capacitor is 2 mm. A dielectric slab (K = 2) of thickness 1 mm is inserted between the plates. Then new capacitance is given by

a. $15\,\mu F$ **b.** $20\,\mu F$

c. $30\,\mu F$ **d.** $25\,\mu F$

49. The force between the plates of a parallel plate capacitor of capacitance C and distance of separation of the plates d with a potential difference V between the plates, is

a. $\frac{CV^2}{2d}$ **b.** $\frac{C^2V^2}{2d^2}$

c. $\frac{C^2V^2}{d^2}$ **d.** $\frac{V^2d}{C}$

50. If a slab of insulating material $4\times10^{-5}\,m$ thick is introduced between the plate of a parallel plate capacitor, the distance between the plates has to be increased by $3.5\times10^{-5}\,m$ to restore the capacity to original value. Then the dielectric constant of the material of slab is

a. 10 **b.** 12

c. 6 **d.** 8

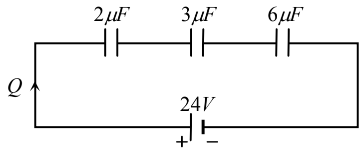
51. A capacitor when filled with a dielectric $K=3$ has charge Q_0, voltage V_0 and field E_0. If the dielectric is replaced with another one having $K = 9$, the new values of charge, voltage and field will be respectively

a. $3Q_0, 3V_0, 3E_0$ **b.** $Q_0, 3V_0, 3E_0$

c. $Q_0, \frac{V_0}{3}, 3E_0$ **d.** $Q_0, \frac{V_0}{3}, \frac{E_0}{3}$

Circuit with Resistors and Capacitors

52. Three capacitors of $2\mu f$, $3\mu f$ and $6\mu f$ are joined in series and the combination is charged by means of a 24 *volt* battery. The potential difference between the plates of the $6\mu f$ capacitor is



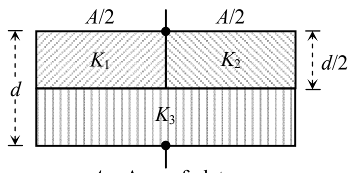
a. 4 *volts* **b.** 6 *volts*

c. 8 *volts* **d.** 10 *volts*

53. Two capacitors each of $1\mu f$ capacitance are connected in parallel and are then charged by $200V$ D.C. supply. The total energy of their charges in joules is

a. 0.01 **b.** 0.02 **c.** 0.04 **d.** 0.06

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

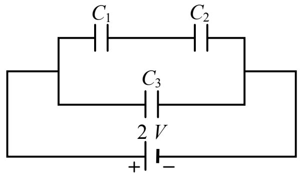


A = Area of plates

a. $\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{2K_3}$ **b.** $\frac{1}{K} = \frac{1}{K_1 + K_2} + \frac{1}{2K_3}$

c. $K = \frac{K_1 K_2}{K_1 + K_2} + 2K_3$ **d.** $K = K_1 + K_2 + 2K_3$

55. Two capacitors $C_1 = 2\mu F$ and $C_2 = 6\mu F$ in series, are connected in parallel to a third capacitor $C_3 = 4\mu F$. This arrangement is then connected to a battery of e.m.f. = 2 V, as shown in the fig.



How much energy is lost by the battery in charging the capacitors?

a. $22 \times 10^{-6} J$ **b.** $11 \times 10^{-6} J$

c. $\left(\frac{32}{3}\right) \times 10^{-6} J$ **d.** $\left(\frac{16}{3}\right) \times 10^{-6} J$

NCERT EXEMPLAR PROBLEMS

More than One Answer

56. A parallel plate capacitor is charged and the charging battery is then disconnected. If the plates of the capacitor are moved further apart by means of insulating handles:

a. the charge on the capacitor increases
b. the voltage across the plates increases
c. the capacitance increases.
d. the electrostatic energy stored in the capacitor increases

57. The plates of a parallel plate capacitor are not exactly parallel. The surface charge density therefore:

a. higher at the closer end
b. the surface charge density will not be uniform
c. Each plate will have the same potential at each point
d. the electric field is smallest where the plates are closest

58. A parallel plate capacitor is first connected to a D.C. source. It is then disconnected and then immersed in a liquid dielectric then:

a. the capacity increases
b. the liquid level between the plates increases
c. the liquid level will remain same as that outside the plates
d. the potential on the places will decrease

59. A parallel plate condenser of plate area A and separation d is charged to a potential V and then the battery is removed. Now a slab of dielectric constant K is introduced 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 introduction of dielectric slab) and work done on the system in the process of introducing the slab, then:

a. $Q = \frac{\varepsilon_0 AV}{d}$ **b.** $Q = \frac{\varepsilon_0 KAV}{d}$

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

60. A parallel plate capacitor has a parallel sheet of copper inserted between and parallel to the two plates, without touching the plates. The capacity of the capacitor after the introduction of the copper sheet is:

a. minimum when the copper sheet touches one of the plates
b. maximum when the copper sheet is midway between the two plates
c. invariant for all positions of the sheet between the two plates
d. greater than that before introducing the sheet

61. When a parallel plate capacitor is connected to a source of constant potential difference:
a. all the charge drawn from the source is stored in the capacitor
b. all the energy drawn from the source is stored in the capacitor
c. the potential difference across the capacitor grows very rapidly initially and this rate decreases to zero eventually
d. only half of the energy drawn from source is dissipated outside the capacitor

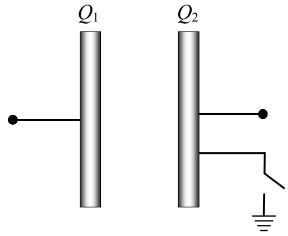
62. When two identical capacitors are charged individually to different potentials and then connected in parallel, after disconnecting from the source:
a. net charge < sum of initial charges
b. net charge = sum of initial charges
c. net potential difference across them ≠ sum of individual initial potential differences
d. net energy stored in the two capacitors < sum of individual initial energies

63. Two parallel plate air capacitors are constructed, one by a pair of iron plates and the second by a pair of copper plates, of same area and same spacing's. Then:
a. the copper plate capacitor has a greater capacitance than the iron one
b. both capacitors have equal non zero capacitances, in the uncharged state
c. both capacitors will have equal capacitances only if they are charged equally
d. the capacitances of the two capacitors are equal even if they are unequally charged

64. The plates of a parallel plate capacitor are charged with surface densities σ_1 and σ_2 respectively. The electric field at points ($\sigma_1 = +\sigma$, $\sigma_2 = -\sigma$)
a. inside the region between the plates will be zero
b. above the upper plate and below the lower plate will be zero
c. everywhere in space will be zero
d. inside the region between the plates will be uniform and non zero

65. The force with which the plates of a parallel plate capacitor, having charge Q and area of each plate A, attract each other, is:
a. directly proportional to Q **b.** directly proportional Q^2
c. inversely proportional to A **d.** directly proportional A

66. Charges Q_1 and Q_2 are given to two plates of a parallel plate capacitor. The capacity of the capacitor is C. When the switch is closed, mark the correct statement(s). Assume both Q_1 and Q_2 to be positive.)

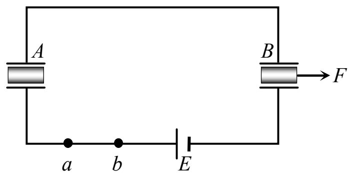


a. the charge flowing through the switch is zero
b. the charge flowing through the switch is $Q_1 + Q_2$
c. Potential difference across the capacitor plate is Q_1 / C
d. The charge of the capacitor is Q_1

67. A parallel plate air capacitor has initial capacitance C. If plate separation is slowly increased form d1 to d2, then mark the correct statement(s). (Take potential of the capacitor to be constant, i.e., throughout the process it remains connected to battery.)
a. Work done by electric force = negative of work done by external agent.
b. Work done by external force $= -\int \vec{F} \cdot \vec{dx}$, where $\vec{F}$ is the electric force of attraction between the plates at plat separation x.
c. Work done by electric force ≠ negative of work done by external agent.
d. Work done by battery = two times the change in electric potential energy stored in capacitor.

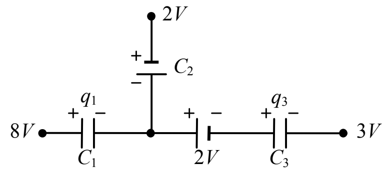
68. A capacitor of 5 μF is charged to a potential of 100 V. Now this charged capacitor is connected to a battery of 100 V with the positive terminal of the battery connected to the negative plate of the capacitor. For the given situation, mark the correct statements(s)
a. The charge flowing through the 100 V battery is 500μC
b. The charge flowing through the 100V battery is 100μC.
c. Heat dissipated in the circuit is 0.1 J.
d. Work done on the battery is 0.1 J.

69. Two identical capacitors with identical dielectric slabs in between them are connected in series as shown in fig. Now, the slab of one capacitor is pulled out slowly with the help of an external force F at steady state as shown. Mark the correct statement(s).



a. During the process, charge (positive) flows from b to a.
b. During the process, the charge of capacitor B is equal to the charge on A at all instants.
c. Work done by F is positive.
d. During the process, the battery has been charged.

70. In figure shows a part of a circuit. If all the capacitors have a capacitance of $2\mu F$, then the



a. charge on C_3 is zero **b.** charge on C_3 is 12 μF
c. charge on C_1 is 6 μF **d.** charge on C_2 is 6 μF

71. Two capacitors C_1 and C_2 are charged to $120V$ and 200 V respectively. It is found that by connecting them together the potential on each one can be made zero. Then
a. $5C_1 = 3C_2$ **b.** $3C_1 = 5C_2$
c. $3C_1 + 5C_2 = 0$ **d.** $9C_1 = 4C_2$

Assertion and Reason

Note: Read the Assertion (A) and Reason (R) carefully to mark the correct option out of the options given below:

a. If both assertion and reason are true and the reason is the correct explanation of the assertion.
b. If both assertion and reason are true but reason is not the correct explanation of the assertion.
c. If assertion is true but reason is false.
d. If the assertion and reason both are false.
e. If assertion is false but reason is true.

72. **Assertion:** If the distance between parallel plates of a capacitor is halved and dielectric constant is made three times, then the capacitor becomes 6 times.
Reason: Capacity of the capacitor does not depend upon the nature of the material.

73. **Assertion:** A parallel plate capacitor is connected across battery through a key. A dielectric slab of constant K is introduced between the plates. The energy which is stored becomes K times.
Reason: The surface density of charge on the plate remains constant or unchanged.

74. **Assertion:** The capacity of a given conductor remains same even if charge is varied on it.
Reason: Capacitance depends upon nearly medium as well as size and shape of conductor.

75. **Assertion:** A charged capacitor is disconnected from a battery. Now if its plate is separated farther, the potential energy will fall.
Reason: Energy stored in a capacitor is equal to the work done in charging it.

76. **Assertion:** The force with which one plate of a parallel plate capacitor is attracted towards the other plate is equal to square of surface density per ε per unit area.
Reason: The electric field due to one charged plate of the capacitor at the location of the other is equal to surface density per ε.

77. **Assertion:** Circuit containing capacitors should be handled cautiously even when there is no current.
Reason: The capacitors are very delicate and so quickly break down.

78. **Assertion:** If three capacitors of capacitance $C_1 < C_2 < C_3$ are connected in parallel then their equivalent capacitance $C_p > C_s$.
Reason: $\frac{1}{C_p} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

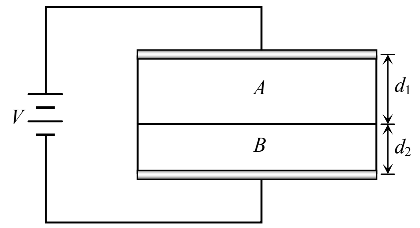
79. **Assertion:** The tyres of aircraft's are slightly conducting.
Reason: If a conductor is connected to ground, the extra charge induced on conductor will flow to ground.

80. **Assertion:** A bird perches on a high power line and nothing happens to the bird.
Reason: The level of bird is very high from the ground.

Comprehension Based

Paragraph –I

A parallel plate capacitor is filled with two layers of different materials A and B as shown in the figure. The material A has dielectric constant ε_1 and conductivity σ_1 and the material B has dielectric constant ε_2 and conductivity σ_2 respectively. The capacitor is connected across a battery of terminal voltage V.



81. Electric fields in material A is:

a. $\frac{V\sigma_1}{d_1\sigma_1+d_2\sigma_2}$ **b.** $\frac{V\sigma_2}{d_1\sigma_1+d_2\sigma_2}$

c. $\frac{V\sigma_1}{d_1\sigma_2+d_2\sigma_1}$ **d.** $\frac{V\sigma_2}{d_1\sigma_2+d_2\sigma_1}$

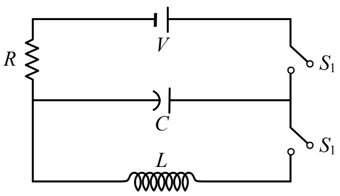
82. What is the total surface charge density on the interface of the two medium?

a. $\frac{\varepsilon_0 V(\varepsilon_1-\varepsilon_2)}{d_1\varepsilon_2+d_2\varepsilon_1}$ **b.** $\frac{\varepsilon_0 V(\sigma_1-\sigma_2)}{d_1\sigma_2+d_2\sigma_1}$

c. $\frac{\varepsilon_0 V(\sigma_1\varepsilon_2-\sigma_2\varepsilon_1)}{d_1\sigma_2+d_2\sigma_1}$ **d** $\frac{V}{\varepsilon_0 d_1 d_2}\left[\frac{d_1}{d_1+d_2}-\frac{d_2}{d_1+d_2}\right]$

Paragraph -II

The capacitor of capacitance C can be charged (with the help of a resistance R) by a voltage source V, by closing switch S_1 while keeping switch S_2 open. The capacitor can be connected in series with an inductor 'L' by closing switch S_2 and opening S_1



83. Initially, the capacitor was uncharged. Now, switch S_1 is closed and S_2 is kept open. If time constant of this circuit is τ, then:

a. after time interval τ, charge on the capacitor is $CV/2$

b. after time interval 2τ, charge on the capacitor is $CV(1-e^{-2})$

c. the work done by the voltage source will be half of the heat dissipated when the capacitor is fully charged

d. after time interval 2τ, charge on the capacitor is $CV(1-e^{-1})$

84. After the capacitor gets fully charged, S_1 is opened and S_2 is closed so that the inductor is connected in series with the capacitor. Then:

a. at $t=0$, energy stored in the circuit is purely in the form of magnetic energy

b. at any time $t>0$, current in the circuit is in the same direction

c. at $t>0$, there is no exchange of energy between the inductor and capacitor

d. at any time $t>0$, instantaneous current in the circuit may $V\sqrt{\frac{C}{L}}$

85. If the total charge stored in the LC circuit is Q_0, then for $t\geq 0$

a. the charge on the capacitor is $Q=Q_0\cos\left(\frac{\pi}{2}+\frac{t}{\sqrt{LC}}\right)$

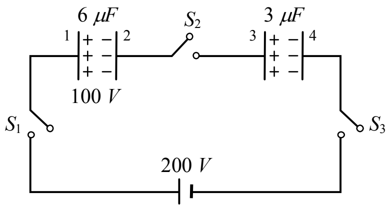
b. the charge on the capacitor is $Q=Q_0\cos\left(\frac{\pi}{2}-\frac{t}{\sqrt{LC}}\right)$

c. the charge on the capacitor is $Q=-LC\frac{d^2Q}{dt^2}$

d. the charge on the capacitor is $Q=-\frac{1}{\sqrt{LC}}\frac{d^2Q}{dt^2}$

Paragraph -III

Two capacitor of capacity $6\mu F$ and $3\mu F$ are charged to 100 V and 50 V separately and connected as shown in figure 4.201. Now all the three switches S_1, S_2 and S_3 are closed.



86. 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

87. Charge on the $6\mu F$ capacitor in steady state will be

a. 400 μC **b.** 700 μC

c. 800 μC **d.** 250 μC

88. Suppose q_1, and q_2 and q_3 be the magnitudes of charges flowing form switches 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.** $q_1=q_2=q_3$

Match the Column

89. Match the statement of Column with those in Column II:

Column I	Column II
(A) The energy of a charged capacitor is given by the expression (q = charge on the conductor and C = its capacity)	**1.** $\frac{q^2}{2C}$
(B) In a charged capacitor, the energy resides	**2.** The field between the plates

(C) The energy stored in a condenser of capacity C which has been raised to a potential V is given by	**3.** $\frac{1}{2}CV^2$
(D) The energy of a charged capacitor resides in	**4.** The electric field only

a. A→1, B→2, C→3, D→4
b. A→2, B→3, C→4, D→1
c. A→4, B→2, C→3, D→1
d. A→3, B→1, C→4, D→2

90. Match the statement of Column with those in Column II:

Column I	Column II
(A) The potential gradient at which the dielectric of a condenser just gets punctured is called	**1.** Dielectric strength
(B) The capacity of parallel plate condenser depends on	**2.** The separation between the plates
(C) When air in a capacitor is replaced by a medium of dielectric constant K, the capacity	**3.** Increases K times
(D) Can a metal be used as a medium for dielectric	**4.** No

a. A→1, B→2, C→3, D→4
b. A→2, B→3, C→4, D→1
c. A→4, B→2, C→3, D→1
d. A→3, B→1, C→4, D→2

91. Match the statements in Column I with the statements in Column II.

Column I	Column II
(A) A charged capacitor is connected to the ends of the wire	**1.** A constant current flows through the wire
(B) Thewire is moved perpendicular to its length with a constant velocity in a uniform magnetic field perpendicular to the plane of motion	**2.** Thermal energy is generated in the wire
(C) The wire is placed in a constant electric field that has a direction along the length of the wire.	**3.** A constant potential difference develops between the ends of the wire
(D) A battery of constant emf is connected to the ends of the wire	**4.**Charges of constant magnitude appear at the ends of the wire

a. A→ 2; B→ 3,4; C→ 3, 4; D→ 1, 2, 3
b. A→ 1; B→ 2,3; C→ 1, 2; D→ 2, 3, 4
c. A→ 3; B→ 1,2; C→ 2, 4; D→ 1, 3, 4
d. A→ 4; B→ 3,4; C→ 1, 3; D→ 2, 3, 4

Integer

92. Two Leyden jars are exactly similar in size and shape but one has glass dielectric and other ebonite. The Leyden jar with glass dielectric is charged, but when the charge is shared between the two Leyden jars, the potential drops to 0.6 of its original value. If Specific Inductive Capacity (SIC) of ebonite is 2, that of glass is:

93. Two capacitors $2\mu F$ and $4\mu F$ are connected in parallel. A third capacitor of $6\mu F$ capacity is connected in series. The combination is connected across a 12 V battery. The voltage across $2\mu F$ capacity is:

94. Three capacitors of $2\mu F$, $3\mu F$ and $6\mu F$ are joined in series and the combination is charged by means of a 24 volt battery. The potential difference between the plates of the $6\mu F$ capacitor is

95. The capacitance of an air filled parallel plate capacitor is $10\mu F$. The separation between the plates is doubled and the space between the plates is then filled with wax giving the capacitance a new value of 40×10^{-12} *farads*. The dielectric constant of wax is

96. A condenser of capacitance $10\mu F$ has been charged to $100\,volts$. It is now connected to another uncharged condenser in parallel. The common potential becomes 40 volts. The capacitance of another condenser is

97. An air filled parallel plate capacitor has capacity C. If distance between plates is doubled and it is immersed in a liquid then capacity becomes twice. Dielectric constant of the liquid is

98. Capacitance of a parallel plate capacitor becomes 4/3 times its original value if a dielectric slab of thickness $t = d/2$ is inserted between the plates (d is the separation between the plates). The dielectric constant of the slab is

99. A parallel plate condenser is connected with the terminals of a battery. The distance between the plates is $6mm$. If a glass plate (dielectric constant K = 9) of 4.5 mm is introduced between them, then the capacity will become:

100. A spherical drop of capacitance 12 μF is broken into eight drops of equal radius. What is the capacitance of each small drop in μF?

ANSWER

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

SOLUTION

Multiple Choice Questions

1. **(d)** By using relation $C = n^{1/3} \cdot c$

$\Rightarrow$ $C = (8)^{1/3} \cdot c = 2c$

2. **(d)** Total charge $Q = 80 + 40 = 120\mu C$.

By using the formula $Q_1' = Q\left[\dfrac{r_1}{r_1 + r_2}\right]$

New charge on sphere A is $Q_A' = Q\left[\dfrac{r_A}{r_A + r_B}\right]$

$= 120\left[\dfrac{4}{4+6}\right] = 48\,\mu C$

Initially it was 80 μC, *i.e.,* $32\mu C$ charge flows from A to B.

3. **(c)** By using $\Delta U = \dfrac{C_1C_2}{2(C_1+C_2)}(V_1 - V_2)^2$; $\Delta U = 0.375\,J$

4. **(d)** $\dfrac{\sigma_{Small}}{\sigma_{Big}} = \dfrac{q/4\pi r^2}{Q/4\pi R^2} = \left(\dfrac{q}{Q}\right)\left(\dfrac{R}{r}\right)^2$

Since $R = n^{1/3}r$ and $Q = nq$

So, $\dfrac{\sigma_{Small}}{\sigma_{Big}} = \dfrac{1}{n^{1/3}} \Rightarrow \dfrac{\sigma_{Small}}{\sigma_{Big}} = \dfrac{1}{4}$

5. **(c)** By placing the smaller sphere inside the bigger one. The potential of the smaller one will now be 150 V.

So, on connecting it with the bigger one charge will flow from the smaller one to the bigger one.

6. **(a)** $U = \dfrac{1}{2}CV^2$

$= \dfrac{1}{2} \times 50 \times 10^{-6} \times (10)^2 = 2.5 \times 10^{-3}\,J$

7. **(a)** $C = 4\pi\varepsilon_0 K\left[\dfrac{ab}{b-a}\right]$

$= \dfrac{1}{9\times10^9} \cdot 6\left[\dfrac{12\times9\times10^{-4}}{3\times10^{-2}}\right] = 24\times10^{-11} = 240\,pF$

8. **(a)** Forcapacitor $\dfrac{V_1}{V_2} = \dfrac{d_1}{d_2}$

$\Rightarrow$ $V_2 = \dfrac{V_1 \times d_2}{d_1} = \dfrac{60\times12}{4} = 180V$

9. **(b)** $C = \dfrac{\varepsilon_0 A}{d} = 1pF$ and $C' = \dfrac{K\varepsilon_0 A}{2d} = 2pF$

$\therefore$ $K = 4$.

10. **(b)** $\Delta E = E_{Final} - E_{Initial} = \dfrac{1}{2}C(V_{Final}^2 - V_{Initial}^2)$

$= \dfrac{1}{2} \times 6 \times (20^2 - 10^2) \times 10^{-6}$

$= 3 \times (400 - 100) \times 10^{-6}$

$= 3 \times 300 \times 10^{-6} = 9 \times 10^{-4}\,J$

11. **(a)** In air the potential difference between the plates

$V_{air} = \dfrac{\sigma}{\varepsilon_0} \cdot d$ . . .(*i*)

In the presence of partially filled medium potential difference between the plates

$V_m = \dfrac{\sigma}{\varepsilon_0}\left(d - t + \dfrac{t}{K}\right)$ . . .(*ii*)

Potential difference between the plates with dielectric medium and increased distance is

$V_m' = \dfrac{\sigma}{\varepsilon_0}\left\{(d + d') - t + \dfrac{t}{K}\right\}$ . . .(*iii*)

According to question $V_{air} = V_m'$ which gives $K = \dfrac{t}{t - d'}$

Hence $K = \dfrac{2}{2 - 1.6} = 5$

12. **(c)** New potential difference $= \dfrac{V}{K} = \dfrac{100}{10} = 10V$

13. **(a)** $4\pi\varepsilon_0 r = 1\times10^{-6}$

$\Rightarrow$ $r = 10^{-6} \times 9 \times 10^9 = 9\,km$

14. **(c)** Battery in disconnected so Q will be constant as $C \propto K$.

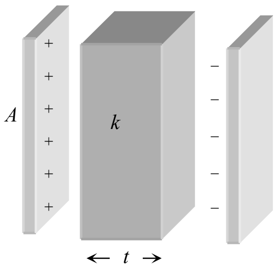
So, With introduction of dielectric slab capacitance will increase using $Q = CV$, V will decrease and using $U = \frac{Q^2}{2C}$, energy will decrease.

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

16. **(c)** Potential difference between the plates $V = V_{air} + V_{medium}$

$$= \frac{\sigma}{\varepsilon_0} \times (d - t) + \frac{\sigma}{K\varepsilon_0} \times t$$

$$\Rightarrow \quad V = \frac{\sigma}{\varepsilon_0}(d - t + \frac{t}{K}) = \frac{Q}{A\varepsilon_0}(d - t + \frac{t}{K})$$



Hence capacitance $C = \frac{Q}{V} = \frac{Q}{\frac{Q}{A\varepsilon_0}(d - t + \frac{t}{K})}$

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

17. **(a)** High K means good insulating property and high x means able to withstand electric field gradient to a higher value.

18. **(b)** $C = \frac{\varepsilon_0 AK}{d} = 4\pi\varepsilon_0 r$

r = Radius of sphere of equivalent capacity

$$\Rightarrow \quad r = \frac{AK}{4\pi d} = \frac{100 \times 10^{-4} \times 6}{1 \times 10^{-3} \times 4 \times 3.14} = \frac{15}{3.14} = 4.77\, m$$

19. **(d)** $C = \frac{A\varepsilon_0}{d} = 10 \mu F$

$$C_1 = \frac{A\varepsilon_0}{d - t + \frac{t}{k}} = \frac{A\varepsilon_0}{d - \frac{d}{2} + \frac{d}{2k}} = \frac{A\varepsilon_0}{\frac{d}{2}\left(1 + \frac{1}{2}\right)} = \frac{4}{3} \cdot \frac{A\varepsilon_0}{d}$$

$$\therefore \quad C_1 = \frac{4}{3} \times 10 = 13.33 \mu F$$

20. **(b)** Capacitor does not work in D.C. for D.C. it's effective resistance is infinite i.e. it blocks the current to flow in the circuit.

21. **(c)** Charge flowing $= \frac{C_1 C_2}{C_1 + C_2} V$

So, potential difference across $C_1 = \frac{C_1 C_2 V}{C_1 + C_2} \times \frac{1}{C_1} = \frac{C_2 V}{C_1 + C_2}$

22. **(a)** Current through the circuit can flow only for the small time of charging, once capacitor get's charged it blocks the current through the circuit and bulb will go off.

23. **(c)** $C = \frac{\varepsilon_0 A}{d} \propto \frac{1}{d}$

$$\therefore \quad \frac{C_1}{C_2} = \frac{d_2}{d_1} \text{ or } C_2 = \frac{d_1}{d_2} \times C_1 = \frac{8}{4} \times 10 = 20 \mu F$$

24. **(c)** $\frac{1}{C} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} \Rightarrow C = \frac{2}{3} F$

25. **(a)** By using the relation $C = \frac{\varepsilon_0 A}{d}$

$$\Rightarrow \quad A = \frac{Cd}{\varepsilon_0} = \frac{3 \times 5 \times 10^{-3}}{8.85 \times 10^{-12}} = 1.694 \times 10^9 m^2.$$

26. **(d)** In series combination of capacitor charge on each capacitor is same $Q_1 = Q_2 = Q = C_{eq} V$

$$\Rightarrow \quad C_{eq} V = \left(\frac{10 \times 20}{10 + 20}\right) \times 30 = \frac{200}{30} \times 30 = 200\, \mu C$$

27. **(d)** Initial energy $U_i = \frac{1}{2} C V_1^2$

Final energy $U_f = \frac{1}{2} C V_2^2$

Increase in energy $\Delta U = U_f - U_i = \frac{1}{2} C (V_2^2 - V_1^2)$

$$= \frac{1}{2} \times 6 \times 10^{-6} (20^2 - 10^2) = 9 \times 10^{-4} J.$$

28. **(b)** According to the question $\frac{\varepsilon_0 A}{d} = 4\pi\varepsilon_0 R$

$$\Rightarrow \quad d = \frac{A}{4\pi R} = \frac{\pi (2 \times 10^{-2})^2}{4\pi \times 10 \times 10^{-2}} = 1 \times 10^{-3}\, m.$$

29. **(c)** Capacitance when outer sphere is earthed

$C_1 = 4\pi\varepsilon_0 \cdot \frac{ab}{b - a}$ and capacitance when inner sphere is earthed $C_2 = 4\pi\varepsilon_0 \cdot \frac{b^2}{b - a}$

Hence $C_2 - C_1 = 4\pi\varepsilon_0 \cdot b$

30. **(d)** This is the discharging condition of capacitor and in this condition energy released $U=\frac{1}{2}CV^2$

$=\frac{1}{2}\times 4\times 10^{-6}\times (400)^2=0.32J$

$=0.32\,J.$

31. **(d)** As we know that work done

$=U_{final}-U_{initial}=\frac{1}{2}C(V_2^2-V_1^2)$

When potential difference increases from $5V$ to $10V$ then

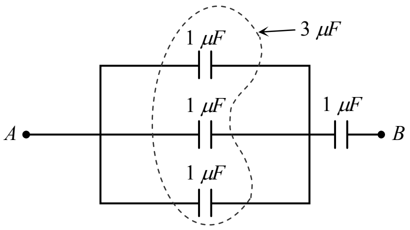
$W=\frac{1}{2}C(10^2-5^2)$ . . . (i)

When potential difference increases from $10V$ to $15V$ then

$W'=\frac{1}{2}C(15^2-10^2)$ . . . (ii)

On solving equation (i) and (ii) we get $W'=1.67\,W$.

32. **(d)** The circuit can be drawn as follows



$\Rightarrow$ $C_{AB}=\frac{3\times 1}{3+1}=\frac{3}{4}\mu F$

33. **(a)** The total energy before connection

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

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

When connected in parallel $4\times 50+2\times 100=6\times V$

$\Rightarrow$ $V=\frac{200}{3}$

Total energy after connection

$=\frac{1}{2}\times 6\times 10^{-6}\times\left(\frac{200}{3}\right)^2=1.33\times 10^{-2}J$

34. **(b)** $\frac{1}{C}=\frac{1}{3}+\frac{1}{6}$

$\Rightarrow$ $C=2\,pF$

Total charge $=2\times 10^{-12}\times 5000=10^{-8}\,C$

The new potential when the capacitors are connected in parallel is $V=\frac{2\times 10^{-8}}{(3+6)\times 10^{-12}}=2222V$

35. **(a)** Loss of energy during sharing $=\frac{C_1C_2(V_1-V_2)^2}{2(C_1+C_2)}$

In the equation, put $V_2=0, V_1=V_0$

$\therefore$ Loss of energy $=\frac{C_1C_2V_0^2}{2(C_1+C_2)}=\frac{C_2U_0}{C_1+C_2}\left[\because U_0=\frac{1}{2}C_1V_0^2\right]$

36. **(c)** Charge on $C_1=$ charge on C_2

$\Rightarrow$ $C_1(V_A-V_D)=C_2(V_D-V_B)\Rightarrow\ C_1(V_1-V_D)=C_2(V_D-V_2)$

$\Rightarrow$ $V_D=\frac{C_1V_1+C_2V_2}{C_1+C_2}$

37. **(c)** Initial energy of the system $U_i=\frac{1}{2}CV_1^2+\frac{1}{2}CV_2^2$

When the capacitors are joined, common potential

$V=\frac{CV_1+CV_2}{2C}=\frac{V_1+V_2}{2}$

Final energy of the system $U_f=\frac{1}{2}(2C)V^2$

$=\frac{1}{2}2C\left(\frac{V_1+V_2}{2}\right)^2=\frac{1}{4}C(V_1+V_2)^2$

Decrease in energy $=U_i-U_f=\frac{1}{4}C(V_1-V_2)^2$

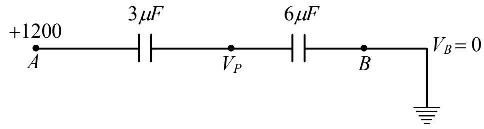
38. **(d)** Equivalent capacitance $=\frac{2\times 3}{2+3}=\frac{6}{5}\mu F$

Total charge by $Q=CV=\frac{6}{5}\times 1000=1200\mu C$

Potential (V) across $2\mu F$ is $V=\frac{Q}{C}=\frac{1200}{2}=600\,volt$

$\therefore$ Potential on internal plates $=1000-600=400V$

39. **(c)** Given circuit can be reduced as follows



In series combination charge on each capacitor remain same. So using $Q=CV$

$\Rightarrow$ $C_1V_1=C_2V_2\Rightarrow 3(1200-V_p)=6(V_P-V_B)$

$\Rightarrow$ $1200-V_p=2V_p\quad(\because V_B=0)$

$\Rightarrow$ $3V_p=1200\ \Rightarrow V_p=400\,volt$

40. **(d)** $Q_1=CV$ and $Q_2=CV$

Applying charge conservation $CV_1+CV_2=Q_1+Q_2$

$CV_1+CV_2=2CV$

$\Rightarrow$ $V_1+V_2=2V$

41. **(c)** $C_{eq} = \dfrac{C_1C_2}{C_1+C_2} = 2.4\mu F$

Charge flown $= 2.4\times100\times10^{-6}C = 1200\mu C$

42. **(a)** $\dfrac{1}{C_s} = \dfrac{1}{3}+\dfrac{1}{9}+\dfrac{1}{18} = \dfrac{1}{2} \Rightarrow C_s = 2\mu F$

$\Rightarrow \quad C_p = 3+9+18 = 30\,\mu F \Rightarrow \dfrac{C_s}{C_p} = \dfrac{2}{30} = \dfrac{1}{15}$

43. **(b)** In series combination Q is constant, hence according to $U = \dfrac{Q^2}{2C}$

$\Rightarrow \quad U \propto \dfrac{1}{C} \Rightarrow \dfrac{U_1}{U_2} = \dfrac{C_2}{C_1} = \dfrac{0.6}{0.3} = \dfrac{2}{1}$

44. **(d)** Total capacitance $\dfrac{1}{C} = \dfrac{1}{20}+\dfrac{1}{8}+\dfrac{1}{12} \Rightarrow C = \dfrac{120}{31}\mu F$

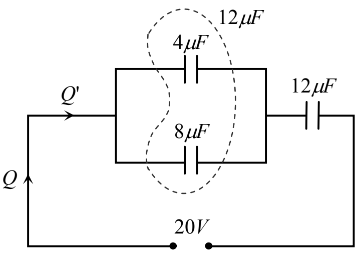
Total charge $Q = CV = \dfrac{120}{31}\times300 = 1161\mu C$

Charge, through 4 μF condenser $= \dfrac{1161}{2} = 580\mu C$ and

potential difference across it $= \dfrac{580}{4} = 145V$

45. **(b)** Equivalent capacitance of the circuit $C_{eq} = 6\mu F$

Charge supplied from source $Q = 6\times20 = 120\ \mu C$



Hence charge on the plates of 4 μF capacitor

$= Q' = \dfrac{4}{(4+8)}\times120 = 40\mu C$

46. **(d)** 12 μF and 6μF are in series and again are in parallel with 4μF.

Therefore, resultant of these three will be

$= \dfrac{12\times6}{12+6}+4 = 4+4 = 8\mu F$

This equivalent system is in series with 1 μF.

Its equivalent capacitance $= \dfrac{8\times1}{8+1} = \dfrac{8}{9}\mu F \qquad \ldots(i)$

Equivalent of 8μF, 2μF and 2μF

$= \dfrac{4\times8}{4+8} = \dfrac{32}{12} = \dfrac{8}{3}\mu F \qquad \ldots(ii)$

(i) and (ii) are in parallel and are in series with C

$\therefore \quad \dfrac{8}{9}+\dfrac{8}{3} = \dfrac{32}{9}$ and $C_{eq} = 1 = \dfrac{\frac{32}{9}\times C}{\frac{32}{9}+C}$

$\Rightarrow \quad C = \dfrac{32}{23}\mu F$

47. **(a)** Energy density $= \dfrac{1}{2}\varepsilon_0E^2 = \dfrac{1}{2}\varepsilon_0\left(\dfrac{Q}{A\varepsilon_0}\right)^2 = \dfrac{Q^2}{2\varepsilon_0A^2}$.

48. **(b)** Given $C = \dfrac{\varepsilon_0A}{d} = 15\mu F \qquad \ldots(i)$

Then by using $C' = \dfrac{\varepsilon_0A}{d-t+\dfrac{t}{K}} = \dfrac{\varepsilon_0A}{2\times10^{-3}-10^{-3}+\dfrac{10^{-3}}{2}}$

$= \dfrac{2}{3}\times\varepsilon_0A\times10^3$

From equation (i) $C' = 20\mu F$.

49. **(a)** Since $F = \dfrac{Q^2}{2\varepsilon_0A}$

$\Rightarrow \quad F = \dfrac{C^2V^2}{2\varepsilon_0A} = \dfrac{CV^2}{2d}$.

50. **(d)** By using $K = \dfrac{t}{t-d'}$

Here $t = 4\times10^{-5}\,m$; $d' = 3.5\times10^{-5}\,m$

$\Rightarrow \quad K = \dfrac{4\times10^{-5}}{4\times10^{-5}-3.5\times10^{-5}} = 8$

51. **(d)** Suppose, charge, potential difference and electric field for capacitor without dielectric medium are Q, V and E respectively

With dielectric medium of $K = 3$;

With dielectric medium of $K = 9$

Charge $Q_0 = Q$

Charge $Q' = Q = Q_0$

Potential difference $V_0 = \dfrac{V}{3}$

Potential difference $V' = \dfrac{V}{9} = \dfrac{V_0}{3}$

Electric field $E_0 = \dfrac{E}{3}$

Electric field $E' = \dfrac{E}{9} = \dfrac{E_0}{3}$.

52. **(a)** Equivalent capacitance of the network is

$$\frac{1}{C_{eq}} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6};\ C_{eq} = 1\mu F$$

Charge supplied by battery $Q = C_{eq}.V$

$\Rightarrow$ $1 \times 24 = 24\ \mu C$

Hence potential difference across $6\mu F$ capacitor

$$= \frac{24}{6} = 4\ volt.$$

53. **(c)** By using formula $U = \frac{1}{2}C_{eq}V^2$

Here $C_{eq} = 2\mu F$

$\therefore$ $U = \frac{1}{2} \times 2 \times 10^{-6} \times (200)^2 = 0.04\ J$

54. **(b)** The effective capacitance is given by

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

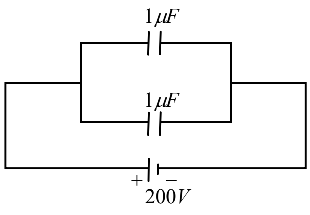
The capacitance of capacitor with single dielectric of dielectric constant K is $C = \frac{K\varepsilon_0 A}{d}$

According to question $C_{eq} = C$ *i.e.*,

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

$\Rightarrow$ $\frac{1}{K} = \frac{1}{2K_3} + \frac{1}{K_1 + K_2}.$

55. **(b)** Equivalent capacitance



$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} + C_3 = \frac{2 \times 6}{8} + 4 = 5.5\mu F$$

$\therefore$ $U = \frac{1}{2}C_{eq}.V^2 = \frac{1}{2} \times 5.5 \times (2)^2 = 11 \times 10^{-6} J$

NCERT Exemplar Problems

More than One Answer

56. **(b, d)** As battery is disconnected, hence Q = Constt, plates of capacitor are moved apart, hence $C \to$ decreases $\left(C \propto \frac{1}{d}\right)$. Now $V = \frac{Q}{C}$ and $U = \frac{Q^2}{2C}$

57. **(a, b, c)** Being a conductor, each plate has the same potential at each point. But because $E = -\left(\frac{\Delta V}{\Delta x}\right)$

Hence E is highest where the plates are closest to each other. Hence surface charge density is also higher at the closer end.

58. **(a, b, d)** As the capacitor is immersed in a liquid, its capacity increases, thus lowering the energy $= \frac{Q^2}{2C}$

As the energy is lowered, the liquid level between the plates rises, thus compensating loss in E.P.E., by increase in gravitational P.E. As Q = constant and C is increased, hence potential on the plates is decreased.

59. **(a, c, d)** $C_0 = \frac{\varepsilon_0 A}{d}$, $Q = C_0 V = \frac{\varepsilon_0 AV}{d}$, $E_0 = \frac{V}{d}$,

$$E = \frac{E_0}{K} = \frac{V}{kd},\ U_1 = \frac{1}{2}C_0 V^2$$

$$U_2 = \left(\tfrac{1}{2}\right)CV^2{}_{\text{slab}} = \left(\tfrac{1}{2}\right)(KC_0)(V/K)^2 = \left(\tfrac{1}{2}\right)C_0 V^2/K$$

$$W = \Delta U = U_1 - U_2 = \left(\tfrac{1}{2}\right)C_0 V^2(1 - 1/K)$$

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

60. **(c, d)** $C_{\text{pm}} = \frac{\varepsilon_0 A}{d - t}$, $C_0 = \frac{\varepsilon_0 A}{d}$, $C_{\text{pm}} > C_0$

61. **(a, c, d)** Initially when potential difference is high, hence rate of flow of charge is high. But when potential difference across capacitor reaches the applied potential difference, this rate tends towards zero. Energy drawn from source $= QV$ but Energy stored in capacitor $= \left(\frac{1}{2}\right)QV$.

62. **(b, c, d)** As source is disconnected hence $Q = q_1 + q_2$; after disconnecting from the source they are connected in paralled hence net p.d. $\neq V_1 + V_2$; when charged capacitor at different potentials are connected together, there always occurs a loss of energy in the form of heat energy.

63. **(b,d)** Capacity of a capacitor does not depend upon the metal used for making its plates and the charge given to the plates $C = \frac{\varepsilon_0 A}{d}$.

64. **(b,d)** E = 0, at all points outside the region between the plates. For points inside $E = \frac{\sigma}{\varepsilon_0}$

65. **(b, c)** $U=\frac{1}{2}CV^2=\frac{1}{2}\left(\frac{\varepsilon_0 AV^2}{x}\right)$

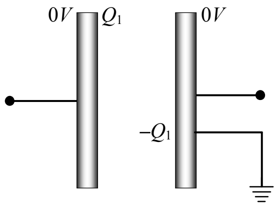
And $U'=\frac{1}{2}\frac{\varepsilon_0 AV^2}{x+dx}$

(When plates are pulled apart)

$$\Delta U=U'-U=-\frac{1}{2}\left(\frac{\varepsilon_0 AV^2}{x}\right)V^2$$

$$F=-\frac{\Delta U}{\Delta x}=\frac{1}{2}\left(\frac{\varepsilon_0 AV^2}{x^2}\right)=\frac{Q}{2\varepsilon_0 A}$$

66. **(b, c, d)** As the switch is closed, the charge on the outer surface of the second plate becomes zero. From the concept in electrostatics that electric field inside the bulk of the material of conductor is zero, we can find the charges on various faces. So it is clear that Q_1+Q_2 charge goes from the second plate to the earth. Charge on capacitor is Q_1 and hence its potential is Q_1/C.



67. **(a, b, d)** $C=\frac{\varepsilon_0 A}{d_1}, C'=\frac{\varepsilon_0 A}{d_2}$

Extra charge flown $=Q'-Q=(C'-C)V$

$$=\varepsilon_0 AV\left[\frac{1}{d_2}-\frac{1}{d_1}\right]$$

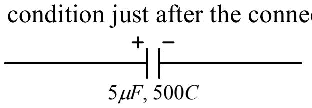
Work done by battery is $W_b=V\times$ charge flown

$$=\varepsilon_0 AV^2\left[\frac{1}{d_2}-\frac{1}{d_1}\right]$$

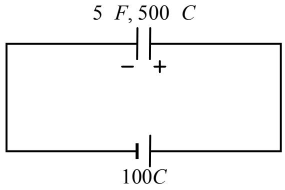
Change in potential energy of capacitor is

$$\Delta U=\frac{1}{2}(C'-C)V^2=\frac{1}{2}\varepsilon_0 AV\left[\frac{1}{d_2}-\frac{1}{d_2}\right]$$

68. **(b, c)** Initial condition just after the connection of battery:



Condition after a long time: It means battery suplies 1000 μC charge from its positive terminal and an equal and opposite charge enters from its negative terminal, i.e., charge flow through battery is 1000 μC. Work done by the battery is $W_{battery}=100V\times 10^3\,\mu C=0.1\,J$



From energy conservation law,

$$U_i+W_{battery}=U_f+\Delta H$$

$$U_i=U_f$$

So, $\Delta H=0.1\,J$

69. **(b, c, d)** As the dielectric slab is pulled out, the equivalent capacity of the system decreases, and hence charge supplied by the battery decreases as potential of the system remains constant. It means charging of battery takes place and a positive charge flows form *a* to *b*. As the two capacitors are connected in series, so charge on both capacitors remains the same at all instants. From energy conservation law,

$U_i+W_{ext}=U_f+$ work done on battery $+\Delta H$

As dielectric slab is attracted by the plates of capacitors, to pull it out, F has to perform some work, i.e., $W_{ext}(F)>0$.

70. **(a, c)** $8-\frac{q_1}{2}-2-\frac{q_3}{2}=3$

Or $6-3=\frac{q_1}{2}+\frac{q_3}{2}$

$q_1+q_3=6$ . . .(*i*)

$8-\frac{q_1}{2}+\frac{q_2}{2}=2$

or $\frac{q_1}{2}-\frac{q_2}{2}=6$

$q_1-q_2=12$ . . .(*ii*)

Also $q_1+q_2=q_3$ . . .(*iii*)

Solving (*i*), (*ii*) and (*iii*), we get $q_1=6\,\mu C, q_2=-6\,\mu C$ and $q_3=0$

71. **(b, d)** After switch S_1 is closed, C_1 is charged by $2CV_0$, when switch S_2 is closed, C_1 and C_2 both have plate charge CV_0.

When S_3 is closed, then upper plate of C_2 becomes charged by $-CV_0$ and lower plate by $+CV_0$.

Assertion and Reason

72. **(b)** By the formula capacitance of a capacitor

$$C_1 = \varepsilon_0 \times \frac{KA}{d} \propto \frac{K}{d}$$

Hence, $\frac{C_1}{C_2} = \frac{K_1}{d_1} \times \frac{d_2}{K_2} = \frac{K_1}{K_2} \times \frac{d/2}{3K} = \frac{1}{6}$

or $C_2 = 6C_1$

Again for capacity of a capacitor $C = \frac{Q}{V}$

Therefore, capacity of a capacitor does not depend upon the nature of the material of the capacitor.

73. **(c)** In the given case $V = V_0$ (constant)

Energy stored in the capacitor $= \frac{1}{2}CV^2$

$C \to KC$, so energy stored will become A times

$Q = CV$, so Q will become K times

$\therefore$ Surface charge density $\sigma' = \frac{Kq}{A} = K\sigma_0$.

74. **(a)** Capacitance is basically a geometrical quantity.

75. **(e)** Battery is disconnected from the capacitor.

76. **(d)** The electric field due to one charged plate at the location of the other is $E = \frac{\sigma}{2\varepsilon_0}$ and the force per unit area is $E = \sigma$,

$\Rightarrow$ $E = \frac{\sigma^2}{2\varepsilon_0}$.

77. **(c)** A charged capacitor, after removing the battery, does not discharge itself. If this capacitor is touched by someone, he may feel shock due to large charge still present on the capacitor. Hence it should be handled cautiously otherwise this may cause a severe shock.

78. **(c)** Equivalent capacitance of parallel combination is $C_p = C_1 + C_2 + C_3$.

79. **(b)** During take off and landing, the friction between tyres and the run way may cause electrification of tyres. Due to conducting nature of tyre, the charge so collected is conducted to a ground and electrical sparking is avoided.

80. **(c)** When the bird perches on a single high power line, no current passes through its body because its body is at equipotential surface *i.e.*, there is no potential difference. While when man touches the same line, standing bare foot on ground the electrical circuit is completed through the ground. The hands of man are at high potential and his feet's are at low potential. Hence large amount of current flows through the body of the man and person therefore gets a fatal shock.

Comprehension Based

81. **(d)** $\frac{V\sigma_2}{d_1\sigma_1 + d_2\sigma_2}$

82. **(b)** $\frac{\varepsilon_0 V(\sigma_1 - \sigma_2)}{d_1\sigma_2 + d_2\sigma_1}$

83. **(b)** $Q = Q_0(1 - e^{-t/\tau})$

$\Rightarrow$ $Q = CV(1 - e^{-t/\tau})$ after time interval 2τ.

84. **(d)** $q = Q_0 \cos \omega t$

$\Rightarrow$ $i = -\frac{dq}{dt} = Q_0\omega \sin \omega t$

$\Rightarrow$ $i_{kax} = C\omega V = V\sqrt{\frac{C}{L}}$

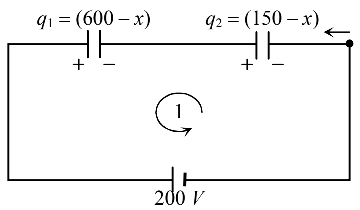
85. **(c)**

86. **(c), 87, (b), 88 (d)**

1 $\frac{(150 - x)}{3} + \frac{(600 - x)}{6} - 200 = 0$

$x = -100\mu C$

Hence, final charge on $6\mu F$ capacitor is $q_1 = 700\mu C$ and charge on $3\mu F$ is $q_2 = 250\mu C$



Plates 2 and 3 and plates 1 and 4 form isolated system. Hence $q_1 = q_2 = q_3 = x = -100\mu C$

Match the Column

89. **(a)** A→1, B→2, C→3, D→4

90. **(a)** A→1, B→2, C→3, D→4

91. **(a)** A→ 2; B→ 3,4; C→ 3,4; D→ 1,2,3

Integer

92. **(3)** Let the capacity of Leyden jar with glass dielectric be $K_g\varepsilon_0 A/d$ and that for Leyden jar with ebonite as dielectric be $K_e\varepsilon_0 A/d$. If be the charge on the Leyden jar with glass as dielectric and V be its potential, then

$V = qd/K_g\varepsilon_0 A$

On sharing charge with Leyden jar with ebonite dielectric, the common potential drops to 0.6 volt.

Therefore, common potential $= \dfrac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$

or $\quad 0.6V = \dfrac{(K_g\varepsilon_0 A/d)\times V + 0}{\dfrac{K_g\varepsilon_0 A}{d} + \dfrac{K_e\varepsilon_0 A}{d}} = \dfrac{K_g}{K_g + K_e}$

As $K_e = 2$, hence $K_g = 3$

93. **(6)** Resultant capacitance of condensers of capacity $2\mu F$ and μF when connected in parallel, $C' = 2 + 4 = 6\mu F$

This is connected in series with a capacitor of capacity $6\mu F$ in series.

The resultant capacity C is given by:

$\dfrac{1}{C} = \dfrac{1}{6} + \dfrac{1}{6} = \dfrac{1}{3}$ or $C=3\mu F$

Charge on combination. $q = (3\times10^{-6})\times12 = 36\times10^{-6}C$

Let the charge on $2\mu F$ capacitor be q_1; then

$\dfrac{q_1}{2} = \dfrac{q - q_1}{4}$ or $q_1 = \dfrac{q}{3}$

$\therefore \quad q_1 = 12\times10^{-16}C$

Now, potential difference across $2\mu F$ capacitor

$= \dfrac{q_1}{2\times10^{-6}} = \dfrac{12\times10^{-6}}{2\times10^{-6}} = 6\,\text{volt}$

94. **(4)** $\dfrac{1}{C_{eq}} = \dfrac{1}{2} + \dfrac{1}{3} + \dfrac{1}{6} \Rightarrow C_{eq} = 1\,\mu F$

Total charge $Q = C_{eq}.V = 1 \times 24 = 24\ \mu C$

So, p.d. across 6 μF capacitor = $\dfrac{24}{6} = 4\,volt$

95. **(8)** $C_1 = \dfrac{\varepsilon_0 A}{d}$ and $C_2 = \dfrac{K\varepsilon_0 A}{2d} \Rightarrow \dfrac{C_2}{C_1} = \dfrac{K}{2}$

$\Rightarrow \quad \dfrac{40\times10^{-12}}{10\times10^{-12}} = \dfrac{K}{2} \Rightarrow K = 8$

96. **(15)** By using $V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$

$\Rightarrow \quad 40 = \dfrac{10\times100 + C_2\times0}{10 + C_2}$

$\Rightarrow \quad C_2 = 15\mu F$

97. **(4)** $C = \dfrac{\varepsilon_0 A}{d}$ $\quad \ldots(i)$

$C' = \dfrac{\varepsilon_0 KA}{2d}$ $\quad \ldots(ii)$

From equation (i) and (ii) $\dfrac{C'}{C} = \dfrac{K}{2}$

$\Rightarrow \quad 2 = \dfrac{K}{2} \Rightarrow K = 4$

98. **(2)** $C_{air} = \dfrac{\varepsilon_0 A}{d}$,

with dielectric slab $C' = \dfrac{\varepsilon_0 A}{\left(d - t + \dfrac{t}{K}\right)}$ given $C' = \dfrac{4}{3}C$

$\Rightarrow \quad \dfrac{\varepsilon_0 A}{\left(d - t + \dfrac{t}{K}\right)} = \dfrac{4}{3}\times\dfrac{\varepsilon_0 A}{d}$

$\Rightarrow \quad K = \dfrac{4t}{4t - d} = \dfrac{4(d/2)}{4[(d/2) - d]} = 2$

99. **(3)** $C \propto \dfrac{1}{d}$

$\Rightarrow \quad \dfrac{C_{medium}}{C_{air}} = \dfrac{d}{d - t + \dfrac{t}{K}} = \dfrac{6}{6 - 4.5 + \dfrac{4.5}{9}} = \dfrac{6}{2} = 3$

100. **(6)** Volume of eight drops = Volume of big drop

$8\times\dfrac{4}{3}\pi r^3 = \dfrac{4}{3}\pi R^3$

or $\quad R = \dfrac{R}{2}$

$C = 4\pi\varepsilon_0 R = 12\mu F$

Thus, capacitance of smaller drop is

$C = 4\pi\varepsilon_0 r = \dfrac{4\pi\varepsilon_0 R}{2} = \dfrac{12}{2} = 6\mu F$

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