Q. Write the relation between q, V and C where terms have usual meaning.

Ans: q=CV

Where q= charge, V = potential and C = capacitance of the conductor.

Q. Define capacitance of a conductor and hence define one farad

Ans: The Capacitance of a conductor is defined as the ratio of charge given to the conductor to rise in its potential.

Capacitance of a conductor is said to be one farad when a charge of one coulomb given to the conductor raises its potential by one volt.

Q. Mention the factors on which the capacitance of a conductor depends.

Ans: Capacitance of a conductor depends on

1) The size and shape of the conductor
2) The dielectric medium surrounding the conductor.
3) Presence of nearby conductors.

Q. Define capacitance of a capacitor and also define its SI unit.

Ans: Capacitance of a capacitor is defined as the ratio of the charge given to either of its conductor to the potential difference between them.

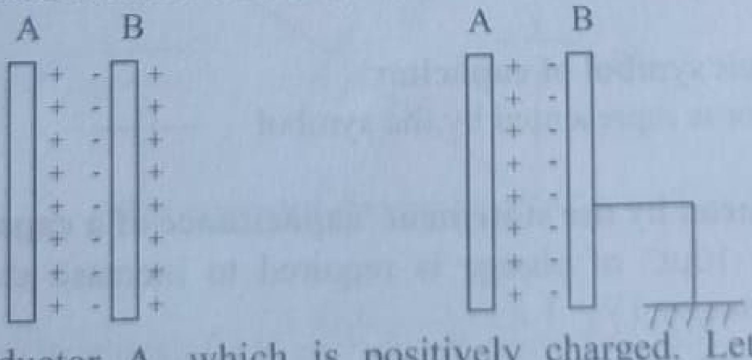
Capacitance of a capacitor is said to be one farad if the addition of one coulomb of charge given to either of its conductor raises the potential difference between them by one volt.

Q. What is a capacitor? [July 2014]

Ans: Capacitor is a device used for storing charges. It consists of two conductors separated by a small distance with a dielectric medium between them.

Q. What is "capacitor" and explain the principle of a capacitor or condenser.

Ans: Capacitor is a device used for storing charges. It consists of two conductors separated by a small distance with a dielectric medium between them.



Consider a conductor A, which is positively charged. Let another uncharged conductor B be placed near A, then negative charge is induced on the inner surface of B close to A and equivalent amount of positive charge is induced on the other surface of B. The induced negative charge on B decreases the potential of A. The induced positive charge on B, increases the potential of A. But the effect of the

negative charge is more as it is closer to A. Thus the potential of A is reduced and consequently capacitance is increased.(since c= q/V)
If the conductor B is now earthed, then all positive charges on it are neutralized due to flow of electrons from earth. Therefore potential of A further decreases and hence its capacity increases considerably.

Q. Why is the capacity of a charged conductor increases when an earthed conductor brought near to it?
Ans: When an earthed conductor is brought near a charged conductor its potential decreases, hence its capacity increases.

Q. Mention the factors on which capacitance of a capacitor depend.
Ans: Capacitance of a capacitor depends on
1) The shape and size of the conductor
2) The separation between the conductors
3 The dielectric medium between the conductors.

Q. Does the capacitance of a conductor depend on the charge on the conductor?
Ans: No
($\because C = Q/V \Rightarrow$ When Q increases, V also increases such that C remains constant.)

Q. A solid and hollow spherical conductors have equal radii. Which one has higher capacitance?
Ans: Capacity of both the conductors is same.
(Capacity of a conductor depends on its radius. As the radius of both solid and hollow spheres is same, capacity of both the conductors is same.)

. How does capacitance of a conductor vary with the increase of permittivity of medium around it?
Ans: Capacitance of conductor increases with the increase of permittivity of medium.

Write the circuit symbol of capacitor
Ans: A capacitor is represented by the symbol —||—

What do you mean by the statement 'capacitance of a capacitor is 10μF'?
Ans: It means 10μC of charge is required to increase the potential difference between the plates by 1V.

What is the charge on a capacitor of capacitance 10μF charged to 40V?
Ans: $C = 10\mu F$, $V = 40V$
$q = CV = 10 \times 10^{-6} \times 40 = 400\mu C$

Q. Can we give any desired amount of charge to a capacitor?

Ans: No.

(When we charge a capacitor its potential increases. There is a certain value of p.d between the plates of the capacitor beyond which dielectric breakdown occurs.)

Q. What form of energy is stored in a charged capacitor?

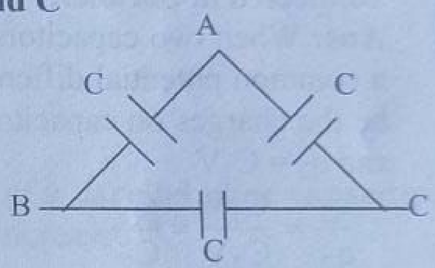
Ans: Electric potential energy is stored in the electric field between the two plates of a capacitor..

Q. Compare the effective capacitances of two equal capacitors when connected in series and in parallel.

Ans: The ratio of effective capacitance of n similar capacitors first connected in series and then in parallel is $1:n^2$

Here $n = 2$, $\therefore$ Ratio of the capacitance is 1:4.

Q. Three capacitors each of capacitance C farad are connected to form a triangle ABC. Find the effective capacitance between B and C

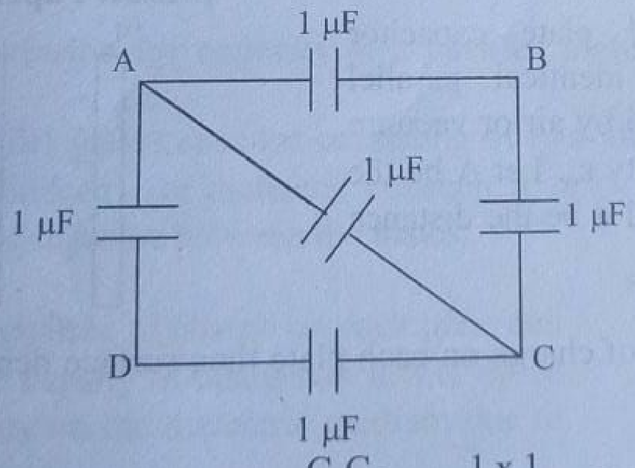


Ans: When C and C are in series $C_S = \frac{c \times c}{c + c} = \frac{C}{2}$

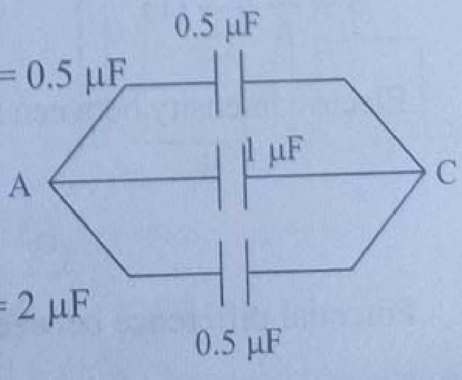
This $\frac{C}{2}$ is in parallel with another C

Therefore effective capacitance between B and C is $= \frac{C}{2} + C = \frac{3}{2}C$

Q. Find the effective capacitance between A and C in the following figure.



Ans: 1 μF and 1 μF are in series. $C_5 = \frac{C_1 C_2}{C_1 + C_2} = \frac{1 \times 1}{1+1} = 0.5\ \mu F$



All the 3 capacitors are in parallel, $\therefore C_P = 0.5 + 1 + 0.5 = 2\ \mu F$

Q. When a dielectric is introduced between the plates of a charged air capacitor disconnected from a cell, what happens to its (i) capacitance (ii) charge stored (iii) potential difference (iv) energy stored?

Ans: When a dielectric is introduced between the plates of a charged air capacitor disconnected from a cell, then capacity increases, charge remain constant, whereas p.d and energy stored decreases.

Q. When a dielectric is introduced between the plates of a charged air capacitor connected to a cell, what happens to its (i) capacitance (ii) charge stored (iii) potential difference (iv) energy stored ?

Ans: When a dielectric is introduced between the plates of a charged air capacitor connected to a cell, then p.d remain constant, whereas capacity, charge and energy stored increases

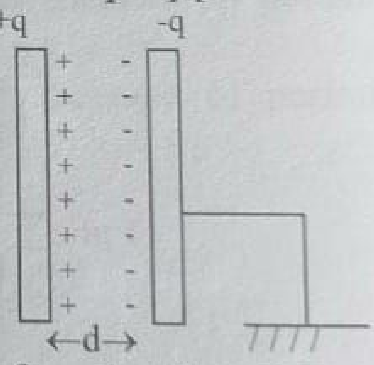
Q. Two capacitors with capacitances C_1 and C_2 are charged to potentials V_1 and V_2 respectively. What is the ratio of their respective charges when they are connected in parallel?

Ans: When two capacitors charged to different potentials are connected in parallel, a common potential difference V is established across the combination. If q_1 and q_2 be the charges on capacitors of capacitances C_1 and C_2 respectively, then $q_1 = C_1V$ and $q_2 = C_2V$

$$\therefore \frac{q_1}{q_2} = \frac{C_1V}{C_2V} = \frac{C_1}{C_2}$$

Q. Derive an expression for capacity of a parallel plate capacitor separated by air or vacuum. [Model Paper] [March 2015]

Consider a parallel plate capacitor consisting of two identical parallel metal plates separated by air or vacuum of absolute permittivity ε_0. Let A be the area of each plate and d be the distance between the plates.



If q is the magnitude of charge on each plate then surface density of charge on it is

$$\sigma = \frac{q}{A} \text{ ----- (1)}$$

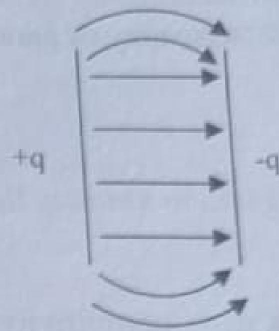
Electric intensity between the plates $E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

$$E = \frac{q}{A\varepsilon_0} \text{ --- (2) from (1)}$$

Potential difference between the plates $V = Ed = \frac{q\,d}{A\varepsilon_0}$ ----- (3) $\left(\because E = \frac{V}{d}\right)$

Capacity of parallel plate capacitor $C = \frac{q}{V} = \frac{q}{\left(\frac{q\,d}{A\,\varepsilon_o}\right)}$ from (3)

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

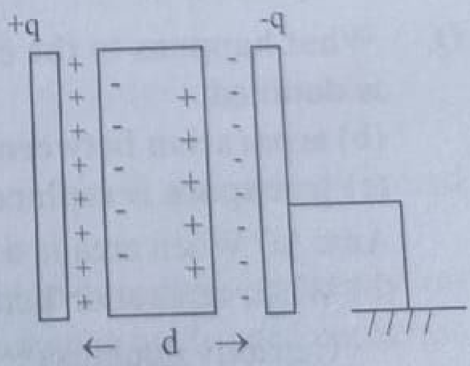


Note: Fringing of the electric field:
In the case of parallel plate capacitor, electric field lines are parallel to each other but at the edge or at the corner of the plate, field lines are curved (as shown in the diagram). This is known as fringing of the electric field.

Q. Mention the factors on which capacitance of a parallel plate capacitor depends.
Ans: Capacitance of a parallel plate capacitor depends on
1. area of the plates
2. distance between the plates
3. dielectric medium between the plates

Q. Mention the methods to increase the capacitance of a parallel plate capacitor.
Ans: Capacitance of parallel plate capacitor can be increased
1. by increasing the area of the plates
2. by decreasing the distance between the plates
3. by using a medium of higher dielectric constant between the plates

Q Derive the expression for capacity of a parallel plate capacitor with dielectric medium.
Consider a parallel plate capacitor consisting of two identical parallel metal plates separated by a dielectric of dielectric constant K or ε_r. Let A be the area of each plate and d be the distance between the plates.



Let q be the magnitude of charge on each plate and σ be the surface density of charge on it. Let σ_P be the charge density on the dielectric medium due to electric polarization.
Net charge density = $\sigma - \sigma_P$.

Let E be the net electric field between the plates.

Net electric field between the plates given by $E = \frac{\sigma - \sigma_p}{\varepsilon_o}$.

But for linear dielectrics, $\sigma - \sigma_p = \frac{\sigma}{K}$.

$$\therefore\ E = \frac{\sigma - \sigma_p}{\varepsilon_o} = \frac{\sigma}{K\varepsilon_o}.$$

Potential difference between the plates $V = Ed = \frac{\sigma}{K\varepsilon_o} \times d \qquad (\because E = \frac{V}{d})$

Capacity of parallel plate capacitor

$$C = \frac{q}{V} = \frac{q}{\left(\frac{\sigma d}{K\varepsilon_o}\right)} = \frac{q}{\left(\frac{qd}{AK\varepsilon_o}\right)} \qquad (\because \sigma = \frac{q}{A})$$

$$C = \frac{AK\varepsilon_o}{d} \quad \text{Or} \quad C = \frac{A\varepsilon_o\varepsilon_r}{d}$$

ε_o = permittivity of free space and ε_r or K= dielectric constant of the medium between the plates.

Note: From the equation of capacitance of different capacitors it can be shown that $\varepsilon_r = \frac{C_m}{C_a}$ where C_m is the capacitance of the capacitor with dielectric medium and C_a is the capacitance same capacitor with air as electric medium.

Q. Define dielectric constant

Ans: Dielectric constant of the medium is defined as the ratio of the capacitance of a capacitor with medium as dielectric to the capacitance of the same capacitor with air as dielectric.

Q. What happens to the charge on a parallel plate capacitor when the potentia difference between its plates is doubled?

Ans: When the p.d across the plates of the capacitor is doubled, then charge on i doubles.

$(\because C = \frac{Q}{V}$, C is a constant)

What happens to the capacity of a parallel plate air capacitor, when (a) its ar is doubled

(b) separation between conductors is halved

(c) free space is replaced by mica?

Ans: (a) When area is doubled, Capacity doubles ($\because C \propto A$)

(b) When separation between conductors is halved,

Capacity doubles ($\because C \propto 1/d$)

(c) When free space is replaced by mica, Capacity increases ($\because C \propto \varepsilon_r$)

Q. Derive the expression for energy stored in a capacitor. [March 2016]

Ans: A capacitor can be charged to a certain potential by connecting its terminals to a battery. During the process of charging, work is done. The energy equivalent of work done is stored in the form of electric potential energy in the electric field between the plates of the capacitor

Consider a capacitor of capacity C connected to a battery. During the process of charging let q be the charge and V' be the p.d between the plates of the capacitor at an instant of time t.

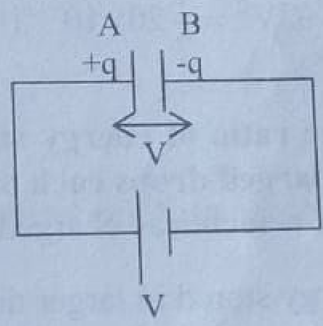
Then $q = CV'$ or $V' = \frac{q}{C}$ ---- (1)

Let dW be the small amount of work done in transferring a small quantity of charge dq through the pd V'.

$dW = V'\,dq = \left(\frac{q}{C}\right)dq$ From eq^n (1)

$\therefore$ Total work done in charging the capacitor to a charge Q is

$$W = \int_0^Q dW = \int_0^Q \frac{q}{C}\,dq = \frac{1}{C}\int_0^Q q\,dq$$



$$W = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q \quad \because \int x\,dx = \frac{x^2}{2}$$

$$W = \frac{1}{C}\left[\frac{Q^2}{2} - 0\right]$$

$$W = \frac{Q^2}{2C}$$

This work done by the battery in charging the capacitor is stored as electric potential energy U in it. $\therefore U = \frac{Q^2}{2C}$

Also $U = \frac{1}{2}CV^2 = \frac{1}{2}\left(\frac{Q^2}{C}\right) = \frac{1}{2}QV$ ($\because Q = CV$ where V is the p.d between the plates.)

Note:

1. When n identical charged drops each of energy U_S are combined, then energy stored in the larger drop is $U_L = n^{5/3}U_S$
2. Graph of q Vs V is a straight line with slope (q/V) equal to capacity and area below the graph (½ qV) gives energy stored in the charged conductor or charged capacitor.

3. When a dielectric is introduced between the plates of a charged air capacitor disconnected from a cell, then capacity increases, charge remains constant, where as p.d and energy stored decreases.
4. When a dielectric is introduced between the plates of a charged air capacitor connected to a cell or battery, then p.d remain constant, where as capacity, charge and energy stored increases.

Q. Two capacitors of capacity 2μF and 4μF are connected in parallel across 20V supply. What is the energy stored in the combination?

Ans: $C_1 = 2\mu F$, $C_2 = 4\mu F$, $V = 20V$ $\therefore C_P = C_1 + C_2 = 6\mu F$

Energy stored in the combination is $U = \frac{1}{2} C_P V^2 = \frac{6\times10^{-6}\times400}{2}$

$$= 12\times10^{-4} = 1.2\times10^{-3}\,J$$

Q. A 20pF capacitor is connected to 100v battery. What is the energy stored in the capacitor

Ans: $U = \frac{1}{2}CV^2 = \frac{1}{2}20\times10^{-12}(100)^2 = 100\times10^{-9}\,J = 10^{-7}\,J$

Q. What is the ratio of energy stored in the larger drop to smaller drop when n identical charged drops each of energy U_S are combined?

Ans: When n identical charged drops each of energy U_S are combined, then the ratio of energy stored in larger drop to the smaller drop is $\frac{U_B}{U_S} = n^{5/3}$

Two charged spheres of radii r and 2r are connected together. Compare the energy stored in them.

Ans: Energy stored in a charged sphere of capacity C is $U = \frac{1}{2}CV^2$

When the potentials of the spheres are same $U \propto C$, but $C \propto R \Rightarrow U \propto R$

$$\therefore \frac{U_1}{U_2} = \frac{R_1}{R_2} = \frac{r}{2r} = \frac{1}{2}$$

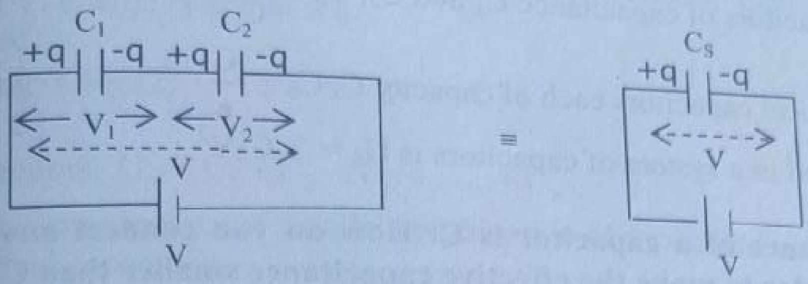
What is equivalent (effective) capacitor?

Ans: An equivalent capacitor is a single capacitor that has the same capacitance as that of combination of the capacitors.

What is meant by series combination of capacitors? Derive an expression for the equivalent capacitance when two capacitors connected in series (or number of capacitors connected in series). [Model paper]

Ans: A number of capacitors are said to be in series when they are connected end to end such that

1) The charge on each capacitor is same and



2) Potential difference across the combination is equal to the sum of the potential differences across the individual capacitors.

Let C_1 and C_2 be the capacitances of two capacitors connected in series. When a potential difference V is applied across the combination, the charge 'q' stored in each capacitor. If V_1 and V_2 are the potential differences across individual capacitors, then,

$V = V_1 + V_2$ (from the law of conservation of energy)

But $V_1 = \frac{q}{C_1}$ and $V_2 = \frac{q}{C_2}$

$$\therefore V = \frac{q}{C_1} + \frac{q}{C_2} = q\left(\frac{1}{C_1} + \frac{1}{C_2}\right) \text{------------ (1)}$$

If C_S is the equivalent capacitance of the combination, then for the pd of V, charge stored in it q.

ie, $q = C_S V$ or $V = \frac{q}{C_S}$ ----------------(2).

Sub. eq(1) in eq (2), $\frac{q}{C_S} = q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$

$$\frac{1}{C_S} = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

Or for n capacitors, $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots + \frac{1}{C_n}$

Thus the reciprocal of equivalent capacity of series combination of capacitors is equal to the sum of the reciprocals of the individual capacitances.

Note:

In series combination of capacitors

1. The effective capacity is always less than the least capacity in the combination.
2. The capacitance of a capacitor is inversely proportional to the potential difference across it.

$\therefore$ For two capacitors in series, $\frac{C_1}{C_2} = \frac{V_2}{V_1}$

3. For two capacitors of capacitance C_1 and C_2, $C_S = \dfrac{C_1C_2}{C_1 + C_2}$

4. For 'n' identical capacitors each of capacity C, $C_S = \dfrac{C}{n}$

5. Energy stored in a system of capacitors is $U_S = \frac{1}{2} C_S V^2$

Q. The capacitance of a capacitor is C. How do you connect another capacitor with it, in order to make the effective capacitance smaller than C?

Ans: By connecting a capacitor in series with C.

Q. Calculate the effective capacitance of two capacitors 2μF and 6μF connected end to end.

Ans: Effective capacitance of 2 capacitors when connected end to end is

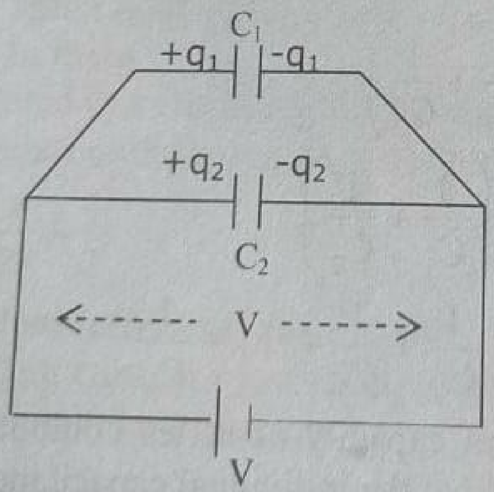
$$C_S = \frac{C_1C_2}{C_1 + C_2} = \frac{2 \times 6}{2+6} = \frac{12}{8} = \frac{3}{2} = 1.5\ \mu F$$

Q. What is meant by parallel combination of capacitors? Derive an expression for equivalent capacitance when two capacitors connected in parallel (or number of capacitors connected in parallel). [Model Paper]

Ans: A number of capacitors are said to be in parallel when they are connected between two points such that

1) The potential difference across each capacitor is same.

2) The total charge stored in the combination is equal to the sum of the charges stored in the individual capacitors.



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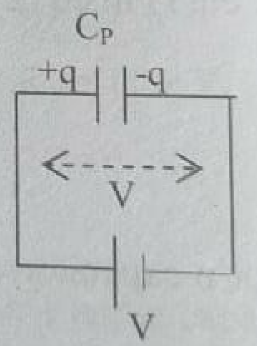

Consider two capacitors of capacitance C_1 and C_2 connected in parallel. Let V be the potential difference across each capacitor or combination and q_1 and q_2 be their charges respectively.

Then total charge, $q = q_1 + q_2$ ---- (1) (from the law of conservation of charge)

But, $q_1 = C_1V$ and $q_2 = C_2V$

Substituting in (1) $q = C_1V + C_2V$

$q = V(C_1 + C_2)$ ---- (2)

If C_P is the equivalent capacitance of the combination, then for the potential difference V, charge stored in it q.

ie, $q = C_P V$

Substituting in eqn(2) $C_P V = V(C_1 + C_2)$

$C_P = C_1 + C_2$

For n capacitors, $C_p = C_1 + C_2 + C_3 + ... + C_n$.

Thus equivalent capacity of parallel combination of capacitors is equal to the sum of the individual capacitances.

Note:

In parallel combination of capacitors,

1. The effective capacitance is always greater than the greatest capacity in the combination.
2. The capacitance of a capacitor is directly proportional to the charge on it.
3. For n identical capacitors each of capacity C, $C_P = nC$
4. Energy stored in the system of capacitors is $U_P = \frac{1}{2} C_P V^2$
5. Two capacitors of capacity C_1 and C_2 are charged to a potential of V_1 and V_2 and then connected in parallel.

	Before the combination	**After the combination**
Capacity	C_1 & C_2	C_1 & C_2
Potential	V_1 & V_2	Common Potential $V = \frac{C_1V_1 \pm C_2V_2}{C_1 + C_2} = \frac{Q_1 \pm Q_2}{C_1 + C_2}$
Charge	$q_1 = C_1V_1$ & $q_2 = C_2V_2$	$Q_1 = C_1V$ & $Q_2 = C_2V$
Energy	$U_1 = \frac{1}{2} C_1V_1^2$ & $U_2 = \frac{1}{2} C_2V_2^2$	$U_1' = \frac{1}{2} C_1V^2$ & $U_2' = \frac{1}{2} C_2V^2$
Loss of energy	$\Delta U = (U_1 + U_2) - (U_1' + U_2')$	

6. The ratio of equivalent capacitance of n similar capacitors first connected in parallel and then in series is $\frac{C_P}{C_S} = n^2 \Rightarrow C_P : C_S = n^2 : 1$
7. Loss of energy when two charged capacitors are connected in parallel is, $\Delta U = \frac{1}{2} C_S(V_1 \sim V_2)^2$
   This energy appears in the form of heat in the connected wire.

Q. In a particular combination of capacitors, charges stored are proportional to their capacitance. What is the type of combination used?

Ans: Parallel combination.

($\because Q = CV$. For parallel combination, V is same $\therefore Q \propto C$)

Q. Two capacitors of capacitance 1 μF and 1.25 nF are connected in parallel. What is the effective capacitance of the combination?

Ans: $C_p = C_1 + C_2 = 1 \times 10^{-6} F + 1.25 \times 10^{-9} F$

$= 1 \times 10^{-6} F + 0.00125 \times 10^{-6} F = 1.00125 \times 10^{-6} F$

Q. Write the expression for the common potential across the combination when two charged capacitors are connected in parallel.

Ans: Two capacitors of capacity C_1 and C_2 are charged to a potential of V_1 and V_2 and then connected in parallel, then the common potential V across the combination is

$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$ when their like charged plates are connected together.

Q. The dielectric constant of water is a high value of about 80, still it is not used as a dielectric medium in capacitors. Why?

Ans: Water is a good insulator only when it is pure. A slight impurity in water makes it conducting and also holding a liquid between the plates of a capacitor is practically difficult

Q. Define dielectric constant of a medium in terms of capacitance of a capacitor

Ans: Dielectric constant of a medium is defined as the ratio of the capacitance of a capacitor with the medium as dielectric to the capacitance of the same capacitor with air as dielectric.

Q. What is the effect of introducing a dielectric between the plates of a parallel plate air capacitor?

Ans: Capacitance of the capacitor increases.

Q. Is there any kind of material which when inserted between the plates of a capacitor reduces its capacitance?

Ans: No.

($C_m = C_a \varepsilon_r$. For any material other than air or free space, $\varepsilon_r > 1 \therefore C_m > C_a$)

Q. Mention the uses of capacitors.

Ans: Capacitors are used

1) to store electric charges
2) to eliminate sparks in induction coil.
3) to establish strong electric field.
4) to block dc and allow ac (hence used in filter circuits).
5) to determine dielectric constant