Capacitance

1. Capacitance

1.1 Concept of Capacitance

Capacitance of a conductor is a measure of its ability to store charge. When a conductor is charged its potential changes. The increase in potential is directly proportional to the charge given to the conductor.

$Q \propto V \qquad \Rightarrow \qquad Q = CV$

The constant C is known as the capacity or capacitance of the conductor.

Capacitance is a scalar quantity with dimensions $C = \frac{Q}{V} = \frac{Q^2}{W} = \frac{A^2T^2}{M^1L^2T^{-2}}$

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

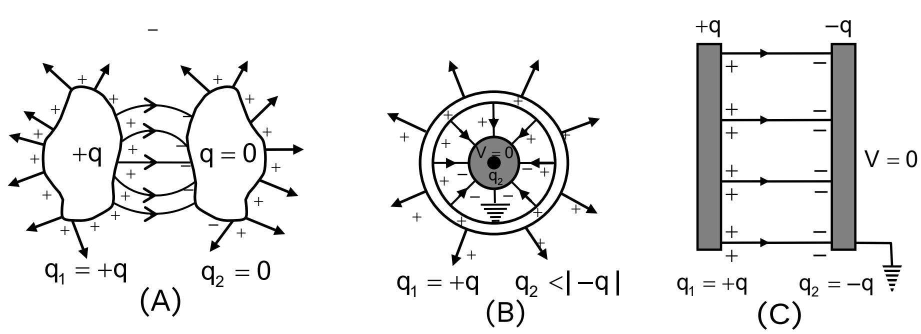
Unit:- farad, coulomb/volt

- The capacitance of a conductor is independent of the charge given or rise in its potential. It is also independent of the nature of material and thickness of the conductor. Theoretically, infinite amount of charge can be given to a conductor. However, practically the electric field becomes so intense that it causes ionisation of the medium surrounding it. Consequently, the charge on the conductor leaks, reducing its potential.
- It is clear that every conductor has a capacity to store charge which is numerically equal to the ratio of charge given to it to the rise in potential.

1.2 Capacitor/Condenser

Capacitor is a device which is used to store the electrostatic energy in the form of electric field. A pair of conductors having opposite charges of equal magnitude is defined as capacitor. In case of two conductors (close to each other), if the conductors (called plates) carry equal and opposite charges and are at small separation, the system is called a capacitor. The capacity or capacitance of a capacitor is defined as

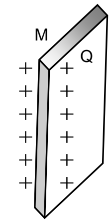
$$C = \frac{\text{Magnitude of charge on either plate}}{\text{Potential difference between the plates}}$$



The capacity of a capacitor depends upon the geometry

- Shape of conductor
- Size of conductor
- Separation between the conductors
- Interfering medium
- Presence of other nearby conductors
- Orientation of plates

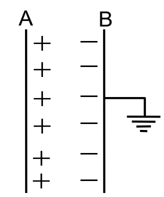
1.3 Principle of a Capacitor



It is based on the fact that capacitance can be increased by reducing potential, keeping the charge constant. Consider a conducting plate M which is given a charge Q such that its potential rises to V then

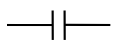
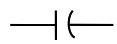
$$C = \frac{Q}{V}$$

1.4 Formation of Capacitor



If some charge is given to conductor A, its potential increases, and soon becomes maximum. If some more charge is given to it, it leaks out. Now if an earthed conductor B is placed near A, opposite charges induces on B and potential at A decreases, hence more charge can be given to A.

- Representation of capacitor

  It is represented as  and 

Key Points

- It must be noted that the charges on the plates of a capacitor are equal and opposite, hence total charge on it is zero and all the electric lines of force which originate from one plate terminate on the other plate.
- If a capacitor is connected across a battery, then the charges will be equal in magnitude even if the plates are of different sizes.

Example 1:

A capacitor gets a charge of 50 μC when it is connected to a battery of emf 5 V. Calculate the capacity of the capacitor.

Solution:

Capacity of the capacitor

$$C = \frac{Q}{V} = \frac{50 \times 10^{-6}}{5} = 10\mu F$$

Example 2:

A capacitor of 0.75 μF is charged to a voltage of 16 V. What is the magnitude of the charge on each plate of the capacitor ?

Solution:

$q = CV = (0.75 \times 10^{-6}\ F)\ (16\ V) = 1.2 \times 10^{-5} C$

Example 3:

Two insulated conductors are charged by transferring electrons from one conductor to another. A potential difference of 100 V is produced by transferring 6.25×10^{15} electrons from one conductor to the other. The capacity of the system will be.

Solution:

$$Q = CV \Rightarrow C = \frac{Q}{V} = \frac{ne}{V}$$

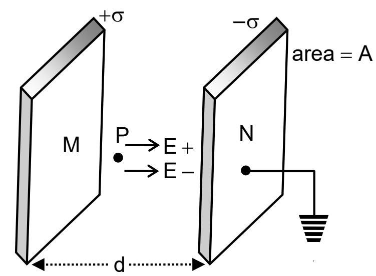
Given V = 100 volts; n = 6.25×10^{15}

$$\therefore \quad C = \frac{6.25 \times 10^{15} \times 1.6 \times 10^{-19}}{100} = 10\mu F$$

2. Parallel Plate Capacitor

2.1 Capacitance

It consists of two metallic plates M and N each of area A at separation d. Plate M is positively charged and plate N is earthed. If ε_r is the dielectric constant of the material medium, E is the field at a point P that exists between the two plates, then



I step: Finding electric field

$$E = E_+ + E_- = \frac{\sigma}{2\varepsilon} + \frac{\sigma}{2\varepsilon} = \frac{\sigma}{\varepsilon} = \frac{\sigma}{\varepsilon_0\varepsilon_r} [\varepsilon = \varepsilon_0\varepsilon_r]$$

II step: Finding potential difference

$$V = Ed = \frac{\sigma}{\varepsilon_0\varepsilon_r} d = \frac{qd}{A\varepsilon_0\varepsilon_r} \qquad \left(\because E = \frac{V}{d} \text{ and } \sigma = \frac{q}{A}\right)$$

III step: Finding capacitance

$$C = \frac{q}{V} = \frac{\varepsilon_r\varepsilon_0 A}{d}$$

If the medium between the plates is air or vacuum, then $\varepsilon_r = 1 \Rightarrow C_0 = \frac{\varepsilon_0 A}{d}$

C_0 = Cap. b/w the plates in vacuum/Air

so $C = \varepsilon_r C_0 = KC_0$

(where $\varepsilon_r = K$ = dielectric constant)

Note : The capacitance of capacitor is independent of charge and potential. It only depends on physical construction (area), separation (d) and medium between conductors.

2.2 Force Between the Plates

The two plates of capacitor attract each other because they are oppositely charged.
Electric field due to positive plate

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

Force on negative charge −Q is

$$F = -Q\, E_+ = -\frac{Q^2}{2\varepsilon_0 A}$$

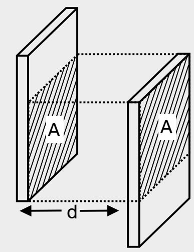
Magnitude of force $\boxed{F = \frac{Q^2}{2\varepsilon_0 A} = \frac{1}{2}\varepsilon_0 A E^2 = \frac{\sigma^2 A}{2\varepsilon_0}}$

E = Net electric field between the plates of capacitor.

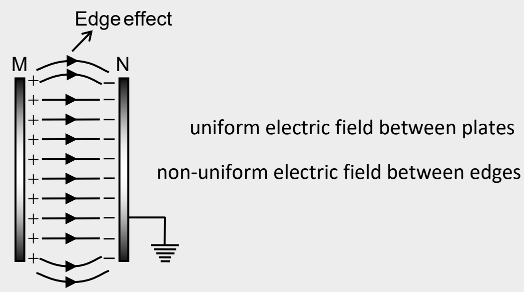
Energy Density or Electrostatic Pressure (Force per unit area) $= \frac{F}{A} = U = P = \frac{1}{2}\varepsilon_0 E^2 = \frac{\sigma^2}{2\varepsilon_0}$

Key Points

- If one of the plates of a parallel plate capacitor slides parallel to the other then C decreases (As overlapping area decreases). $C = \frac{\varepsilon_0 A}{d}$
  where A = overlapping area



- If both the plates of parallel plate capacitor are touched each other then resultant charge and potential difference becomes zero.
- Electric field between the plates of a capacitor is shown in figure. Non-uniformity of electric field at the boundaries of the plates is negligible if the distance between the plates is very small as compared to the length of the plates.



- Capacitance of a parallel plate capacitor does not depend on thickness and nature of metal of plates.
- For a parallel plate capacitor:
  (i) Intensity of electric field between the plates $E = \frac{\sigma}{\varepsilon_0} = \frac{V}{d}$(uniform)
  (ii) Force between the plates
  ($E \rightarrow$ Electric field) $\frac{Q^2}{2A\varepsilon_0} = \frac{C^2V^2}{2A\varepsilon_0} \cdot \frac{d}{d} = \frac{CV^2}{2d} = \frac{QE}{2}$
  (iii) Pressure on the plates = $\frac{\sigma^2}{2\varepsilon_0}$
- If a small charge q is moved along a closed path in the field between the plates of a parallel-plate capacitor, no work will be done by the agent.

Example 4:

If the distance between the plates of a capacitor of capacitance C_1 is halved and the area of plates is doubled then what will be the capacitance ?

Solution:

$C = \frac{\varepsilon_0 A}{d}$ $\Rightarrow \frac{C_1}{C_2} = \frac{A_1}{A_2} \cdot \frac{d_2}{d_1} = \frac{A_1}{2A_1} \times \left(\frac{1}{d_1}\right)\left(\frac{d_1}{2}\right) = \frac{1}{4}$ $\Rightarrow C_2 = 4C_1$

Example 5:

A parallel plate capacitor has a potential 20 kV and capacitance 2×10^{-4} μF. If area of each plate is 0.01 m^2 and distance between them is 2 mm then find the

(a) potential gradient (b) dielectric constant of medium

Solution:

(a) potential gradient

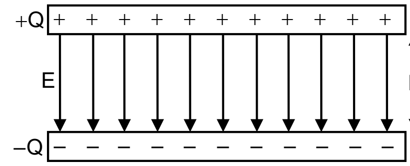
$= \frac{V}{d} = \frac{20000}{0.002} = 1 \times 10^7 \text{ V/m}$

(b) $C = \frac{\varepsilon_0 \varepsilon_r A}{d} \Rightarrow \varepsilon_r = \frac{Cd}{\varepsilon_0 A}$

$= \frac{2 \times 10^{-10} \times 2 \times 10^{-3}}{8.85 \times 10^{-12} \times 0.01} = 4.52$

Example 6:

A parallel plate capacitor is constructed with plates of area 0.0280 m^2 and separation 0.550 mm. Find the magnitude of the charge on each plate of this capacitor when the potential difference between the plates is 20.1 V.



Solution:

Using formula

$$C = \frac{\varepsilon_0 A}{d} = \frac{(8.85 \times 10^{-12} C^2 / N\cdot m^2)(0.0280 m^2)}{0.550 \times 10^{-3} m}$$

$C = 4.51 \times 10^{-10} F$

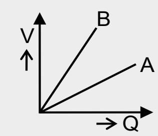
Since $Q = CV$

$Q = (4.51 \times 10^{-10}\ F)\ (20.1\ V) = 9.06 \times 10^{-9} C$

Concept Builder-1

Q.1 When 2×10^{16} electrons are transferred from one conductor to another, a potential difference of 10 V appears between the conductors. Calculate the capacitance of the two conductor system.

Q.2 The graph shows the variation of voltage V across the plates of two capacitors A & B with charge Q. Which of the two capacitors has larger capacitance?



Q.3 What will be the percentage change in capacitance of a PPC, if the side of square plates is decreased by 10% & separation between then is decreased by 20%.

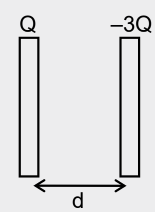
Q.4 A PPC has capacitance 2μF & plate area of 0.03 m^2. What is the separation between the plates.

Q.5 A PPC has capacitance of 6μF. If its plate is displaced in such a manner that the second plate is adjusted $\frac{1}{3}h$ below the top of first plate where h is height of plate. What will be the new capacitance of arrangement.

Q.6 A parallel plate capacitor has capacitance C. If the charges of the plates are Q and –3Q. find

i. Charges at the inner surfaces of the plates

ii. potential difference between the plates



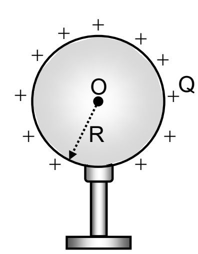
3. The Capacitance of a Spherical Conductor/ Capacitor

3.1 Isolated Sphere

When a charge Q is given to an isolated spherical conductor, its potential rises.

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

or $C = \frac{Q}{V} = 4\pi\varepsilon_0 R$



If the conductor is placed in a certain medium then $C_{medium} = 4\pi\varepsilon_0\varepsilon_r R$

Example 7:

Calculate the capacitance of earth.

Solution:

Earth can be treated as isolated sphere

so $C = 4\pi\varepsilon_0 R$ for earth $R = 6.4 \times 10^6$ m

so $C = \dfrac{1}{9\times10^9} \times 6.4 \times 10^6 = 0.711 \times 10^{-3} F$

$C = 711\ \mu F$

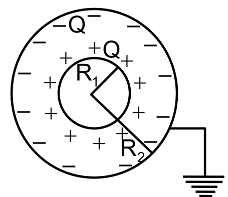
3.2 Outer Sphere is Earthed

When a charge Q is given to inner sphere it is uniformly distributed on its surface. A charge –Q is induced on inner surface of outer sphere. The charge +Q induced on outer surface of outer sphere flows to earth as it is grounded.

[$E = 0$ for $r < R_1$ and $r > R_2$]

Potential of inner sphere

$$V_1 = \frac{Q}{4\pi\varepsilon_0 R_1} + \frac{-Q}{4\pi\varepsilon_0 R_2} \Rightarrow \frac{Q}{4\pi\varepsilon_0}\left(\frac{R_2 - R_1}{R_1 R_2}\right)$$



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As outer surface is earthed so potential

$V_2 = 0$

Potential difference between plates

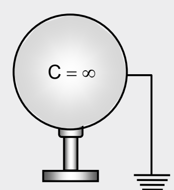
$$V = V_1 - V_2 = \frac{Q}{4\pi\varepsilon_0}\left(\frac{R_2 - R_1}{R_1 R_2}\right)$$

$$\text{So } C = \frac{Q}{V} = 4\,\pi\,\varepsilon_0\,\frac{R_1 R_2}{R_2 - R_1} \text{ (in air or vacuum)}$$

In presence of medium between plate $\boxed{C = 4\pi\varepsilon_r\varepsilon_0 \dfrac{R_1 R_2}{R_2 - R_1}}$

Key Points

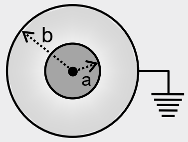
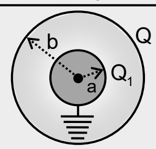
- As the potential of the Earth is assumed to be zero practically, capacity of earth or a conductor connected to earth will be infinite

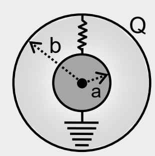
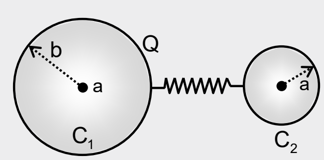


$$C = \frac{q}{V} = \frac{q}{0} = \infty$$

- Theoretically, capacity of the Earth

$$C = 4\pi\varepsilon_0 R = \frac{1}{9\times10^9} \times 64 \times 10^5 = 711\mu F$$

Spherical capacitor outer plate is earthed	Inner plate is earthed and outer plate is given a charge
 $C = \dfrac{4\pi\varepsilon_0 ab}{b-a}$ $(b > a)$	 $C = \dfrac{4\pi\varepsilon_0 b^2}{b-a}$ $(b > a)$

Connected and outer plate is given a charge	Connected spheres
 $C = 4\pi\varepsilon_0 b$	 $C = C_1 + C_2$ $C = 4\pi\varepsilon_0(a+b)$

Example 8:

An arrangement of two concentric spheres of radius 24 cm & 18 cm. Calculate the capacitance, if the inner sphere is grounded.

Solution:

$$C = \frac{4\pi\varepsilon_0 R_0^2}{(R_0 - R_i)} = \frac{1}{9\times10^9}\frac{(24)^2}{6}\times10^{-2}$$

$$C = \frac{32}{3}\times10^{-11}F$$

Example 9:

Calculate the capacitance if air between concentric spheres is replaced with a medium of dielectric strength 9 in previous example

Solution:

Now the capacitance will be

$$C = \frac{4\pi\varepsilon_0 k R_0^2}{R_0 - R_i} = 96\times10^{-11}\ F$$

4. Energy Stored in a Charged Capacitor

Let C be the capacitance of a capacitor. On being connected to a battery. It charges to a potential V from zero potential. When charge is given to capacitor the potential difference between its plates increases. Let at any instant when charge on capacitor q the potential difference between its plates $V = \frac{q}{C}$. Now work done in giving an additional infinitesimal charge dq to capacitor (which is stored as energy) :-

$$dW = dU = Vdq = \frac{q}{C}dq$$

$$\Rightarrow\ U = \int_0^Q \frac{q}{C}dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q \qquad \Rightarrow U = \frac{Q^2}{2C}$$

where Q is the final charge acquired by the conductor.

$$\text{So } U = \frac{Q^2}{2C} = \frac{1}{2}\frac{(CV)^2}{C} = \frac{1}{2}CV^2$$

$$= \frac{1}{2}\left(\frac{Q}{V}\right)V^2 = \frac{1}{2}QV$$

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

Note :- Work done by battery = Charge supplied × potential

$$\boxed{W_{Battery} = QV = CV^2 = \frac{Q^2}{C}}$$

Key Points

- Work done by a battery W_b = (charge passing through battery) × (emf) = QV

  Energy stored in conductor = $\frac{1}{2}QV$

  So 50% of the energy supplied by the battery is lost in the form of heat, if Capacitor is initially uncharged.
- The amount of energy stored depends on the size of the conductor.
- When a capacitor C charged upto a voltage V is discharged by means of any resistance then heat loss = $\frac{CV^2}{2}$ (independent of R)

Concept Builder-2

Q.1 Calculate radius of a sphere having capacitance 1 farad.

Q.2 Calculate the capacitance of a metallic ball of radius 30 cm.

Q.3 The capacitance of a spherical condenser whose inner sphere is grounded is 1pF. If the spacing between the two spheres is 1 mm then what is the radius of the outer sphere?

Q.4 For flash pictures, a photographer uses a 30 μF capacitor and a charger that supplies 3×10^3 volt. Calculate the charge and the energy spent for each flash.

Q.5 Two capacitors C_1 and C_2 have equal amount of energy stored in them. What is the ratio of potential differences across their plates?

Q.6 The capacitance of a parallel plate capacitor is 400 pico farad and its plates are separated by 2 mm of air.
(i) What will be the energy when it is charged to 1500 volt ?
(ii) What will be the potential difference with the same charge if separation is doubled ?
(iii) How much energy is needed to double the distance between its plates ?

Q.7 If the distance between the plates of a capacitor is d and potential difference is V then what is the energy density between the plates ?

Q.8 A parallel plate capacitor has rectangular plate with dimensions 6.0 cm × 8.0 cm. If the plates are separated by a sheet of teflon (K =2.1) 1.5 mm thick, how much energy is stored in the capacitor when its is connected to a 12 V battery?

Q.9 A capacitor of capacitance C has charge Q. The net charge on a capacitor is always .... and capacitor stores .... energy.

4.1 Energy Density (U)

Energy associated per unit volume of electric field is defined as energy density.

$$U = \frac{dW}{dV} = \frac{\varepsilon_0 E^2}{2} = \frac{\sigma^2}{2\epsilon_0} \text{ J/m}^3$$

5. Effect of Dielectric

- The insulators in which microscopic local displacement of charges takes place in presence of electric field are known as **dielectrics**.
- Dielectrics are non-conductors upto certain value of field depending on its nature. If the field exceeds this limiting value called **dielectric strength** they lose their insulating property and begin to conduct.
- **Dielectric strength** is defined as the maximum value of electric field that a dielectric can withstand/tolerate without breakdown.
  Unit = volt/metre, Dimensions = $[M^1L^1T^{-3}A^{-1}]$

5.1 Polar Dielectrics

- In absence of external field, the centres of positive and negative charges do not coincide in these atoms or molecules due to asymmetric shape of molecules.
- Each molecule has permanent dipole moment.
- The dipole are randomly oriented so average dipole moment per unit volume of polar dielectric in absence of external field is zero.
- In presence of external field, dipoles tends to align in direction of field.

  Ex. Water, Alcohol, HCl, NH_3 etc.

5.2 Non Polar Dielectrics

- In the absence of external field the centres of positive and negative charge coincides in these atoms or molecules because they are symmetric.
- The dipole moment is zero in normal state.
- In presence of external field, they acquire induced dipole moment.

  Ex. Nitrogen, Oxygen, Benzene, Methane etc.

5.3 Polarisation

The alignment of dipole moments of permanent or induced dipoles in the direction applied electric field is called polarisation.

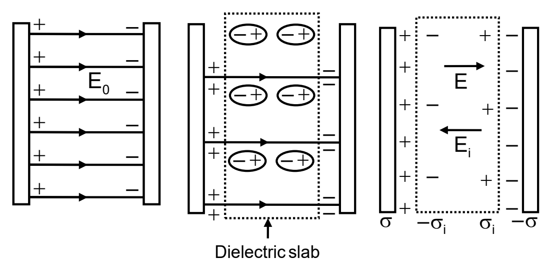
5.4 Polarisation Vector $\vec{P}$

It is a vector quantity which describes the extent to which molecules of dielectric become polarized by an electric field or oriented in direction of field.

$\vec{P}$ = the dipole moment per unit volume of dielectric = $n\vec{p}$

where n is number of atoms per unit volume of dielectric and $\vec{p}$ is dipole moment of an atom or molecule.

$$\vec{P} = n\vec{p} = \frac{q_i d}{Ad} = \left(\frac{q_i}{A}\right) = \sigma_i$$



σ_i = induced surface charge density.

Unit of $\vec{P}$ is C/m^2 ; Dimension is $[L^{-2}T^1A^1]$

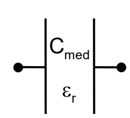
Let E_0, V_0, C_0 be electric field, potential difference and capacitance in the absence of dielectric. Let E, V, C be the corresponding quantities in presence of dielectric respectively.

Electric field in absence of dielectric

$$E_0 = \frac{V_0}{d} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$

Electric field in presence of dielectric

$$E_{net} = E_0 - E_i \qquad \Rightarrow \frac{E_0}{k} = E_0 - E_i \qquad \Rightarrow E_i = E_0 - \frac{E_0}{k}$$



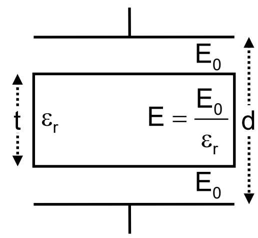
$$E_i = E_0\left(1-\frac{1}{k}\right) \qquad \Rightarrow \sigma_i = \sigma_0\left(1-\frac{1}{k}\right) \qquad \Rightarrow Q_i = Q_0\left(1-\frac{1}{k}\right)$$

5.5 If Capacitor is Partially Filled with Dielectric

When the capacitor is filled partially with dielectric between plates, and thickness of dielectric slab is t(t < d).

For capacitor, the field E_0 is given by $E_0 = \frac{\sigma}{\varepsilon_0}$, exists in a space d.

On inserting the slab of thickness t, a field $E = \frac{E_0}{\varepsilon_r}$ appears inside the slab and a field E_0 exists in the remaining space (d – t). If V is the potential difference between the plates then $V = E_0(d - t) + E\,t$



$$\Rightarrow V = E_0\left[d - t + \left(\frac{E}{E_0}\right)t\right]$$

$$\because \frac{E_0}{E} = \varepsilon_r = \text{Dielectric constant}$$

$$\Rightarrow V = \frac{\sigma}{\varepsilon_0}\left[d - t + \frac{t}{\varepsilon_r}\right] = \frac{q}{A\varepsilon_0}\left[d - t + \frac{t}{\varepsilon_r}\right]$$

$$\Rightarrow C = \frac{q}{V} = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{\varepsilon_r}\right)} \qquad ...(i)$$

5.6 If the Dielectric Medium is Present Between the Entire Space

Then t = d

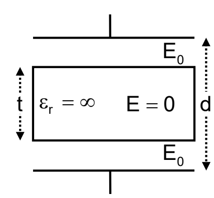
Now from equation

$$C_{medium} = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

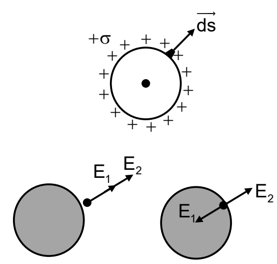
If capacitor is partially filled with a conducting slab of thickness t (t< d)

$\varepsilon_r = \infty$ for conductor

so $C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{\infty}\right)}$ $\quad \Rightarrow C = \frac{\varepsilon_0 A}{(d - t)}$



6. Electrostatic Pressure



Force due to electrostatic pressure is directed outwards normal to the surface.

Force on a small element ds of a charged conductor

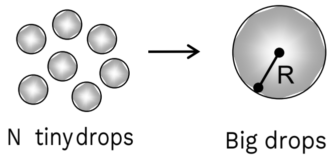
dF = (Charge on ds) × Electric field

$$dF = (\sigma ds)\,\frac{\sigma}{2\,\epsilon_0} = \frac{\sigma^2}{2\,\epsilon_0}\,ds$$

6.1 Combination of Identical Charged Tiny Drops

Let number of tiny drops = N

for each **tiny** drop	for **Big** drop
(r, q, C, σ, E, V)	$(R, Q, C_B, \sigma_B, E_B, V_B)$



(i) Charge conservation Q = Nq

(ii) Volume conservation $N\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

Hence $R = N^{1/3} r$

$Q = Nq$ $\quad C_B = N^{1/3}C$ $\quad \sigma_B = N^{1/3}\sigma$

$E_B = N^{1/3}E$ $\quad V_B = N^{2/3}V$

Key Points

- When an initially uncharged soap bubble is charged (either positive or negative) then the size (radius) increases and mass may increase or decease
  Positive charge ⇒ mass ↓
  Negative charge ⇒ mass ↑

Example 10:

Twenty seven charged water droplets, each of radius 10^{-3}m and having a charge of 10^{-12}C, coalesce to form a single drop. Calculate the potential of the bigger drop.

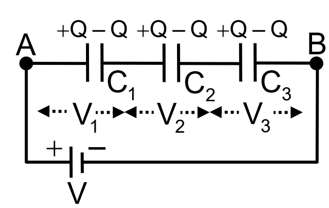
Solution:

$$V_B = n^{2/3}V_0 = (27)^{2/3}\left[\frac{9\times10^9\times10^{-12}}{10^{-3}}\right]$$

V_B = 81 volts

7. Combination of Capacitor

7.1 Capacitors in Series



In this arrangement of capacitors, the charge has no alternative path(s) to flow.

(i) The charge on each capacitor is equal (if they are initially uncharged)

i.e. $Q = C_1V_1 = C_2V_2 = C_3V_3$

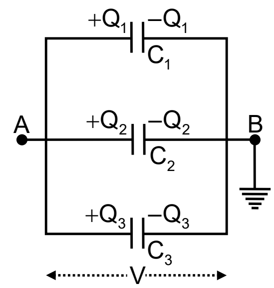
(ii) The total potential difference across AB is shared by the capacitors in the inverse ratio of their respective capacitance $\left[V \propto \frac{1}{C}\right]$

$V = V_1 + V_2 + V_3$

If C_S is the net capacitance of the series combination, then

$$\frac{Q}{C_s} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \quad \Rightarrow \quad \boxed{\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

7.2 Capacitors in Parallel



In such in arrangement of capacitors, charge has some alternative path(s) to flow.

(i) The potential difference across each capacitor is same

i.e. $V = V_1 = V_2 = V_3$ $\Rightarrow V = \dfrac{Q_1}{C_1} = \dfrac{Q_2}{C_2} = \dfrac{Q_3}{C_3}$

(ii) The total charge Q is shared by each capacitor in the direct ratio of their respective capacitances. [$Q \propto C$]

$Q = Q_1 + Q_2 + Q_3$

If C_P is the net capacitance for the parallel combination of capacitors, then :

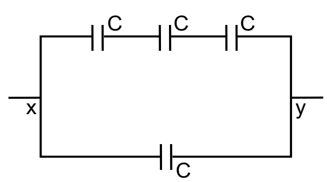
$C_PV = C_1V + C_2V + C_3V \quad \Rightarrow C_P = C_1 + C_2 + C_3$

Key Points

- For a given voltage, in order to store maximum energy, capacitors should be connected in parallel.
- If N identical capacitors each having breakdown voltage V are joined in (i) series then the break down voltage of the combination = NV (ii) parallel then the breakdown voltage of the combination = V
- If N identical capacitors are connected then $C_{series} = \dfrac{C}{N}$, $C_{parallel} = NC$

Example 11:

The capacitance between x and y is :

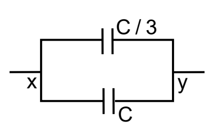


Solution:

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

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

$$C' = \frac{C}{3}$$

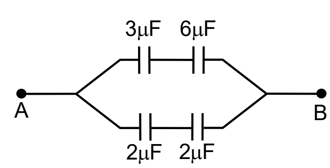


$\dfrac{C}{3}$ and C are in parallel

$$C_{eq} = \frac{C}{3} + C \Rightarrow C_{eq} = \frac{4}{3}C$$

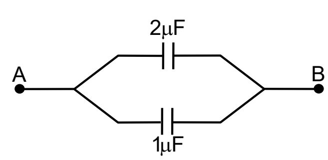
Example 12:

What is the effective capacitance between points A and B of the network of capacitors shown in figure?



Solution:

$$C_1 = \frac{3\mu \times 6\mu}{3\mu + 6\mu} = 2\ \mu F,\ C_2 = \frac{4\mu}{4} = 1\mu F$$



$$\Rightarrow C_{eq} = 2\mu + 1\mu = 3\mu F$$

Example 13:

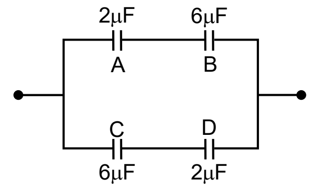
Three identical capacitors are connected together differently. For the same voltage applied across each combination, which one stores maximum energy?

Solution:

When all three are connected in parallel combination then this combination stores maximum energy because C_{eq} will be maximum in parallel combination and $u = \frac{1}{2} C_{eq} V^2$

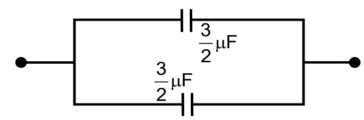
Example 14:

Four capacitors are arranged to form the given circuit. If this arrangement is connected across a voltage source then charge supplied by the source is 24μC. Calculate the charge on capacitor A.



Solution:

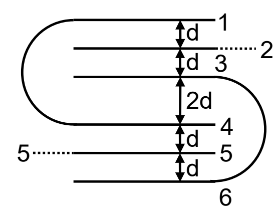
Given circuit can be redrawn as shown in figure. As capacitance of both the branches are same so 24μC charge will be equally divided.



$\therefore$ Charge on capacitor A = 12μC

Example 15:

There are six plates of equal area A and separation between the adjacent plates is d or 2d (d<<A). They are arranged as shown in figure. Find the equivalent capacitance between points 2 and 5.

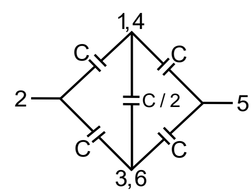


Solution:

Redrawing the circuit

It is a whetstones bridge with points (3, 6) and (1, 4) being equipotential.

So, the capacitance C/2 can be removed.



$\therefore C_{eq} = C = \frac{\epsilon_0 A}{d}$

8. Kirchhoff's Law for Capacitance

In a complex circuit containing capacitor and the batteries, charges on different capacitors can be obtained with the help of Kirchhoff's law.

8.1 First Law

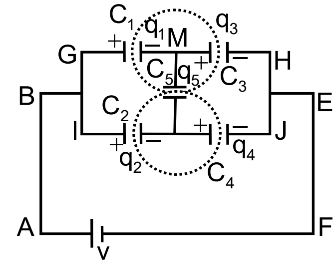
This law is basically law of conservation of charge which is normally applied across a battery or in an isolated system.

(i) In case of a battery, charge pass through both terminals is of equal amount.

(ii) In an isolated system (not connected to any source of charge like terminal of a battery or earth), net charge remains constant.

For example, in the figure, the positive terminals of the battery supplies a positive charge q_1+q_2. Similarly, the negative terminal supplies a negative charge of magnitude $q_3 + q_4$.

Hence $q_1 + q_2 = q_3 + q_4$



Further, the plate enclosed by the dotted lines from an isolated system, as they are neither connected to a battery terminal nor to the earth. Initially, no charge was present in these plates. hence, after charging, net charge on these plates should also be zero. Or

$q_3 + q_5 - q_1 = 0$ and $q_4 - q_2 - q_5 = 0$

So, these are the three equations which can be obtained from the first law.

8.2 Second Law

In a capacitor, potential drops by q/C, when one moves from positive plate to the negative plate and in a battery it drops by an amount equal to the emf of the battery. Applying second law in loop ABGHEFA, we have

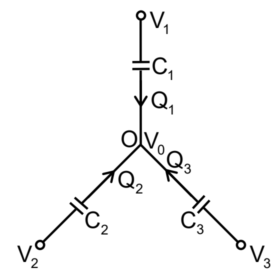
$$-\frac{q_1}{C_1} - \frac{q_3}{C_3} + V = 0$$

Similarly, the second law in loop GMDIG gives the equation, $-\frac{q_1}{C_1} - \frac{q_5}{C_5} + \frac{q_2}{C_2} = 0$

Example 16:

Calculate the potential of point O in terms of C_1, C_2, C_3, V_1, V_2 & V_3 in the following circuit.

Solution:



Let the potential of the junction O be V_0. Now apply Kirchhoff's current law at a junction.

$Q_1 + Q_2 + Q_3 = 0$

$C_1 (V_1 - V_0) + C_2 (V_2 - V_0) + C_3 (V_3 - V_0) = 0$

$$\Rightarrow V_0 = \frac{C_1V_1 + C_2V_2 + C_3V_3}{C_1 + C_2 + C_3}$$

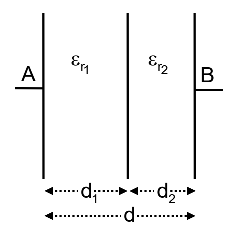
9. Combination of Dielectric Slabs

9.1 Plate Separation Division

(i) Plate separation gets divided and area remains same

(ii) Capacitors are in series

(iii) Individual capacitance are



$$C_1 = \frac{\varepsilon_0 \varepsilon_{r_1} A}{d_1}, \qquad \Rightarrow C_2 = \frac{\varepsilon_0 \varepsilon_{r_2} A}{d_2}$$

These two are in series

$$\therefore \frac{1}{C_{AB}} = \frac{1}{C_1} + \frac{1}{C_2} \qquad \Rightarrow \frac{1}{C_{AB}} = \frac{d_1}{\varepsilon_0 \varepsilon_{r_1} A} + \frac{d_2}{\varepsilon_0 \varepsilon_{r_2} A}$$

$$C_{AB} = \frac{A\varepsilon_0}{\frac{d_1}{\varepsilon_{r_1}} + \frac{d_2}{\varepsilon_{r_2}}}$$

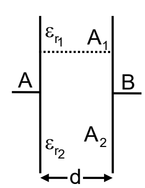
Special Case: If $d_1 = d_2 = \frac{d}{2}$ $\Rightarrow$ $\boxed{C = \frac{\varepsilon_0 A}{d}\left[\frac{2\varepsilon_{r_1}\varepsilon_{r_2}}{\varepsilon_{r_1} + \varepsilon_{r_2}}\right]}$

9.2 Plate Area Division

(i) Plate area gets divided and distance between them remains same.

(ii) Capacitor are in parallel

(iii) Individual capacitances are



$$C_1 = \frac{\varepsilon_0 \varepsilon_{r_1} A_1}{d}, \qquad \Rightarrow C_2 = \frac{\varepsilon_0 \varepsilon_{r_2} A_2}{d}$$

These two are parallel so $C_{AB} = C_1 + C_2$

$$C_{AB} = \frac{\varepsilon_0 \varepsilon_{r_1} A_1}{d} + \frac{\varepsilon_0 \varepsilon_{r_2} A_2}{d} = \frac{\varepsilon_0}{d}\left(\varepsilon_{r_1} A_1 + \varepsilon_{r_2} A_2\right)$$

Special Case:

If $A_1 = A_2 = \frac{A}{2}$ Then $\boxed{C = \frac{\varepsilon_0 A}{d}\left(\frac{\varepsilon_{r_1} + \varepsilon_{r_2}}{2}\right)}$

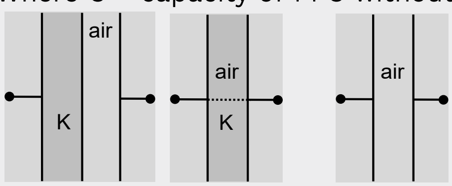
Key Point

- If space between the plates is divided equally into two parts.

  (i) Distance-wise division C_e = (Harmonic mean of ε_{r_1} & ε_{r_2}) × C = $\left(\frac{2\varepsilon_{r_1}\varepsilon_{r_2}}{\varepsilon_{r_1}+\varepsilon_{r_2}}\right)C$

  (ii) Area wise division C_e= (Arithmetic mean of ε_{r_1} & ε_{r_2}) × C = $\left(\frac{\varepsilon_{r_1}\varepsilon_{r_2}}{2}\right)C$

  Where C = capacity of PPC without any dielectric

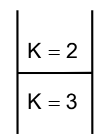
- 

  $C_1 = \left[\frac{2K}{K+1}\right]C$; $C_2 = \left[\frac{K+1}{2}\right]C$; $C_3 = C$

  $C_2 > C_1 > C_3$

Example 17:

A parallel plate capacitor with no dielectric has a capacitance of 0.5μF. Half of the space between the plates is filled with medium of dielectric constant 2 and remaining half is filled with a medium of dielectric constant of 3 as shown in figure. Find its net capacity.



Solution:

Given that original capacitance C = $\frac{\epsilon_0 A}{d}$ = 0.5μF

Capacitance of part with dielectric constant 2 is $C_1 = \frac{2\epsilon_0 A/2}{d} = \frac{\epsilon_0 A}{d} = 0.5\mu F$

Capacitance of part with dielectric constant 3

is $C_2 = \frac{3\epsilon_0 A/2}{d} = \frac{3\epsilon_0 A}{2d} = 0.75\mu F$

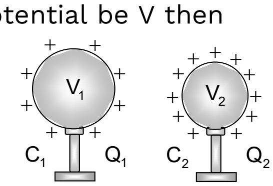
As both the capacitors are connected in parallel so

$C_{eq} = C_1 + C_2$ OR $C_{eq} = \frac{\varepsilon_0}{d}\left(A_1K_1 + A_2K_2\right) = \left(\frac{2+3}{2}\right)C = 1.25\mu F$

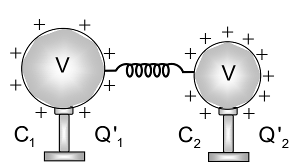
10. Sharing of Charges

When two charged conductors are connected by a conducting wire then charge flows from a conductor at higher potential to that at lower potential. This flow of charge stops when the potential of both conductors become equal.

Let the amount of charges after the conductors are connected be Q_1' and Q_2' respectively and their common potential be V then



(Before connection)



(After connection)

10.1 Common Potential

According to law of Conservation of charge $Q_{\text{before connection}} = Q_{\text{after connection}}$

$\Rightarrow \; C_1V_1 + C_2V_2 = C_1V + C_2V$

Common potential after connection

$$\boxed{V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}} = \frac{Q_1 + Q_2}{C_1 + C_2}$$

10.2 Charges After Connection

$$Q_1' = C_1V = C_1\left(\frac{Q_1 + Q_2}{C_1 + C_2}\right) = \left(\frac{C_1}{C_1 + C_2}\right)Q$$

(Q : Total charge on the system)

$$Q_2' = C_2V = C_2\left(\frac{Q_1 + Q_2}{C_1 + C_2}\right) = \left(\frac{C_2}{C_1 + C_2}\right)Q$$

Ratio of the charges after redistribution

$$\frac{Q_1'}{Q_2'} = \frac{C_1V}{C_2V} = \frac{R_1}{R_2} \text{(in case of spherical conductors)}$$

- **Loss of energy in charge redistribution**

  When charge flows through the conducting wire certain **energy is lost** and electrical energy is converted into heat energy, so change in energy of this system is

  $\Delta U = U_f - U_i$

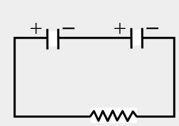
  $$\Rightarrow \left(\frac{1}{2}C_1V^2 + \frac{1}{2}C_2V^2\right) - \left(\frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2\right) \qquad \Rightarrow \Delta U = -\frac{1}{2}\left(\frac{C_1C_2}{C_1 + C_2}\right)(V_1 - V_2)^2$$

  Here negative sign indicates that energy of the system decreases in the process.

Key Points

- If $V_1 = V_2$ then neither charge flows nor energy is lost when two charged conductors are connected.
- A charged capacitor of energy U is connected to an identical uncharged capacitor.

  Then electrostatic potential energy of the system = $\frac{U}{2}$, Heat loss = $\frac{U}{2}$ and energy of each capacitor = $\frac{U}{4}$
- Two capacitors are connected in series with a battery. Now, the battery is removed and loose wires ends are connected together then the final charge on each capacitor is zero.



Example 18:

Two identical capacitors each of capacity C are charged upto same potential V. Now their oppositely charged plates are connected together then calculate

(a) energy of each capacitor before connection.

(b) potential of each capacitor after connection.

(c) charge of each capacitor after connection.

(d) energy stored in each capacitor after connection.

(e) energy loss in the form of heat.

Solution:

(a) Energy of each capacitor is = $\frac{1}{2}CV^2$

(b) Potential of each capacitor V' = CV − CV ⇒ V' = 0

(c) Charge of each capacitor = CV = C × 0 = 0

(d) Energy of each capacitor = $\frac{1}{2}CV^2 = 0$

(e) Energy loss = $U_f - U_i = CV^2$

10.3 Inserting a Dielectric Slab

When battery is disconnected (isolated)

[Q = constant]

New capacitance = KC_0

New potential difference = $\frac{Q_0}{KC_0} = \frac{V_0}{K}$

New EF = $E = \frac{Q}{A\varepsilon_0 K} = \frac{E_0}{k}$

New energy stored $U = \frac{Q^2}{2C} = \frac{Q^2}{2C_0K} = \frac{U_0}{K}$

Charge on each plate remains same.

When battery is connected [V = constant]

New C = KC_0 New V = V_0 New Q = KQ_0

New $U = \frac{1}{2}(KC_0)(V_0)^2 = KU_0$

New EF = E = V/d = E_0

Concept Builder-3

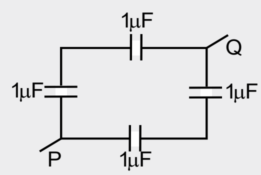
Q.1 A capacitor of capacitance 10μF is connected to battery of emf 20V. Without disconnecting the source, a dielectric (K=4) is introduced to fill the space between the two plates of the capacitor. Calculate

(a) charge before the dielectric was introduced

(b) charge after the dielectric is introduced

Q.2 The capacity and the energy stored in a parallel plate condenser with air between its plates are respectively C_0 and W_0. if the air between the plates is replaced by glass (dielectric constant =5) find the capacitance of the condenser and the energy stored in it.

Q.3 Four capacitors are connected as shown in the figure. The equivalent capacitance between P and Q is :



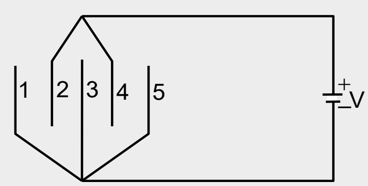
(1) 1 μF (2) $\frac{1}{4}$μF (3) $\frac{3}{4}$μF (4) 5 μF

Q.4 Three capacitors each of capacitance 9pF are connected in series.

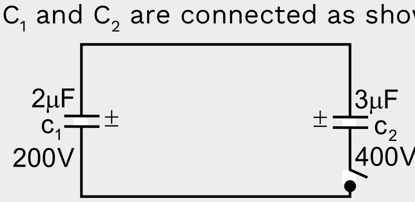
(a) What is the total capacitance of the combination ?

(b) What is the potential difference across each capacitor if the combination is connected to a 120V supply ?

Q.5 Five identical plates each of area A are joined as shown in the figure. The distance between successive plates is d. The plates are connected to potential difference of V volt. Find the charges of plates 1 and 4.



Q.6 Two capacitors of capacity C_1 and C_2 are connected as shown in figure.



Now the switch is closed. Calculate the charge on each capacitor.

Q.7 An air capacitor of capacity C = 10μF is connected to a constant voltage battery of 10V. Now the space between the plates is filled with a liquid of dielectric constant 5. Calculate additional charge which flows from the battery to the capacitor.

Key Points

- If nothing is mentioned then assume the battery to be disconnected and Q is constant.

Battery disconnected (Q is constant)

Change executed	Q	$V = \frac{Q}{C}$ $V \propto \frac{1}{C}$	$E = \frac{Q}{\varepsilon_0 \varepsilon_r A}$	$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$	$U = \frac{Q^2}{2C}$ $U \propto \frac{1}{C}$
Filled with dielectric	Unchanged	Decreases	Decreases	Increases	Decreases
Distance is decreased	Unchanged	Decreases	Unchanged	Increases	Decreses
Area is increased	Unchanged	Decreases	Decreases	Increases	Decreases

- A parallel plate capacitor is connected to a battery (V = const.) and a slab of dielectric constant, ε_r is inserted between the plates then the total energy delivered by the battery is divided into two parts :
  (i) Half is used to insert the slab (work is done by field)
  (ii) Half is stored in the form of electrostatic potential energy.

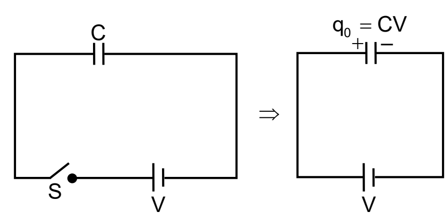
Battery still connected (V is constant)

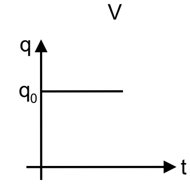
Change executed	$Q = CV$ $Q \propto C$	V constant	$E = \frac{V}{d}$ $E \propto \frac{1}{d}$	$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$	$U = \frac{1}{2}CV^2$ $U \propto C$
Filled with dielectric	Increases	Unchanged	Unchanged	Increases	Increases
Distance is Decreased	Increases	Unchanged	Increases	Increases	Increases
Area is increased	Increases	Unchanged	Unchanged	Increases	Increases

11. R.C. Circuit

To understand the charging of a capacitor in R-C circuit, let us first consider the charging of a capacitor without resistance.

Consider a capacitor connected to a battery of emf V through a switch S. When we close the switch, the capacitor gets charged immediately. Charging takes no time. A charge $q_0 = CV$ appears in the capacitor as soon as switch is closed and the q-t graph in this case is a straight line parallel to t-axis as shown in figure.

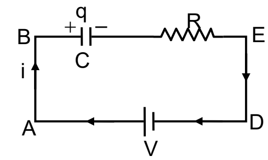




If there is some resistance in the circuit charging takes some time. Because resistance opposes the charging (or current flow in the circuit).

11.1 Charging of Capacitor in R-C Circuit

Consider a capacitor initially uncharged. Suppose that switch is closed at time t = 0. At some instant of time, let charge in the capacitor is q and it is still increasing and hence current is flowing in the circuit.



Applying KVL in ABEDA, we get

$$-\frac{q}{C} - iR + V = 0$$

Here $i = \frac{dq}{dt}$ $\quad \therefore -\frac{q}{C} - \left(\frac{dq}{dt}\right) R + V = 0 \quad \therefore \frac{dq}{V - \frac{q}{C}} = \frac{dt}{R}$ or $\int_0^q \frac{dq}{V - \frac{q}{C}} = \int_0^t \frac{dt}{R}$

This gives $q = CV\left(1 - e^{-\frac{t}{CR}}\right)$

Substituting $CV = q_0$ and $CR = \tau_C$

$$q = q_0\left(1 - e^{-\frac{t}{\tau_C}}\right)$$

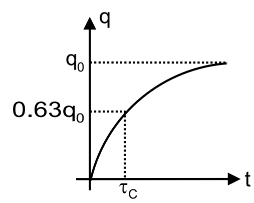
The charge q increases exponentially from 0 to q_0. q-t graph is an exponentially increasing graph.

From the graph and equation, we see that

at t = 0, q = 0

at t = RC, q = .63 q_0

at t = ∞ , q = q_0



11.1.1 Definition of Time Constant (τ_C)

Time constant is the time in which 63.2% charging is over. Its value is RC.

At $\quad t = \tau_C = RC$

$q = q_0(1 - e^{-1}) \approx 0.632\, q_0$

Dimension formula of time constant is $[M^0L^0T]$.

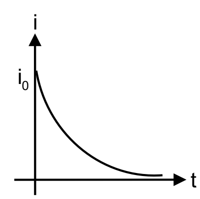
The current at any time t can be calculated by differentiating q with respect to t. Hence,

$$i = \frac{dq}{dt} = \frac{d}{dt}\{q_0\,(1 - e^{-t/\tau_C})\} \qquad \text{or } i = \frac{q_0}{\tau_C} e^{-t/\tau_C}$$

Substituting $q_0 = CV$ and $\tau_C = CR$

$$i = \frac{V}{R} e^{-t/\tau_C} \qquad \Rightarrow i = i_0\, e^{-t/\tau_C}$$

Here $i_0 = \frac{V}{R}$ is the current at time t = 0



i.e. Current decreases exponentially with time.

The i – t graph is as shown in figure. Once charging is over or the steady state condition is reached the current becomes zero.

11.1.2 Behavior of capacitor

(i) At time t = 0, when capacitor is uncharged it offers maximum current passing through it. So, it may be assumed like a conducting wire of zero resistance. With this concept, find initial values of q or i etc.

(ii) At time t = ∞, when capacitor is fully charged it does not allow current through it, so its resistance may be assumed as infinite. With this concept, find steady state values of q or i at t = ∞.

(iii) **Equivalent time constant:** To find the equivalent time constant of a circuit, the following steps are followed :

(a) Short-circuit the battery

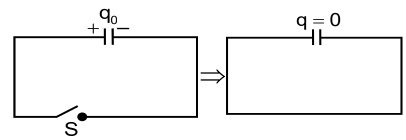
(b) Find net resistance (R_{net}) across the capacitor

(c) $\tau_C = (R_{net})C$

11.2 Discharging of a Capacitor In RC Circuit

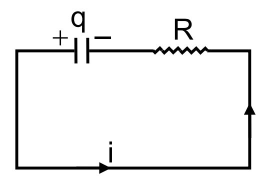
To understand discharging through a RC circuit again we first consider the discharging without resistance.

Suppose a capacitor has a charge q_0. The positive plate has a charge $+q_0$ and negative plate $-q_0$. It implies that the positive plate has deficiency of electrons and negative plate has excess of electrons. When the switch is closed, the extra electrons on negative plate immediately rush to the positive plate and net charge on both plates becomes zero. So, we can say that discharging takes place immediately.



In case of a RC circuit, discharging also takes time. Final charge on the capacitor is still zero but after sufficiently long period of time.

Consider a circuit as shown. Initial charge is q_0. Now we close switch at t = 0 and assume that charge on capacitor at time t is q and current in the circuit is i.



From KVL

$-iR + \frac{q}{C} = 0 \quad \Rightarrow \quad \frac{q}{C} = iR$ ....(i)

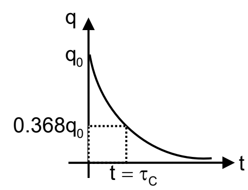
$-\frac{dq}{dt} = i$ ...(ii)

From (i) & (ii)

$$\frac{q}{c} = -R\frac{dq}{dt} \Rightarrow \int_{q_0}^{q}\frac{dq}{q} = -\int_0^t \frac{dt}{RC}$$

$$\boxed{q = q_0 e^{-t/RC}}$$

Thus, q decreases exponentially from q_0 to zero, as shown in figure.



From the graph and the equation, we see that

At $t = 0$, $q = q_0$

At $t = \tau$, $q = 0.368q_0$

At $t = \infty$, $q = 0$

11.2.1 Definition of Time Constant (τ_c)

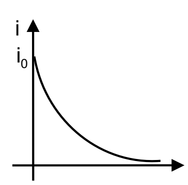
In case of discharging, definition of τ_C is changed.

At time $t = \tau_C = RC \Rightarrow q = q_0e^{-1} = 0.368\ q_0$

Hence, in this case τ_C can be defined as the time when charge reduces to 36.8% of its maximum value q_0.

During discharging, current flows in the circuit till q becomes zero. This current can be found by differentiating q with respect to t but with negative sign because charge is decreasing with time. So

$$i = \left(-\frac{dq}{dt}\right) = -\frac{d}{dt}(q_0e^{-t/\tau_c}) = \frac{q_0}{\tau_C}e^{-t/\tau_c}$$



As $\frac{q_0}{\tau_C} = i_0$

We have $i = i_0 e^{-t/\tau_c}$

This is an exponentially decreasing equation. Thus i – t graph decreases exponentially with time from i_0 to 0.

11.2.2 Behavior of Capacitor

In discharging circuit at t = 0, charge capacitor behaves like a battery of emf q_0/C.

ANSWER KEY FOR CONCEPT BUILDERS

CONCEPT BUILDER-1

1. C = 320 μF

2. $C_A > C_B$

3. 1.25% increase

4. $d = 13.275 \times 10^{-8}$ m

5. 4 μF

6. (i) +2Q and −2Q; (ii) $\Delta V = \left(\frac{2Q}{A\varepsilon_0}\right)d$

CONCEPT BUILDER-2

1. $R = 9 \times 10^9$ m

2. 33.3pF

3. b = 3 mm

4. Q = 90 mC; E = 135 J

5. $\frac{v_1}{v_2} = \sqrt{\frac{c_2}{c_1}}$

6. (i) u = 450 μJ; (ii) V = 3000 V; (iii) energy needed = 450μ J

7. E.D. = $\frac{1}{2}\varepsilon_0\left(\frac{v^2}{d^2}\right)$

8. 4.29×10^{-9} J

9. (i) Zero; (ii) $\frac{Q^2}{2C}$

CONCEPT BUILDER-3

1. (i) $Q_i = 200$ μC; (ii) $Q_f = 800$ μC

2. $C = 5C_0$; $W' = \frac{W_0}{5}$

3. (1)

4. (a) $C_{eq} = 3$pF; (b) V = 40 V

5. Charge on plate

(1) = $-\frac{\varepsilon_0 AV}{d}$ Charge on plate (4) = $\frac{2\varepsilon_0 AV}{d}$

6. $Q_1 = 640$ μC; $Q_2 = 960$ μC

7. 400 μC

Exercise - I

Capacitor and Capacitance, Parallel Plate Capacitor, Change in Capacitance by Change in Area Distance and Dielectric

1. The capacitance C of a capacitor is :
(1) independent of the charge and potential of the capacitor
(2) dependent on the charge and independent of potential.
(3) independent of the geometrical configuration of the capacitor.
(4) independent of the dielectric medium between the two conducting surfaces of the capacitor.

2. To increase the charge on the plate of a capacitor implies to
(1) decrease the potential difference between the plates.
(2) decrease the capacitance of the capacitor.
(3) increase the capacitance of the capacitor.
(4) increase the potential difference between the plates.

3. The net charge on the internal surface of a plate of capacitor is :
(1) 2q (2) q/2
(3) 0 (4) q

4. The earth has Volume 'V' and Surface area 'A' then its capacitance would be :
(1) $4\pi \epsilon_0 \frac{A}{V}$ (2) $4\pi \epsilon_0 \frac{V}{A}$
(3) $12\pi \epsilon_0 \frac{V}{A}$ (4) $12\pi \epsilon_0 \frac{A}{V}$

5. Capacitors are used in electrical circuits where appliances need rapid :
(1) Current (2) Voltage
(3) Power (4) Resistance

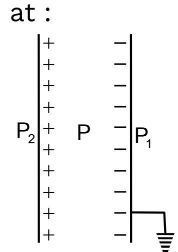
6. Which of the following is called electrical energy tank ?
(1) Resistor (2) Inductance
(3) Capacitor (4) Motor

7. The potential to which a conductor is raised, depends on :
(1) the amount of charge
(2) the geometry and size of the conductor
(3) both (1) and (2)
(4) none of these

8. The capacity of parallel plate condenser depends on :
(1) the type of metal used
(2) the thickness of plates
(3) the potential difference applied across the plates
(4) the separation between the plates.

9. A parallel plate capacitor has rectangular plates of 400 cm^2 area and are separated by a distance of 2 mm with air as the medium. What charge will appear on the plates if a 200 volt potential difference is applied across the capacitor ?
(1) 3.54×10^{-6} C (2) 3.54×10^{-8} C
(3) 3.54×10^{-10} C (4) 1770.8×10^{-13} C

10. There are two metallic plates of a parallel plate capacitor. One plate is given a charge +q while the other is earthed as shown. Point P, P_1 and P_2 are taken as shown in adjoining figure. Then the electric intensity is not zero at :



(1) P only (2) P_1 only
(3) P_2 only (4) P, P_1 and P_2

11. The distance between the plates of a circular parallel plate capacitor of diameter 40mm, whose capacity is equal to that of a metallic sphere of radius 1m will be :
(1) 0.01 mm (2) 0.1 mm
(3) 1.0 mm (4) 10 mm

12. A charged parallel plate capacitor of distance (d) has U_0 energy. A slab of dielectric constant (K) and thickness (d) is then introduced between the plates of the capacitor. The new energy of the system is given by :

(1) KU_0 (2) K^2U_0

(3) $\frac{U_0}{K}$ (4) $\frac{U_0}{K^2}$

Spherical and Cylindrical Capacitor

13. A solid conducting sphere of radius R_1 is surrounded by another concentric hollow conducting sphere of radius R_2. The capacitance of this assembly is proportional to :

(1) $\frac{R_2 - R_1}{R_1R_2}$ (2) $\frac{R_2 + R_1}{R_1R_2}$

(3) $\frac{R_1R_2}{R_1 + R_2}$ (4) $\frac{R_1R_2}{R_2 - R_1}$

14. Two spherical conductors A and B of radius 2m and 6m (b>a) are placed in air concentrically. B is given a charge +Q coulombs and A is grounded. The equivalent capacitance of the system is :

(1) $8\pi\epsilon_0$ (2) $4\pi\epsilon_0$

(3) $24\pi\epsilon_0$ (4) $36\pi\epsilon_0$

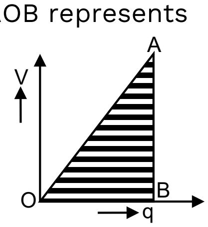
Energy Stored in Charged Capacitor, Energy Density Behaviour of Dielectric in Capacitor

15. The two parallel plates of a condenser have been connected to a battery of 300 V and the charge collected at each plate is 1μC. The energy supplied by the battery is:

(1) 6×10^{-4} J (2) 3×10^{-4} J

(3) 1.5×10^{-4} J (4) 4.5×10^{-4} J

16. The charge q on a capacitor varies with voltage as shown in figure. The area of the triangle AOB represents



(1) electric field between the plates
(2) electric flux between the plates
(3) energy density
(4) energy stored by the capacitor

17. An uncharged capacitor is connected to a battery. On charging the capacitor :

(1) all the energy supplied is stored in the capacitor
(2) half the energy supplied is stored in the capacitor
(3) the energy stored depends upon the capacity of the capacitor only
(4) the energy stored depends upon the time for which the capacitor is charged

18. The energy density in a parallel plate capacitor is given as 2.1×10^{-9} J/m^3. The value of the electric field in the region between the plates is :

(1) 2.1 NC^{-1} (2) 21.6 NC^{-1}

(3) 72 NC^{-1} (4) 8.4 NC^{-1}

19. A glass slab is put within the plates of a charged parallel plate condenser. Which of the following quantities does not change ?

(1) energy of the condenser
(2) capacity
(3) intensity of electric field
(4) charge

20. Can a metal be used as a medium for capacitor (fully filled) ?

(1) Yes
(2) No
(3) Depends on its shape
(4) Depends on its dielectric

21. Energy per unit volume for a capacitor having area A and separation d kept at potential difference V is given by :

(1) $\frac{1}{2}\varepsilon_0\frac{V^2}{d^2}$ (2) $\frac{1}{2\varepsilon_0}\frac{V^2}{d^2}$

(3) $\frac{\varepsilon_0 V^2A^2}{2d^2}$ (4) $\frac{1}{2}\frac{V^2A^2}{\varepsilon_0 d^2}$

22. A conducting sphere of radius 10cm is charged with 10μC. Another uncharged sphere of radius 20cm is allowed to touch it for some time. After that, if the spheres are separated, then surface density of charge on the spheres will be in the ratio of :

(1) 1 : 4 (2) 1 : 3

(3) 2 : 1 (4) 1 : 1

23. Mean electric energy density between the plates of a charged capacitor is :
Here q = charge on capacitor
A = Area of each plate of the capacitor
(1) $q^2 / (2\varepsilon_0 A^2)$ (2) $q / (2\varepsilon_0 A^2)$
(3) $q^2 / (2\varepsilon_0 A)$ (4) None of these

24. If potential difference across a capacitor is changed from 15V to 30V, work done is W. The work done when potential difference is changed from 30V to 60V, will be :
(1) W (2) 4 W
(3) 3 W (4) 2 W

25. Two capacitor each having a capacitance C and breakdown voltage V are joined in series. The effective capacitance and maximum working voltage of the combination is :
(1) 2C, 2V (2) $\frac{C}{2}, \frac{V}{2}$
(3) 2C, V (4) $\frac{C}{2}, 2V$

26. A parallel plate capacitor C has a charge q and potential V between the plates. Work required to double the distance between the plates is :
(1) $\frac{1}{2}CV^2$ (2) $\frac{1}{4}CV^2$
(3) $\frac{1}{2}C\left(\frac{V}{2}\right)^2$ (4) CV^2

27. Total energy stored in a 900μF capacitor at 100 volts is transferred into a 100μF capacitor. The potential drop across the new capacitor is (in volts):
(1) 900 (2) 200
(3) 100 (4) 300

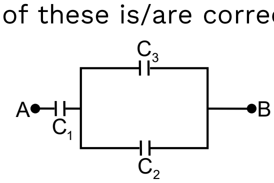
28. If the distance between plates of a capacitor having capacity C & charge Q is doubled then the work done will be :
(1) $Q^2/4C$ (2) $Q^2/2C$
(3) Q^2/C (4) $2Q^2/C$

29. A slab of copper of thickness $\frac{d}{2}$ is introduced between the plates of a parallel plate capacitor where d is the separation between its two plates. If the capacitance of the capacitor without the copper slab is C and with copper slab is C' then $\frac{C'}{C}$ is :
(1) $\sqrt{2}$ (2) 2
(3) 1 (4) $\frac{1}{\sqrt{2}}$

30. Two parallel plates of the same metal and same area are placed between the plates of a parallel plate capacitor of capacity C, If the thickness of each plate is equal to $\frac{1}{5}$th of the distance between the plates of the original capacitor then the capacity of the new capacitor is :
(1) $\frac{5}{3}C$ (2) $\frac{3}{5}C$
(3) $\frac{3}{10}C$ (4) $\frac{10}{3}C$

Combination of Capacitors & Combination of Dielectric, Kirchhoff's Law

31. The combination of capacitors with C_1 = 3μF, C_2 = 4μF and C_3 = 2μF is charged by connecting AB to a battery. Consider the following statements :
(I) Energy stored in C_1 = Energy stored in C_2 + Energy stored in C_3
(II) Charge on C_1 = Charge on C_2+ Charge on C_3
(III) Potential drop across C_1 = Potential drop across C_2 = Potential drop across C_3
Which of these is/are correct ?



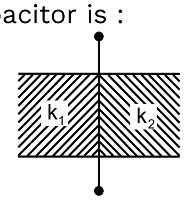
(1) I and II (2) only II
(3) I and III (4) only III

32. Two capacitors with capacity C_1 and C_2, when connected in series, have a capacitance C_s and when connected in parallel have a capacitance C_p. Which of the following is true?

(1) $C_s = C_1 + C_2$ (2) $C_p = \frac{C_1C_2}{C_1+C_2}$

(3) $\frac{C_s}{C_p} = \frac{C_1}{C_2}$ (4) $C_sC_p = C_1C_2$

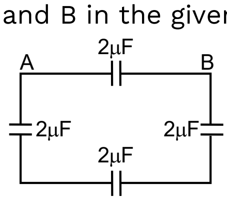
33. Two materials of dielectric constants k_1 and k_2 are introduced to fill the space between the two parallel plates of a capacitor as shown in figure. The capacity of the capacitor is :



(1) $\frac{A\in_0(k_1+k_2)}{2d}$ (2) $\frac{2A\in_0}{d}\left(\frac{k_1k_2}{k_1+k_2}\right)$

(3) $\frac{A\in_0}{d}\left(\frac{k_1k_2}{k_1+k_2}\right)$ (4) $\frac{A\in_0}{2d}\left(\frac{k_1+k_2}{k_1k_2}\right)$

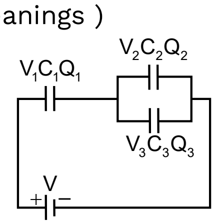
34. The equivalent capacitance between the points A and B in the given diagram is :



(1) 8 μF (2) 6 μF

(3) $\frac{8}{3}$ μF (4) $\frac{3}{8}$ μF

35. In an adjoining figure three capacitor C_1, C_2 and C_3 are joined to a battery. The correct condition will be : (Symbols have their usual meanings)



(1) $Q_1 = Q_2 = Q_3$ and $V_1 = V_2 = V_3 = V$

(2) $Q_1 = Q_2 + Q_3$ and $V = V_1 + V_2 + V_3$

(3) $Q_1 = Q_2 + Q_3$ and $V = V_1 + V_2$

(4) $Q_2 = Q_3$ and $V_2 = V_3$

36. A number of capacitors, each of capacitance 1μF and each one of which gets punctured if a potential difference just exceeding 500 volt is applied, are provided. Then an arrangement suitable for giving a capacitor of capacitance 3μF across which 2000 volt may be applied requires at least :

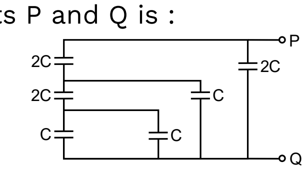
(1) 4 component capacitors

(2) 12 component capacitors

(3) 48 component capacitors

(4) 16 component capacitors

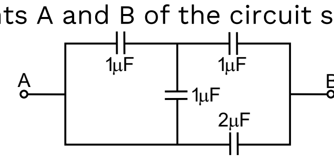
37. The value of equivalent capacitance of the combination shown in figure, between the points P and Q is :



(1) 3C (2) 2C

(3) C (4) C/3

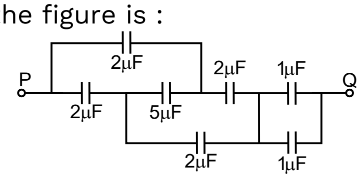
38. The equivalent capacitance between points A and B of the circuit shown will be:



(1) $\frac{2}{3}$μF (2) $\frac{5}{3}$μF

(3) $\frac{8}{3}$μF (4) $\frac{7}{3}$μF

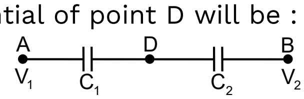
39. The effective capacitance between the points P and Q of the arrangement shown in the figure is :



(1) (1/2) μF (2) 1μF

(3) 2 μF (4) 1.33 μF

40. Two capacitance 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 :



(1) $\frac{1}{2}(V_1 + V_2)$ (2) $\frac{C_2V_1+C_1V_2}{C_1+C_2}$

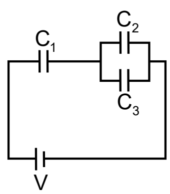
(3) $\frac{C_1V_1+C_2V_2}{C_1+C_2}$ (4) $\frac{C_2V_1+C_1V_2}{C_1-C_2}$

41. Two capacitances C_1 and C_2 are connected in series; assume that $C_1 < C_2$. The equivalent capacitance of this arrangement is C, where :

(1) $C < C_1/2$ (2) $C_1/2 < C < C_1$

(3) $C_1 < C < C_2$ (4) $C_2 < C < 2C_2$

42. Capacitance $C_1 = 2C_2 = 2C_3$ and potential difference across C_1, C_2 and C_3 are V_1, V_2 and V_3 respectively then :



(1) $V_1 = V_2 = V_3$ (2) $V_1 = 2V_2 = 2V_3$

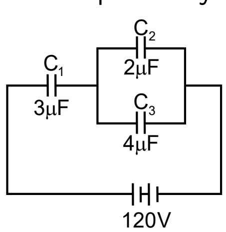
(3) $2V_1 = V_2 = V_3$ (4) $2V_1 = 2V_2 = V_3$

43. Three capacitors of capacitances 3 μF, 10 μF and 15 μF are connected in series to a voltage source of 100V. The charge on 15 μF is :

(1) 50 μC (2) 160 μC

(3) 200 μC (4) 280 μC

44. The charge on each capacitors shown in figure and the potential difference across them will be respectively:



(1) 240μC, 80μC, 160μC and 80V, 40V, 40V

(2) 300μC, 75μC, 150μC and 40V, 80V, 60V

(3) 220μC, 70μC, 140μC and 60V, 50V, 40V

(4) None of these

45. Three capacitance 2μF, 3μF and 6μF are connected in series with a 10volt battery, then charge on 3μF capacitor is :

(1) 5μC (2) 10μC

(3) 11μC (4) 15μC

46. A capacitor of capacity C_1 charged upto a voltage V and then connected to an uncharged capacitor of capacity C_2. Then final potential across each will be:

(1) $\dfrac{C_2V}{C_1+C_2}$ (2) $\dfrac{C_1V}{C_1+C_2}$

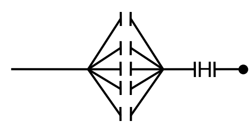
(3) $\left(1+\dfrac{C_2}{C_1}\right)V$ (4) $\left(1+\dfrac{C_1}{C_2}\right)V$

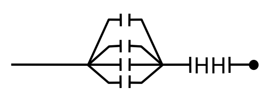
47. A capacitor of 0.2μF capacitance is charged to 600V. After removing the battery, it is connected with a 1.0μF capacitor in parallel, then the potential difference across each capacitor will become :

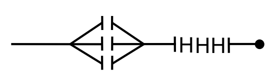
(1) 300 V (2) 600V

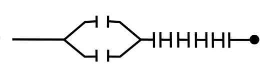
(3) 100V (4) 120V

48. Seven capacitors each of capacitance 2μF are connected so as to have a total capacity of $\dfrac{10}{11}$μF. Which will be the combination shown ?

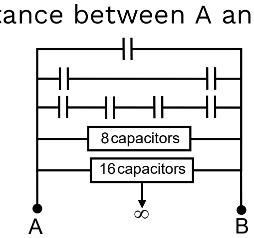
(1) 

(2) 

(3) 

(4) 

49. An infinite number of identical capacitors each of capacitance 1μF are connected as in the adjoining figure. Then the equivalent capacitance between A and B is :



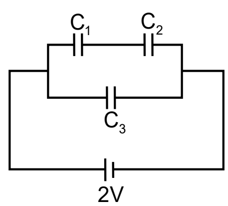
(1) 1μF (2) 2μF

(3) $\dfrac{1}{2}$μF (4) ∞

50. A 3μF capacitor is charged to a potential of 300V and 2μF capacitor is charged to 200V. The capacitors are then connected in parallel with plates of opposite polarities joined together. What amount of charge will flow, when the plates are so connected :

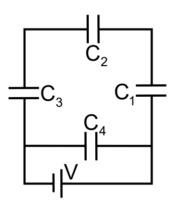
(1) 1300 μC (2) 800 μC
(3) 600 μC (4) 300 μC

51. Two capacitors C_1 = 2μF and C_2 = 6μF in series, are connected in parallel to a third capacitor C_3 = 4μF. This arrangement is then connected to a battery of e.m.f. = 2V, as shown in the figure. How much energy is given by the battery in charging the capacitors ?



(1) 22×10^{-6} J (2) 11×10^{-6} J
(3) $\left(\frac{32}{3}\right) \times 10^{-6}$ J (4) $\left(\frac{16}{3}\right) \times 10^{-6}$ J

52. A network of four capacitors of capacity equal to C_1 = C, C_2 = C, C_3 = C and C_4 = C are connected to a battery as shown in the figure. The ratio of the charges on C_2 and C_4 is :



(1) $\frac{7}{4}$ (2) $\frac{22}{3}$
(3) $\frac{1}{3}$ (4) $\frac{4}{7}$

53. A capacitor of capacitance C is initially charged to a potential difference of V volts. Now, it is connected to a battery of 2V emf with opposite polarity. The ratio of heat generated to the final energy stored in the capacitor will be :

(1) 1.75 (2) 2.25
(3) 2.5 (4) 1/2

Sharing of Charge

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

(1) 3V (2) zero
(3) 6 V (4) 4 V

55. An uncharged capacitor having capacitance C is connected across a battery of emf V. Now the capacitor is disconnected and then reconnected across the same battery but with reversed polarity. Then which of the statements is incorrect?

(1) After reconnecting, charge delivered by the battery is 2CV.
(2) After reconnecting, no energy is supplied by battery.
(3) After reconnecting, whole of the energy supplied by the battery is converted into heat.
(4) After reconnecting, thermal energy produced in the circuit will be equal to $2CV^2$.

56. Two spheres of radii 1cm and 2cm have been charged with 1.5×10^{-8} and 0.3×10^{-7} coulombs of positive charge. When they are connected with a wire, charge : $\left[V = \frac{KQ}{R}\right]$

(1) will flow from the first to the second
(2) will flow from the second to the first
(3) will not flow at all
(4) may flow either from first to second, or from the second to first, depending upon the length of the connecting wire

57. Two conducting spheres of radii R_1 and R_2 are charged with charges Q_1 and Q_2 respectively. On bringing them in contact there is :

(1) no change in the energy of the system
(2) an increase in the energy of the system if $Q_1R_2 \neq Q_2R_1$
(3) always a decrease in the energy of the system
(4) a decrease in the energy of the system if $Q_1R_2 \neq Q_2R_1$

58. Two metallic spheres of radii R_1 and R_2 are connected by a thin wire. If $+q_1$ and $+q_2$ are the charges on the two spheres then :

(1) $\frac{q_1}{q_2} = \frac{R_1^2}{R_2^2}$ (2) $\frac{q_1}{q_2} = \frac{R_1}{R_2}$

(3) $\frac{q_1}{q_2} = \frac{R_1^3}{R_2^3}$ (4) $\frac{q_1}{q_2} = \frac{\left(R_1^2 - R_2^2\right)}{\left(R_1^2 + R_2^2\right)}$

59. Two spheres have radii 10cm & 20cm. one of the sphere is given 150μC charge and other remains neutral and then connected by a wire. Their common potential will be :

(1) 9×10^6 volts (2) 4.5×10^6 volts

(3) 1.8×10^6 volts (4) 1.35×10^9 volts

60. Two capacitors, 3μF and 4μF, are individually charged across a 6V battery. After being disconnected from the battery, they are connected together with the negative plate of one connected to the positive plate of the other. What is the final total energy stored ?

(1) 1.26×10^{-4}J (2) 2.57×10^{-4}J

(3) 1.26×10^{-6}J (4) 2.57×10^{-6}J

Insertion of Dielectric Slab

61. When a slab of dielectric medium is placed between the plates of a parallel plate capacitor which is connected with a battery, then the charge on plates in comparison with earlier charge :

(1) is less
(2) is same
(3) is more
(4) depends on the nature of the material inserted

62. A parallel plate capacitor is connected to a battery and a dielectric slab is inserted between the plates, then which quantity increase :

(1) potential difference
(2) electric field
(3) stored energy
(4) E.M.F. of battery

63. A parallel plate capacitor is charged by a battery. After charging the capacitor, battery is disconnected and a dielectric plate is inserted between the plates. Then which of the following statements is not correct there is a/an?

(1) increase in the stored energy
(2) decrease in the potential difference
(3) decrease in the electric field
(4) increase in the capacitance

64. A parallel plate capacitor is charged by a battery. After charging the capacitor, battery is disconnected and distance between the plates is decreased then which of the following statement is correct?

(1) electric field does not remain constant
(2) potential difference is increased
(3) the capacitance decreases
(4) the stored energy decreases

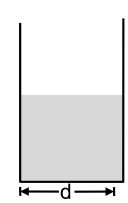
65. A parallel plate capacitor is connected with a battery whose potential difference remains constant. If the plates of the capacitor are shifted apart then the intensity of electric field :

(1) decreases and charge on plates also decreases.
(2) remains constant but charge on plates decreases.
(3) remains constant but charge on the plates increases.
(4) increases but charge on the plates decreases.

66. A parallel plate capacitor is charged with a battery and afterwards the battery is removed. If now, with the help of insulating handles, the distance between the plates is increased, then

(1) charge on capacitor increases and capacity decreases.
(2) potential difference between the plates increases.
(3) capacity of capacitor increases.
(4) value of energy stored in capacitor decreases.

67. A parallel plate air capacitor has a capacitance C. When it is half filled with dielectric of dielectric constant 5, the percentage increases in the capacitance will be :



(1) 400 % (2) 66.6%

(3) 33.3% (4) 200%

68. Half of the space between a parallel plate capacitor is filled with a medium of dielectric constant K parallel to the plates. If initially the capacity was C, then the new capacity will be :

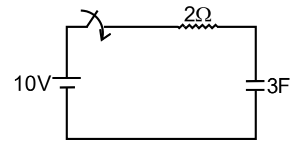
(1) 2KC/(1+K) (2) C (K+1)/2
(3) CK/(1+K) (4) KC

69. An air capacitor of capacity C= 10μF is connected to a constant voltage battery of 12V. Now the space between the plates is filled with a liquid of dielectric constant 5. The additional charge that flows now, from the battery to the capacitor is :

(1) 120 μC (2) 600 μC
(3) 480 μC (4) 24 μC

Paragraph For (Q.70 & 71)

Find out current in the circuit and charge on capacitor which is initially uncharged in the following situations.



70. Just after the switch is closed.

(1) 2A (2) 0A
(3) 4A (4) 5A

71. After a long time when switch was closed.

(1) 2A (2) 0A
(3) 4A (4) 5A

ANSWER KEY

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

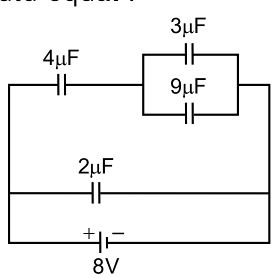
Exercise - II

1. Two sphere of radii R_1 and R_2 having equal charges are joined together with a copper wire. If V is the potential of each sphere after they are separated from each other, then the initial charge on both spheres was :

(1) $\frac{V}{k}(R_1 + R_2)$ (2) $\frac{V}{2k}(R_1 + R_2)$

(3) $\frac{V}{3k}(R_1 + R_2)$ (4) $\frac{V}{k}\left(\frac{R_1R_2}{R_1 + R_2}\right)$

2. A combination of capacitors is set up as shown in the figure. The magnitude of the electric field, due to a point charge Q (having a charge equal to the sum of the charge on the 4μF and 9μF capacitor), at a point distant 30 m from it, would equal :



(1) 240 N/C (2) 360 N/C
(3) 420 N/C (4) 480 N/C

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

(1) 6×10^{-7} C/m^2 (2) 3×10^{-7} C/m^2
(3) 3×10^4 C/m^2 (4) 6×10^4 C/m^2

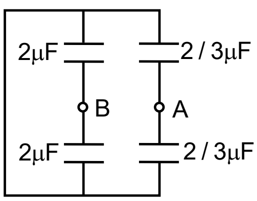
4. A parallel plate capacitor is made by staking n equally spaced plates connected alternately. If the capacitance between any two adjacent plates is C then the resultant capacitance is

(1) (n + 1) C (2) (n − 1)C
(3) nC (4) C

5. The work done in placing a charge of 8×10^{-18} coulomb on a conductor of capacity 100 μF is

(1) 16×10^{-32} J (2) 3.1×10^{-26} J
(3) 4×10^{-10} J (4) 32×10^{-32} J

6. The equivalent capacitance of the circuit across the terminals A and B is equal to-

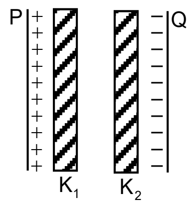


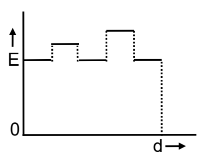
(1) 0.5 μF (2) 2 μF
(3) 1 μF (4) none of these

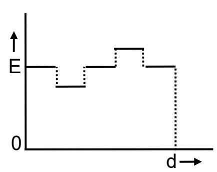
ANSWER KEY						
Que.	**1**	**2**	**3**	**4**	**5**	**6**
Ans.	2	3	1	2	4	3

Exercise – III (Previous Year Question)

1. Two thin dielectric slabs of dielectric constants K_1 and K_2 ($K_1 < K_2$) are inserted between the plates of a parallel plate capacitor, as shown in the figure. The variation of electric field 'E' between the plates with distance 'd' as measured from plate P is correctly shown by : **[AIPMT-2014]**



(1)


(2)


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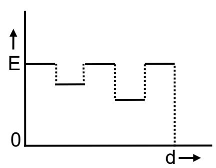
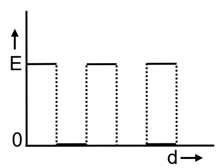


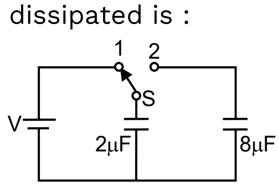
(4)


2. A parallel plate air capacitor has capacity 'C' distance of separation between plates is 'd' and potential difference 'V' is applied between the plates. Force of attraction between the plates of the parallel plate air capacitor is : **[NEET-2015 Pre]**

(1) $\frac{C^2V^2}{2d^2}$ (2) $\frac{C^2V^2}{2d}$

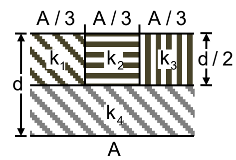
(3) $\frac{CV^2}{2d}$ (4) $\frac{CV}{2d}$

3. A capacitor of 2μF is charged as shown in the diagram. When the switch S is turned to position 2, the percentage of its stored energy dissipated is : **[NEET-2016]**



(1) 0% (2) 20%
(3) 75% (4) 80%

4. A parallel-plate capacitor of area A, plate separation d and capacitance C is filled with four dielectric materials having dielectric constants k_1, k_2, k_3 and k_4 as shown in the figure below. 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 : **[NEET-2016]**



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

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

(3) $k = k_1 + k_2 + k_3 + 3k_4$

(4) $k = \frac{2}{3}(k_1 + k_2 + k_3) + 2k_4$

5. 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 : **[NEET-2017]**

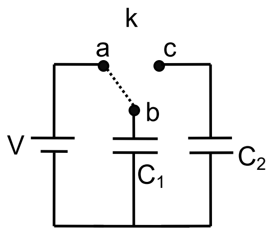
(1) increases by a factor of 4
(2) decreases by a factor of 2
(3) remains the same
(4) increases by a factor of 2

6. The electrostatic force between the metal plates of an isolated parallel plate capacitor C having a charge Q and area A, is **[NEET 2018]**

(1) independent of the distance between the plates
(2) linearly proportional to the distance between the plates
(3) proportional to the square root of the distance between the plates
(4) inversely proportional to the distance between the plates.

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

[NEET-2019 (Odisha)]



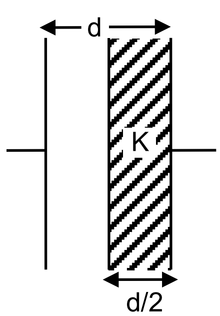
(1) 75% (2) 0%
(3) 50% (4) 25%

8. The capacitance of a parallel plate capacitor with air as medium is 6 μF. With the introduction of a dielectric medium, the capacitance becomes 30 μF. The permittivity of the medium is :

($\varepsilon_0 = 8.85\times10^{-12}\ C^2\ N^{-1}\ m^{-2}$) **[NEET-2020]**

(1) $0.44 \times 10^{-10}\ C^2\ N^{-1}\ m^{-2}$
(2) $5.00\ C^2\ N^{-1}\ m^{-2}$
(3) $0.44 \times 10^{-13}\ C^2\ N^{-1}\ m^{-2}$
(4) $1.77 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$]

9. A parallel plate capacitor having cross-sectional area A and separation d has air in between the plates. Now an insulating slab of same area but thickness d/2 is inserted between the plates as shown in figure having dielectric constant (K = 4). The ratio of new capacitance to its original capacitance will be, **[NEET_Covid_2020]**



(1) 2 : 1 (2) 8 : 5
(3) 6 : 5 (4) 4 : 1

10. A capacitor of capacitance 'C', is connected across an ac source of voltage V, given by $V = V_0 \sin \omega t$ The displacement current between the plates of the capacitor, would then be given by :

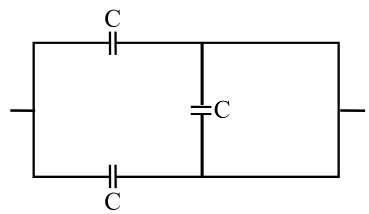
[NEET-2021]

(1) $I_d = V_0 \omega C \cos \omega t$ (2) $I_d = \frac{V_0}{\omega C} \cos \omega t$

(3) $I_d = \frac{V_0}{\omega C} \sin \omega t$ (4) $I_d = V_0 \omega C \sin \omega t$

11. The equivalent capacitance of the combination shown in the figure is :

[NEET-2021]



(1) 3C (2) 2C
(3) C/2 (4) 3C/2

12. A parallel plate capacitor has a uniform electric field '$\vec{E}$' in the space between the plates. If the distance between the plates is 'd' and the area of each plate is 'A', the energy stored in the capacitor is :

(ε_0 = permittivity of free space)**[NEET-2021]**

(1) $\frac{1}{2}\varepsilon_0 E^2$ (2) $\varepsilon_0 EAd$

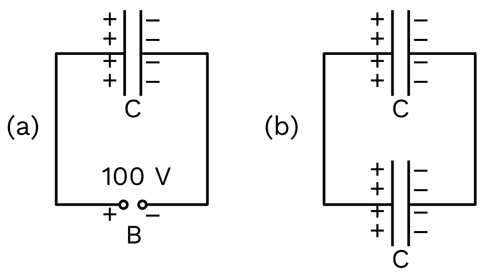
(3) $\frac{1}{2}\varepsilon_0 E^2 Ad$ (4) $\frac{E^2 Ad}{\varepsilon_0}$

13. Polar molecules are the molecules :

[NEET-2021]

(1) having zero dipole moment.
(2) acquire a dipole moment only in the presence of electric field due to displacement of charges.
(3) acquire a dipole moment only when magnetic field is absent.
(4) having a permanent electric dipole moment.

14. A capacitor of capacitance C = 900 pF is charged fully by 100 V battery B as shown in figure (a). Then it is disconnected from the battery and connected to another uncharged capacitor of capacitance C= 900 pF as shown in figure (b). The electrostatics energy stored by the system (b) is **[NEET-2022]**



(1) 4.5×10^{-6} J (2) 3.25×10^{-6} J
(3) 2.25×10^{-6} J (4) 1.5×10^{-6} J

15. The distance between the two plates of a parallel plate capacitor is doubled and the area of each plate is halved. If C is its initial capacitance, its final capacitance is equal to : **[NEET-2022]**

(1) 2 C (2) C/2
(3) 4 C (4) C/4

16. The effective capacitances of two capacitors are 3 μF and 16 μF, when they are connected in series and parallel respectively. The capacitance of two capacitors are : **[NEET-2022]**

(1) 10 μF, 6 μF (2) 8 μF, 8 μF
(3) 12 μF, 4 μF (4) 1.2 μF, 1.8 μF

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ans.	3	3	4	1	2	1	3	1	2	1	2	3	4	3	4	3