**According to new syllabus of all intermediate boards of Sindh.**

## *Prof. Rawala's ........*

# PHYSICS

## HELPING BOOK

***For***
***Class XI***
**(All science students)**



## *UNIT -9*

# *Capacitors.*

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**Thoroughly revised and updated 2026 – 2027**

- ***Detailed notes.***
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***Unit. 9*****.....**

# Capacitors

## Capacitors:

***Q.No.1: What is a capacitor?***

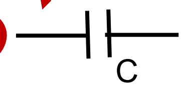
***Ans***: Capacitor is an electrical device used to store ***electric charge*** and ***electrical energy***.

- A simplest capacitor consists of two conducting plates held parallel to each other and separated by small distance. Space between the plates is usually filled with a suitable insulator, called a ***dielectric medium.***

The amount of charge stored "Q" on any one plate of a capacitor is directly proportional to the potential difference "V" across it.

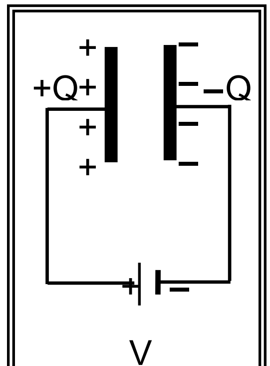
$$Q \propto V$$

$$\boxed{Q = C\,V}$$





***Circuit notation***





***Capacitor***

Where "C" is the constant of proportionality, known as ***capacitance of the capacitor***.

### Definition of capacitance C:

***Q.No.2: Define capacitance of a capacitor and define its S.I unit.***

***Ans***: Capacitance of a capacitor "C" may be defined as:

***"The amount of charge required to produce unit potential difference across its plates"***

- Capacitance of capacitor actually represents its ***charge storing ability*** i.e. it tells us that how much charge a capacitor can store per unit potential difference across its plates.
- Capacitance of capacitor depends upon area "A" of its plates, their separation "d" and properties of the dielectric medium (Which is a suitable insulator) present between its plates **(In other words** capacitance of a capacitor depends upon its ***geometry*** and ***nature of material*** between its plates).

### Unit of capacitance C:

Unit of capacitance is "***farad***".

Capacitance of a capacitor is said to be one farad (1 F) if on giving one coulomb (1 C ) charge to one of its plates the potential difference across it rises by one volt (1 V).

$$1 \text{ farad} = \frac{1 \text{ coulomb}}{1 \text{ volt}}$$

Submultiples of farad are: $1\ \mu F = 10^{-6}\ F$

$1\mu\mu F = 1\text{pico farad } (1\ pF) = 10^{-12}\ F$

## ***Types of capacitors***: **Variable capacitors**:

Capacitance of these capacitors can be changed to any desired value within a suitable range. Usually a variable capacitor has two parallel sets of metallic plates. One set of plates is fixed while the other set can be rotated with its plates rotating between the plates of first without touching it. In this manner distance between plates and the area of a plate facing its nearby plates also changes which results in a change in the overall capacitance of the capacitor.

Variable capacitors are used in tuning circuits of transmitters and receivers of different applications such as radios, televisions etc.

**Ceramic capacitors**:

These capacitors use ceramic as a dielectric medium and are not polarized.Ceramic capacitors are used in high voltage laser power supplies, power circuit breakers etc.

**Mica capacitors**:

These capacitors use mica as a dielectric medium and are not polarized. These capacitors can be operated at high voltages and high power but are of low capacitance.

**Film capacitors**:

Usually paper or polyester is used in these capacitors as dielectric medium Film capacitors are used in high power electronic applications such as X-ray flashes, phase shifters, pulse lasers etc.

**Electrolytic capacitors**:

These capacitors use some electrolyte between their plates as a dielectric medium. Electrolytic capacitors are polarized hence their terminals are marked with + and - signs. These are used to reduce the unwanted ripple voltage.
Electrolytic capacitors have high capacitances and are used in almost all power supplies. These capacitors stabilize output voltage and supply current at a uniform rate.

## ***Some uses of capacitors from daily life electrical appliances***:

Capacitors are widely used in electrical appliances.

***For example***, capacitors are used in all tuning circuits, such as in channel selector of a TV-set, tuning circuits in radio transmitters and receivers, neon signs, road signals, wireless sets, washing machine, water pump, electric fan, mobile phones, automobile indicators, computers, electronic watches, power supplies used to smooth and regulate current, ………….. etc.

- During charging a capacitor, energy is stored in it in its electric field in the form of electrical potential energy, hence when a camera flash light is switched on, capacitor connected with the flash light discharges quickly and this stored energy produces a strong light flash, some heat is also produced.

| Material | Dielectric constant $\varepsilon_r$ |
|---|---|
| Vacuum | 1 |
| Air | 1.0006 |
| Polyethylene | 2.3 |
| Waxed paper | 2.5 |
| Nylon | 4.1 |
| Mica | 7 |
| Water | 81 |

Mica whose $\varepsilon_r$ is 7 (according to the table given in your text book), is the ***most suitable dielectric medium*** for capacitors, because it can withstand **rapid changes in potential difference** and the resulting **rapid changes in electric field** between plates of a capacitor. Chemically it **does not** easily react.

Although water has the highest value of '$\varepsilon_r$' (81) but it ***cannot be*** used as a dielectric medium in a capacitor. Water **conducts** with a slightest acidic impurity in it, so charge cannot stay on any plate. More over chemically water **reacts** with oxygen of the air and/or plate material of the capacitor forming undesirable compounds (especially ionic compounds which conduct away charges).

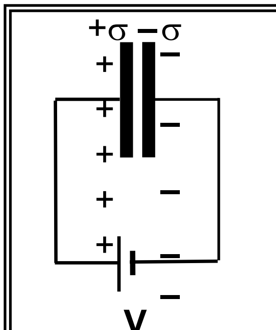
# Capacitance of a parallel plate capacitor

***Q.No.3*: Derive an expression for capacitance of a parallel plate capacitor with air or vacuum between its plates.**

***Ans***: Consider a parallel plate capacitor whose each plate is of area "A" and are separated by a small distance "d". Let "+ $\sigma$" and "– $\sigma$" be the ***surface charge density*** (charge per unit area is called surface charge density) on the two plates respectively. Distance between the two plates must be very ***small*** so that the electric field between them is ***uniform***.

The magnitude of electric intensity "E" or strength of the electric field at any point between the two oppositely charged plates is given by:

$$E = \frac{\sigma}{\varepsilon_o}$$



***Parallel plate capacitor with air***

Hence potential difference "V" between the plates will be:

$$V = E\,d$$

$$V = \frac{\sigma}{\varepsilon_o} \times d$$

But $\sigma = \frac{Q}{A}$ $\qquad \therefore \qquad V = \frac{Q\,d}{A\,\varepsilon_o}$

OR $\qquad Q = \frac{A\,\varepsilon_o\,V}{d}$ ………………… (*i*)

Charge "Q" on a plate of any capacitor is given by:

$$Q = C\,V \quad \text{……………………….. } (ii)$$

Comparing equations (*i*) and (*ii*) we get:

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

$$\therefore \qquad \boxed{C = \frac{A\,\varepsilon_o}{d}}$$

Hence capacitance of a parallel plate capacitor is ***directly proportional to area "A" of the plates*** and ***inversely proportional to separation "d" of plates***.

For high capacitance, plates must be of ***large*** area "A" and their separation "d" must be ***small***.

> ***Note that*:** **Positively charged body is said to be at higher and negatively charged body at a lower potential. Potential of a charged body depends upon the amount of charge on it. If a negatively charged body is brought close to a positively charged body the potential of positive body *lowers* and that of negatively charged body *rises*. *In other words*, when oppositely charged bodies are brought close to each other potential difference between them *decreases* without affecting their charge. This is the idea on which working of a capacitor is based.**

Since plates of a capacitor are oppositely charged, and opposite charges attract each other with a force inversely proportional to squire of distance between them.

Therefore, oppositely charged plates must be separated by a small distance, so that plates can hold large quantity of charge. Opposite charges will stay on the plates because of strong attraction between them. Hence for high capacitance (large charge per unit potential difference) distance "d" between the plates must be ***small***.

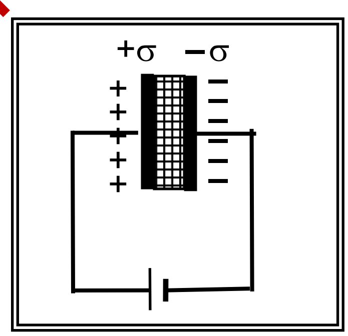
***Q.No.4*: Derive an expression for capacitance of a parallel plate capacitor with a dielectric medium between its plates.**

***Ans***: If the space between plates of a capacitor is completely occupied by a dielectric
medium of relative permittivity "$\varepsilon_r$", then the strength of electric field (or electric intensity) between the two plates decreases by "$\varepsilon_r$" times and is given by:

$$E = \frac{\sigma}{\varepsilon_o \varepsilon_r}$$

But potential difference between the plates is given by:

$$V = E\,d$$




$$\therefore \quad V = \frac{\sigma d}{\varepsilon_o \varepsilon_r}$$

$$\therefore \quad V = \frac{Q d}{A \varepsilon_o \varepsilon_r}$$

$$\therefore \quad Q = \frac{A V \varepsilon_o \varepsilon_r}{d} \;\ldots\ldots\ldots\ldots (i)$$

But the charge stored by any capacitor of capacitance "C′ " is given by:

$$Q = C' V \;\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

Comparing equation (*i*) and (*ii*) we get:

$$C' V = \frac{A V \varepsilon_o \varepsilon_r}{d}$$

$$\therefore \quad \boxed{C' = \frac{A \varepsilon_o \varepsilon_r}{d}}$$

***Q.No.5*: Show that the capacitance of a parallel plate capacitor (or in general capacitance of any capacitor) with a dielectric medium is *more* than it's capacitance without a dielectric medium between its plates.**

***Ans***: Capacitance "C" of a parallel plate capacitor <u>without</u> a dielectric between its plates is given by:

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

But capacitance "C′ " of the same parallel plate capacitor <u>with</u> a dielectric between its plates is given by:

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

Hence,

$$\boxed{C' = \varepsilon_r C}$$

It shows that capacitance "C′ " of a capacitor (Or in other words charge storing capacity) with a dielectric medium is **$\varepsilon_r$ *times greater*** than capacitance "C" of the same capacitor without a dielectric medium between its plates (OR we can say that a capacitor will store more charge with a dielectric medium than without any medium). The value of "$\varepsilon_r$"

is more than 1. Where "$\varepsilon_r$" is known as ***relative permittivity*** of the medium, it is also known as ***dielectric constant*** of the medium.

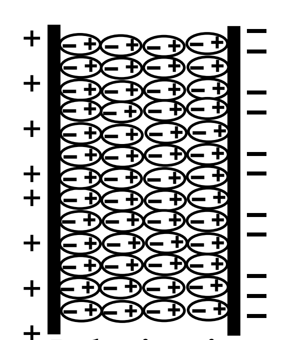
## Explanation of polarization:

***Q.No.6: Why does capacitance of a capacitor increase when a dielectric medium is inserted between its plates?***

***Ans***: When a dielectric medium, which is a suitable ***insulator***, (such as mica, waxed paper etc.) is inserted between plates of a capacitor molecules of the insulator are ***polarized***.

Due to the attraction between positively charged plate and the negatively charged electrons of atoms of the medium. The electrons in each atom are shifted slightly towards positively charged plate. This side of the dielectric, therefore, becomes slightly negative whereas the opposite end of each molecule, due this shift, becomes slightly positive. Hence oppositely charged poles appear on ends of each molecule. This phenomenon is called ***polarization***. "$\varepsilon_r$" measures the ability of polarization. Different media have different value of $\varepsilon_r$. Positively charged end of all molecules will be towards the negative and negatively charged end will be towards positive plate of the capacitor. Due to the presence of oppositely charged molecules in the vicinity of charged plates of the capacitor, potential of plates will ***decrease*** without affecting their charge, as a result of which they can hold more charge.

***In other words***, their capacitance ***increases***.



***Polarization***

***Q.No.7: What is relative permittivity or dielectric constant $\varepsilon_r$?***

***Ans***: Since: $C' = \varepsilon_r C$

$$\therefore \quad \varepsilon_r = \frac{C'}{C}$$

$$\varepsilon_r = \frac{\text{Capacitance of a capacitor with a dielectric medium between its plates}}{\text{Capacitance of the same capacitor without a dielectric medium}}$$

Hence dielectric constant "$\varepsilon_r$" of a medium may be defined as:

***"The ratio of capacitance of a capacitor with the medium to the capacitance of the same capacitor without the medium between its plates".***

Since "$\varepsilon_r$" is a ratio of two similar quantities, therefore, it **does not** have a unit.

***Q.No.8: How can capacitance of a capacitor be increased?***

***Ans***: Capacitance of a capacitor can be ***increased*** by:

(*i*) ***Increasing*** the area of its plates, because $C \propto A$.

(*ii*) ***Decreasing*** the separation of plates, because $C \propto 1/d$.

(*iii*) Using a suitable ***dielectric medium***, because C increases with $\varepsilon_r$.

## Combinations of capacitors:

### Parallel combination of capacitors:

***Q.No.9: When capacitors are connected in parallel, derive an expression for net capacitance of the combination.***

***Ans***: Two or more capacitors are said to be connected ***in parallel*** if each one of them is connected across the ***same two points*** or ***same two wires***. A suitable potential difference "$\Delta V$" is applied across the combination. In a parallel combination of capacitors the potential difference across each capacitor is ***same***, but each capacitor will store ***different charge***, according to its capacitance.

Consider a parallel combination of three capacitors of capacitances "$C_1$", "$C_2$" and "$C_3$", the potential difference across which is "V" Let the charge stored by them be "$Q_1$", "$Q_2$" and "$Q_3$" respectively. Then:

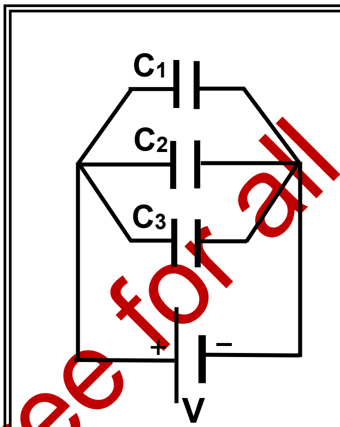
$Q_1 = C_1 V$, $Q_2 = C_2 V$, & $Q_3 = C_3 V$.

Total charge stored by the combination is given by:

$$Q = Q_1 + Q_2 + Q_3$$

$$\therefore \quad Q = C_1 V + C_2 V + C_3 V$$

$$\therefore \quad Q = V (C_1 + C_2 + C_3) \quad \ldots\ldots\ldots\ldots\ldots\ldots (i)$$




**Parallel combination of capacitors**

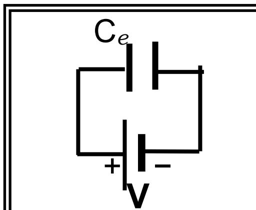
This combination of capacitors can be replaced by a single capacitor whose capacitance "$C_e$", called equivalent capacitance, is of such a value that it stores the same charge "Q" stored by the combination when the same potential difference "V" is applied across it. This is the equivalent capacitor for the combination. Hence,

$$Q = C_e V \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

Comparing equations ($i$) and ($ii$) we get:

$$C_e V = V (C_1 + C_2 + C_3)$$

$$\therefore \quad \boxed{C_e = C_1 + C_2 + C_3}$$




***Equivalent capacitor***

***"When two or more capacitors are connected in parallel their equivalent capacitance is equal to the sum of capacitance of individual capacitors"***

***Note that*** in a ***parallel combination*** of capacitors,

🗣Potential difference across each capacitor is ***same***.

🗣Amount of charge stored is ***different***, according to their individual capacitance (Large capacitance more charge).

🗣Net (or equivalent) capacitance is always ***higher than the highest*** individual capacitance.

## ***Series combination of capacitors***:

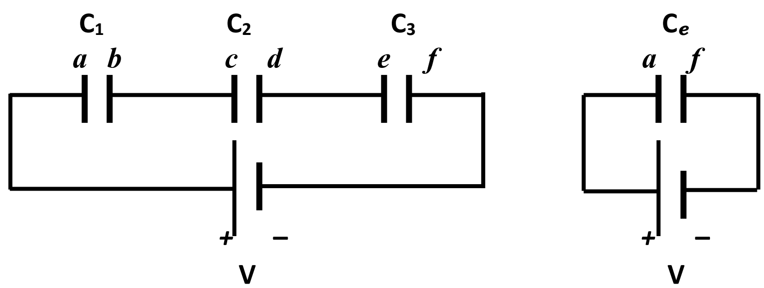
***Q.No.10: When two or more capacitors are connected in series, derive an expression for net or equivalent capacitance of the combination.***

***Ans***: Two or more capacitors are said to be connected ***in series*** if the second plate of first capacitor is connected with the first plate of second capacitor, second plate of second capacitor is connected with the first plate of third capacitor and so on **……….** A suitable potential difference "$\Delta V$" is applied across the combination.

In a series combination of capacitors, the potential difference across different capacitors is ***different***, but each capacitor will store the ***same amount of charge*** whatever their capacitance.

Let "$V_1$", "$V_2$" and "$V_3$" be the potential difference across capacitors of capacitances "$C_1$", "$C_2$" and "$C_3$" respectively and "Q" be the charge stored on each capacitor. Then:

$Q = C_1 V_1 \quad \therefore \quad V_1 = \frac{Q}{C_1}$ Similarly: $V_2 = \frac{Q}{C_2}$ & $V_3 = \frac{Q}{C_3}$




***Series combination of capacitors*** ***Equivalent Capacitor.***

Total potential difference "V" acting across this combination will be equal to the sum of "$V_1$", "$V_2$" and "$V_3$". Hence:

$$\therefore \quad V = V_1 + V_2 + V_3$$

$$\therefore \quad V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\therefore \quad V = Q\left\{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right\} \quad \text{..................} \ (i)$$

This series combination can be replaced by a single capacitor whose capacitance "$C_e$" is of such a value that it stores the same amount of charge "Q" when the same potential difference "V" is applied across it. This single capacitor is called equivalent capacitor, it's capacitance "$C_e$" is called equivalent or net capacitance. Hence,

$$V = \frac{Q}{C_e} \quad \text{................} \ (ii)$$

Comparing equations (*i*) and (*ii*) we get:

$$\frac{Q}{C_e} = Q\left\{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right\}$$

OR

$$\boxed{\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

***"When two or more capacitors are connected in series reciprocal of their equivalent capacitance is equal to the sum of reciprocals of capacitance of individual capacitors"***

***Note that*** in a ***series combination*** of capacitors,

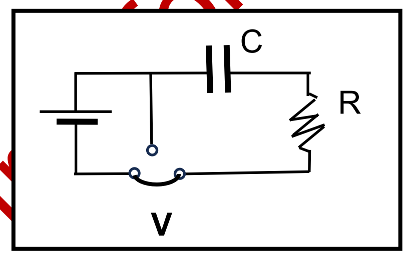
- Charge stored on different capacitors is ***same***.
- Potential difference across different capacitors is ***different***.
- Net (or equivalent) capacitance is always ***less than the least*** individual capacitance.

## ***Charging and discharging of a capacitor through a resistor (RC circuit)*:**

When a certain potential difference V is applied across a capacitor it charges **exponentially**, similarly a charged capacitor also discharges **exponentially**.***it means that*** the capacitor ***does not*** charge or discharge ***immediately***, but depending upon it's capacitance and the value of load (resistance) connected with it, it takes ***some time*** to fully charge or fully discharge.

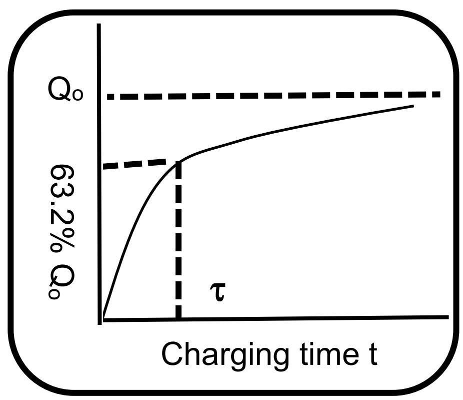
### ***Explanation*: Charging:**

Consider a capacitor of capacitance "C" connected **in series** to a resistance "R" and a battery of voltage "V", through a switch. This series combination is called **RC-circuit.** When the switch is closed in position "1" at that instant since the capacitor initially has no charge, potential difference across it will be zero and the potential difference across the resistor will be "V" (voltage of the battery), as a result of which some current starts flowing through resistor R, this current starts charging the capacitor. As the capacitor charges potential difference across it starts increasing (because Q = CV) whereas potential difference across "R" decreases, so that at any latter instant potential difference of the battery will be equal to the sum of potential difference across "R" and "C" (Series combination). When the capacitor is fully charged the current through "R" stops flowing, at that instant potential difference across "R" becomes zero where as potential difference across "C" will be equal to voltage "V" of the battery.




Capacitor ***charges exponentially***, ***it means that***, at first it charges **quickly** and then with the passage of time charging process **slows down**. Hence at any instant if "Q" is the charge stored and "$Q_o$" be the maximum charge that can be stored, making the capacitor fully charged, then:

$$\boxed{Q = Q_o\,(1 - e^{-t/\tau})}$$




Where "e" is the base of natural logarithm, its value is 2.718, " t " is the charging time and "$\tau$ = RC" is known as "**TIME CONSTANT**" for a given RC- circuit. Value of time constant depends upon the value of product "RC".

**Smaller** the value of time constant (or of RC) **shorter** is the time of charging, ***in other words*** capacitor charges ***quickly***.

**Higher** the value of time constant **longer** is the time of charging, ***in other words*** capacitor charges ***slowly***.

When a capacitor is charged for one time constant, ***in other words,*** t = 1 $\tau$ = 1 RC

Then $\quad Q = Q_o\,(1 - e^{-\tau/\tau})$ OR $Q = Q_o\,(1 - e^{-1})$ OR $Q = Q_o\,(1 - \frac{1}{e})$

Hence, $\quad Q = Q_o\,(1 - \frac{1}{2.718})$ OR $Q = Q_o\,(1 - 0.368)$

$\therefore \quad Q = 0.632\,Q_o$ OR $\boxed{\mathbf{Q = 63.2\ \%\ of\ Q_o}}$

***It means that*** after one time constant (1 $\tau$ = 1 RC) the amount of charge stored on a capacitor will be 63.2% of total amount of charge that a given capacitor can store. Similarly after 2 time constants the amount of charge stored will be 86.5 % of total charge.

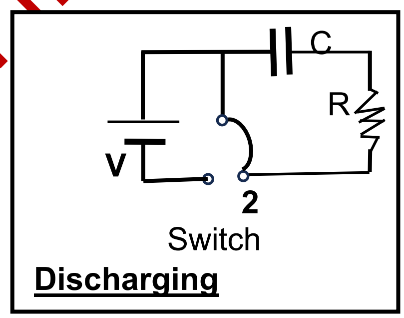
After 3 time constants the amount of charge stored will be 95 % of total charge.
After 4 time constants the amount of charge stored will be 98.2 % of total charge.
After 5 time constants the amount of charge stored will be 99.3 % of total charge.
Hence after five-time constants a capacitor of given value with some load (resistance) connected with it in series may be considered fully charged.

***Note that***, during the charging process charge on the capacitor ***increases***, Current in the circuit ***decreases*** and potential difference (voltage) across the capacitor ***increases***,

## Discharging:

Now if the switch in the circuit is moved to position **2** then the battery will be disconnected ***In other words*** now there is no external source of emf that can supply charge to the capacitor. Hence the capacitor will start **discharging** through the resistor "R" and current will again flow in the circuit through the resistor "R" but this time in opposite direction.

Capacitor ***discharges exponentially***, ***it means that***, at first it discharges **quickly** and then with the passage of time discharging process **slows down**. Hence if at the beginning of discharge "$Q_o$" is the charge on capacitor then at any later instant charge "Q" remaining on it is given by:




$$\boxed{Q = Q_o e^{-\tau/\tau}}$$

After one time constant

i.e. $t = 1\,\tau = 1RC$ $\quad Q = Q_o e^{-RC/RC}$ OR $Q = Q_o e^{-1}$

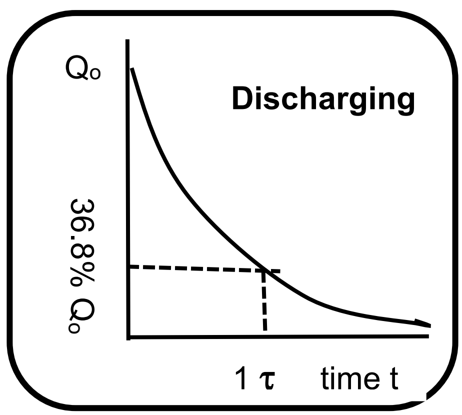
$Q = Q_o \dfrac{1}{2.718}$ OR $Q = 0.368\,Q_o$ OR **Q = 36.8% of $Q_o$**

***It means that*** after 1 time constant **36.8 % of "$Q_o$"** charge will remain on the capacitor whereas 63.2 % of $Q_o$ will discharge through the load (resistance).

After two-time constants $t = 2\,\tau = 2\,RC$

$Q = Q_o e^{-2RC/RC}$ OR $Q = Q_o e^{-2}$ OR $Q = Q_o \dfrac{1}{(2.718)^2}$

$Q = 0.135\,Q_o$ OR **Q = 13.5% of $Q_o$**




***It means that*** after 2 time constants 13.5 % of "$Q_o$" charge will remain on the capacitor whereas 86.5 % of $Q_o$ will discharge through the load (resistance).

Similarly, after 3 time constants 5% of "$Q_o$" will remain on the capacitor whereas 95% of $Q_o$ will discharge through the load (resistance).

After 4 time constants 1.8 % of "$Q_o$" will remain on the capacitor whereas 98.2 % of $Q_o$ will discharge through the load (resistance).

After 5 time constants 0.7 % of "$Q_o$" will remain on the capacitor whereas 99.3 % of $Q_o$ will discharge through the load (resistance).

***Note that***, during the discharging process charge on the capacitor ***decreases***, Current in the circuit ***increases*** and potential difference (voltage) across the capacitor ***decreases***.

***<u>Time constant</u>***. Time constant may, therefore, be defined as the time during which a fully neutral capacitor stores **63.2 % of $Q_o$** charge <u>during charging process</u> or <u>during discharging process</u> **36.8 % of $Q_o$** charge remains and **63.2 % of $Q_o$** charge flows away from it.

## ***<u>Energy stored in a charged capacitor</u>:***

- During charging a capacitor, **energy** along with **charge** is also stored in it, in its electric field, in the form of electrical potential energy. Hence when a camera flash light is switched on, capacitor connected with the flash light discharges quickly and this stored energy produces a strong **<u>light</u>** flash, some **<u>heat</u>** is also produced.

Charging of a capacitor takes some time, during this time each plate stores equal and opposite charge. At the beginning of charging process both plates are neutral so they are at ***<u>zero potential</u>***. But as the charging process continues positive plate receives more and more positive and the negative plate receives more and more negative charge. Electrical potential of positively charged plate ***<u>increases</u>*** and that of negative plate ***<u>decreases</u>***, ***in other words***, the potential difference between the plates ***<u>increases</u>***. This happens until the two plates are fully charged. Let the total amount of charge stored at the end of charging process on any one plate is "Q" (+Q on positive, **–** Q on negative plate) and the potential difference across the plates is "V". At the beginning of charging process potential difference across the plates was "**0**" and at the end is "**V**". Hence the average potential difference is "$\frac{1}{2}$ **V**". Since,

$$\text{Potential difference} = \frac{\text{Work or energy}}{\text{Charge}}$$

Therefore, in this case:

$$\tfrac{1}{2} V = \frac{\text{Energy } E}{Q}$$

$$\therefore \quad \boxed{E = \tfrac{1}{2} Q V} \qquad\qquad \text{But } Q = C V$$

$$\therefore \quad \boxed{E = \tfrac{1}{2} C V^2}$$

Energy stored in a charged capacitor, therefore, depends upon its capacitance "C", charge "Q" stored and the potential difference "V" across its plates.

For a given capacitor (for a given value of "C") energy stored depends upon voltage "V" and charge "Q". Higher the voltage "V" more is the charge "Q" stored and therefore, more is the energy "E". But if a certain limit is crossed charge stored starts leaking. Hence there is a limit to the voltage that can be applied safely. Value of safe maximum operating voltage is written on each capacitor.

## <u>***Section–A Multiple-Choice Questions MCQs***</u>:

***<u>Q.No.1</u>***: The capacitance of a capacitor is NOT influenced by:
(A) Plate thickness. (B) Plate area.
(C) Plate separation (D) Nature of the dielectric

***<u>Q.No.2</u>***: What is the value of capacitance of a capacitor which has a voltage of 4 V and has 16 C of charge?
(A) 2 F (B) 4F. (C) 6 F (D) 8 F

***<u>Q.No.3</u>***: Capacitors are used in electric power supply system to:
(A) Improve power factor.(B)Reduce line current
(C) Provide voltage stability. (D) Switching.

***<u>Q.No.4</u>***: In a variable capacitor, capacitance can be varied by:
(A) Turning the rotatable plates in or out
(B) Changing the plates.
(C) Colliding rotatable plates.
(D) Changing the material of plates.

***<u>Q.No.5</u>***: Energy stored in a capacitor is:
(A) $E = \frac{1}{4} CV$ (B) $E = \frac{1}{2} CV^2$
(C) $E = CV^2$ (D) $E = \frac{1}{2} CV$

***<u>Q.No.6</u>***: The time constant of a series RC circuit consisting of 100 μF capacitor in series with a 100 Ω resistor is:
(A) 0.1 s (B) 0.1 ms (C) 0.01 s (D) 0.01 ms

***<u>Q.No.7</u>***: The charging of a capacitor through a resistance follows:
(A) Linear law. (B) Square law.
(C) Exponential law. (D) None of the above.

***<u>Q.No.8</u>***: When the total charge on a capacitor is doubled, the energy stored:
(A) Remains the same.(B) is doubled.
(C) is halved. (D) is quadrupled.

***<u>Q.No.9</u>***: The capacitor of capacitance C is charged through a resistor R. The time constant of the charging circuit is given by:
(A) C/R (B)1/ RC (C) RC (D) R/C

***<u>Q.No.10</u>***: Capacitor blocks:
(A) alternating current. (B) direct current.
(C) both alternating and direct current.
(D) neither alternating nor direct current.

***<u>Q.No.11</u>***: A dielectric k = 2 is inserted between the plates of a 19.8 μF capacitor. Its capacitance will become.
(***2005 Karachi Board***)
(A)10 μF (B) 18 μF (C) 22 μF (D) 39 μF

***<u>Q.No.12</u>***: Coulomb /volt is the unit of:
(***2007 Karachi Board***)
(A)Resistance (B)Resistivity (C)Current (D)Capacity

***<u>Q.No.13</u>***:The capacitance of a capacitor does not depend on the:
(***2009 Karachi Board***)
(A)Area of the plates(B) Nature of the plates.
(C) Distance between the plates.
(D) medium between the plates.

***<u>Q.No.14</u>***: If the area of the plates of a parallel plate capacitor is doubled, the capacitance: (***2012 Karachi Board***)
(A) Remains unchanged. (B) is half.
(C) is doubled. (D) is increased four times

***<u>Q.No.15</u>***: If two capacitors of capacitances 4 μF and 2 μF are connected in series, the equivalent capacitance is:
(***2021,06 Karachi Board***)
(A) 6 μF (B) 2 μF (C) 1.33 μF (D) 0.76 μF

***<u>Q.No.16</u>***: When a dielectric is placed in an electric field, it becomes:
(***2021, 09 Karachi Board***)
(A) Negatively charged only
(B) Positively charged only
(C) Polarized (D) Conductive

***<u>Q.No.17</u>***: If two capacitors 5μF and 7μF are connected in parallel, their equivalent capacitance will be:
(***2021 Karachi Board***)
(A) 0.12μF (B)12μF. (C)0.34μF (D) 2.9μF

***<u>Q.No.18</u>***: If distance between the plates of a capacitor of capacitance C is doubled and area of plates is halved, the capacitance will become: (***2022,17,16 Karachi Board***)
(A) C/4 (B) C (C) 4C (D) 2 C

***<u>Q.No. 19</u>***: Coulomb/volt is equal to:
(***2023 Karachi Board***)
(A) Newton (B) Joule (C) Farad (D) Ohm

***<u>Q.No.20</u>***: Charging of a capacitor through a resistance follows(***2025 Karachi Board***)
(A) Coulomb's law. (B) Exponential law.
(C) Power law. (D) Inverse square law.

***Q.No.21*:** In a charged parallel plate capacitor , the electric field between the plates is: **(*2026 Karachi Board*)**

(A) Uniform. (B) Non - uniform.
(C) Zero. (D) Infinite.

## ***Answers**:*

(1) (A) Plate thickness.
(2) (B) 4F.
(3) (D) Switching.
(4) (A)Turning the rotatable plates in or out
(5) (D) $E = \frac{1}{2}CV$.
(6) (C) 0.01 s
(7) (C) Exponential law.
(8) (B) is doubled.
(9) (C) RC
(10) (B) direct current.
(11) (D) 39 $\mu$F
(12) (D) Capacity.
(13) (B) Nature of the plates.
(14) (C) is doubled.
(15) (C) 1.33 $\mu$F.
(16) (C) Polarized
(17) (B) 12$\mu$F.
(18) (B) C
(19) (C) Farad
(20) (B) Exponential law.
(21) (A) Uniform.

# Numericals:

***Q.No.1*: The capacitance of air-filled parallel plate capacitor is 1.3 pF. If the separation of plates is doubled and wax is inserted between them. The new capacitance is 2.6 pF.**

**Find the dielectric constant of the wax.**

***Data*:**

Capacitance without wax $C = 1.3$ pF

Capacitance with wax $C' = 2.6$ pF

Separation of plates with wax = 2 d

Dielectric constant of wax $\varepsilon_r = ?$

***Solution*:**

Capacitance without wax is given by $C = A\,\varepsilon_o/d$

Capacitance with wax is given by $C' = A\varepsilon_o\varepsilon_r/2d$

$\therefore \quad C' = \varepsilon_r\, C/2$

$2.6 = \varepsilon_r\, 1.3/2$ OR $\varepsilon_r = \dfrac{2.6 \times 2}{1.3}$

Dielectric constant of wax is **4.**

***Q.No.2*: Three capacitors have capacitances 10, 50 and 25 μF respectively as shown in fig. Calculate:**

**(*i*) Charge on each when connected in parallel to a 250 V supply.**

**(*ii*) total capacitance.**

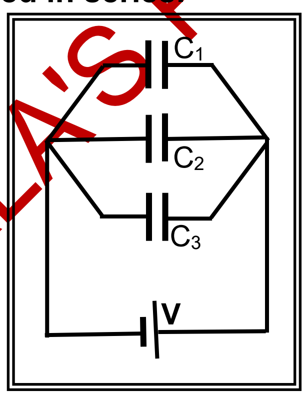
**(*iii*) potential difference across each when connected in series.**

***Data*:**

$C_1 = 10\ \mu F$

$C_2 = 50\ \mu F$

$C_3 = 25\ \mu F$




**In parallel**:

V = 250 v

(*i*)Charge on each.

$Q_1 = ?$, $Q_2 = ?$

$Q_3 = ?$

(*ii*)Total capacitance

C=?

**In series**:

(*iii*) potential difference across each:

$V_1 = ?$ $V_2 = ?$ $V_3 = ?$

***Solution*:**

**In parallel**:

(*i*) In parallel combination potential difference across each capacitor is equal to applied potential difference V, hence

$Q_1 = C_1 V$, | $Q_2 = C_2 V$ | $Q_3 = C_3 V$

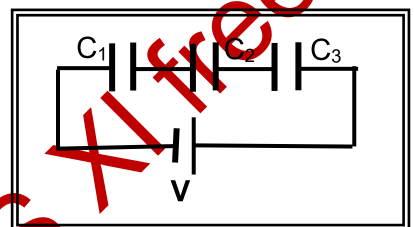
$Q_1 = 10\times 250$, | $Q_2 = 50\times 250$ | $Q_3 = 25\times 250$

$Q_1 = 2500\ \mu C$ | $Q_2 = 12500\ \mu C$ | $Q_3 = 6250\ \mu C$

$Q_1 = 2.5$ mC | $Q_2 = 12.5$ mC | $Q_3 = 6.25$ mC

(*ii*) Total capacitance in parallel combination:

$C = C_1 + C_2 + C_3 = 10 + 50 + 25 =$ **85 μF**




**In series**:

In series combination total capacitance is given by:

$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$ OR $\dfrac{1}{10} + \dfrac{1}{50} + \dfrac{1}{25} = \dfrac{8}{50}$

$C = 50/8 = 6.25\ \mu F$

Charge on each capacitor: $Q = CV = 6.25 \times 250$

$Q = 1562.5\ \mu C$

In series combination of capacitors equal charge stores on each capacitor, hence

$V_1 = \dfrac{Q}{C_1} = \dfrac{1562.5 \times 10^{-6}}{10\times 10^{-6}}$ | $V_2 = \dfrac{Q}{C_2} = \dfrac{1562.5\times 10^{-6}}{50\times 10^{-6}}$

**$V_1 = 156.25$ v** | **$V_2 = 31.25$ v**

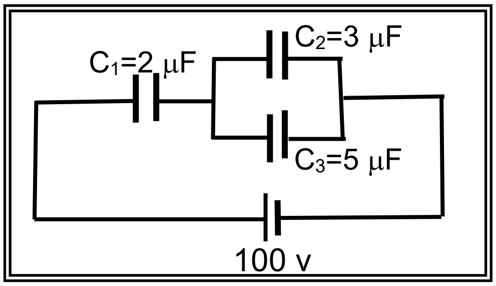
$V_3 = \dfrac{Q}{C_3} = \dfrac{1562.5 \times 10^{-6}}{25\times 10^{-6}}$

**$V_3 = 62.5$ v**

To check the result: $V = V_1 + V_2 + V_3$

$V = 156.25 + 31.25 + 62.5 =$ **250 v**

***Q.No.3*: Three capacitors are connected across a potential difference of 100 volts as shown in fig. Find the charge and potential difference across each.**




***Data***:

$C_1 = 2\ \mu F \quad C_2 = 3\ \mu F \quad C_3 = 5\ \mu F$

$V = 100$ volt

Charge on each $Q_1$=?, $Q_2$=? and $Q_3$=?

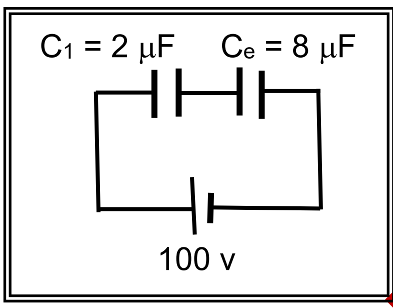
Potential difference across each $V_1$=? $V_2$=? $V_3$=?

***Solution***:

$C_2$ and $C_3$ are connected in parallel,

$\therefore \quad C_e = C_2 + C_3$

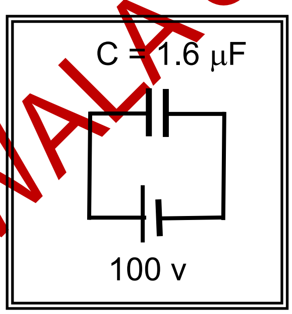
$C_e = 3 + 5 = 8\ \mu F$




$C_e$ and $C_1$ are connected in series.

$$\therefore \quad \frac{1}{C} = \frac{1}{C_e} + \frac{1}{C_1} = \frac{1}{8} + \frac{1}{2} = \frac{5}{8}$$

$$C = \frac{8}{5} = 1.6\ \mu F$$




Charge on C:

$Q = C\,V = 1.6 \times 10^{-6} \times 100 = 1.6 \times 10^{-4}$ C

Since $C_1$ and $C_e$ are in series, therefore charge on each is same ($= 1.6 \times 10^{-4}$ C)

Hence:

$Q_1$ = **$1.6 \times 10^{-4}$ C = 160 μC**

Potential difference across $C_1$:

$$V_1 = \frac{Q_1}{C_1} = \frac{1.6 \times 10^{-4}}{2 \times 10^{-6}} = \mathbf{80\ volt}$$

Potential difference across $C_e$:

$$V_e = \frac{Q_e}{C_e} = \frac{1.6 \times 10^{-4}}{8 \times 10^{-6}} = 20 \text{ volt.}$$

Since $C_2$ and $C_3$ are connected in parallel, therefore potential difference across each is 20 V.

$V_2 = V_3$ = **20 volts**

Charge on each:

$Q_2 = C_2 V_2 = 3 \times 10^{-6} \times 20$ = **$60 \times 10^{-6}$ C=60 μC**

$Q_3 = C_3 V_3 = 5 \times 10^{-6} \times 20$ = **$100 \times 10^{-6}$ C=100 μC**

***Q.No.4***: **Capacitor is charged through a large non- reactive resistance by a battery of constant voltage V. For this arrangement, if the capacitor has a capacitance of 10 μF and the resistance is 1 MΩ, calculate the time taken for the capacitor to receive 90% of its final charge.**

***Data***:

Capacitance $C = 10\ \mu F$

Resistance $R = 1\ M\Omega$

Charge $Q = 90\%$ of $Q_o = 0.9\ Q_o$

Time for 90% total charge $t$ =?

***Solution***:

Time constant of the circuit:

$\tau = RC = 1\times10^{6} \times 10 \times 10^{-6} = 10$ seconds

During charging of a capacitor, at any instant:

$Q = Q_o\,(1 - e^{-t/\tau})$ But $Q = CV$,

$0.90\ V = V\,(1 - e^{-t/\tau})$

$0.90 = (1 - e^{-t/\tau})$ OR $0.9 - 1 = -e^{-t/\tau}$

$0.1 = e^{-t/10}$

Taking natural log (ln) of both sides (use your scientific calculator), we get:

$\ln 0.1 = -t/10$

$t = -10\,(\ln 0.1)$ = <u>23 sec</u>

Hence the capacitor will take **<u>23 sec.</u>** to charge up to 90% of total charge.

***Q.No.5***: **What capacitance is required to store energy of 10 kWh at a potential difference of 1000 V?**

***Data***:

$E = 10$ kWh $= 10\times1000\times60\times60$ J $= 36\times10^{6}$ J

$V = 1000$ volt $\quad$ C=?

***Solution***:

$$E = \tfrac{1}{2} C V^2$$

$$36\times10^6 = \tfrac{1}{2} C (1000)^2 \quad \text{OR} \quad C = \frac{2\times36\times\cancel{10^6}}{\cancel{(1000)^2}}$$

**Capacitor must be of $C = 72$ F**

***Q.No.6***: **A 2.0 μF capacitor and a 4 μF capacitor are connected in parallel across a 300 V potential difference. Calculate the total energy in the capacitors.**

***Data***:

$C_1 = 2$ μF $C_2 = 4$ μF $V = 300$ volt $E = ?$

***Solution***:

$C_1$ and $C_2$ are in parallel, therefore net capacitance in the circuit:

$C = C_1 + C_2$ $C = 2 + 4 = 6$ μF$= 6\times10^{-6}$ F

Total energy in the capacitors:

$$E = \tfrac{1}{2} C V^2$$

$$E = \tfrac{1}{2}\ 6\times10^{-6} \times (300)^2 = \underline{\mathbf{0.27\ J}}$$

***Q.No.7***: **A 12.0 V battery is connected to a capacitor, resulting in 54.0 μC of charge store on the capacitor. How much energy is stored in the capacitor?**

***Data***:

Potential difference $V = 12$ volt

Charge stored $Q = 54.0$ μC$= 54\times10^{-6}$ C

Energy stored $E = ?$

***Solution***:

$$E = \tfrac{1}{2} Q V$$

$$E = \tfrac{1}{2}\ 54\times10^{-6}\times 12 = \underline{\mathbf{3.24\times10^{-4}\ J.}}$$

***Q.No.8***: **Two capacitors 2 μF and 8 μF are joined in series and a potential difference of 300 volt is applied.**

**Find the charge and potential difference for each capacitor.**

***Data***:

Capacitance $C_1 = 2$ μF$= 2\times10^{-6}$ F

Capacitance $C_2 = 8$ μF$= 8\times10^{-6}$ F

Potential difference across the series combination $V = 300$ volt.

Charge on $C_1$ $Q_1 = ?$

Charge on C $Q_2 = ?$

Potential difference $C_1$, $V_1 = ?$

Potential difference $C_2$, $V_2 = ?$

***Solution***:

$C_1$ and $C_2$ are connected in series, therefore, their net capacitance is given by:

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

$$\frac{1}{C} = \frac{1}{2} + \frac{1}{8} = \frac{4+1}{8} = \frac{5}{8}$$

$$\boxed{C = 1.6\ \mu F}$$

Total charge stored on the combination = charge stored on C:

$Q = C\ V = 1.6\times10^{-6}\times 300$

$Q = 4.8\times10^{-4}$ coulomb.

Since $C_1$ and $C_2$ are connected in series, therefore, charge on each capacitor will be same i.e. ***4.8 ×10⁻⁴ coulomb***.

Hence,

$$\boxed{Q_1 = 4.8\times10^{-4}\ \text{coulomb.}}$$

And:

$$\boxed{Q_2 = 4.8\times10^{-4}\ \text{coulomb.}}$$

Potential difference across $C_1$:

$$V_1 = \frac{Q_1}{C_1} = \frac{4.8\times10^{-4}}{2\times10^{-6}} \qquad \boxed{V_1 = 240\ \text{volt.}}$$

Potential difference across $C_2$:

$$V_2 = \frac{Q_2}{C_2} = \frac{4.8\times10^{-4}}{8\times10^{-6}} \qquad \boxed{V_2 = 60\ \text{volt.}}$$

(To check the answer for potential difference, potential difference across the series combination of capacitors, as in this case, must be equal to the total potential difference 'V' across the combination i.e. $V = V_1 + V_2 = 240 + 60 = 300$ volt)

***Q.No.9***: **A capacitor of 100 pF is charged to a potential difference of 50 volt. Its plates are then connected in parallel to another capacitor and it is found that the potential difference between its plates falls to 35 volts.**

**What is the capacitance of the second capacitor?**

(***1997 Karachi Board***)

***Data***:

Capacitance of first capacitor

$C_1 = 100$ pF $= 100\times10^{-12}$ F

Potential difference before connecting $C_1$,

$V_1 = 50$ volt

Potential difference before connecting $C_2$, $V_2 = 35$ volt.

Capacitance of second capacitor $C_2$ =?

***Solution*:**

***Charge stored on $C_1$*:**

Before connecting $C_2$: $Q_1 = C_1 V_1$

$Q_1 = 100 \times 10^{-12} \times 50$

$Q_1 = 5 \times 10^{-9}$ Coulomb.

After connecting $C_2$: $Q_1' = C_1 V_2$

$Q_1' = 100 \times 10^{-12} \times 35$

$Q_1' = 3.5 \times 10^{-9}$ Coulomb.

Charge transferred to $C_2$:

$Q_2 = Q_1 - Q_1'$

$Q_2 = 5 \times 10^{-9} - 3.5 \times 10^{-9}$

$Q_2 = 1.5 \times 10^{-9}$ Coulomb.

Since $C_1$ and $C_2$ are connected in ***parallel***, therefore, potential difference across each will be the same i.e. 35 volts.

$\therefore \quad Q_2 = C_2 V_2$

$$\therefore \quad C_2 = \frac{Q_2}{V_2} = \frac{1.5 \times 10^{-9}}{35}$$

$$\boxed{C_2 = 42.86 \times 10^{-12}\ F = 42.86\ pF}$$

Capacitance of second capacitor is ***42.86 × 10⁻¹² F*** or ***42.86 pF***.

***Q.No.10*: A 10 μF capacitor is charged to a potential difference of 220 V. It is then disconnected from the battery. Its plates are then connected in parallel to another capacitor and it is found that the potential difference falls to 100 V.**

**What is the capacitance of the second capacitor?(*2014,08,1997 Karachi board*)**

***Data*:**

Capacitance $C_1 = 10\ \mu F = 10 \times 10^{-6} F$

Potential difference $V_1 = 220$ V (Before connecting $C_2$)

Potential difference $V_2 = 100$ V (After connecting $C_2$)

Capacitance of second capacitor $C_2$ = ?

***Solution*:**

Charge on $C_1$ before connecting $C_2$:

$Q_1 = C_1 V_1 = 10 \times 10^{-6} \times 220$

$Q_1 = 2.2 \times 10^{-3}$ Coul.

Charge remaining on $C_1$ after connecting $C_2$:

$Q_1' = C_1 V_2 = 10 \times 10^{-6} \times 100$

$Q_1' = 1 \times 10^{-3}$ Coul.

Charge stored by $C_2$ = Charge transferred from $C_1$ to $C_2$, $Q_2 = Q_1 - Q_1'$

$Q_2 = 2.2 \times 10^{-3} - 1 \times 10^{-3}$

$Q_2 = 1.2 \times 10^{-3}$ C

But $Q_2 = C_2 V_2$ Capacitors are connected in parallel. hence the potential difference across them will be same.

$$\therefore \quad C_2 = \frac{Q_2}{V_2} = \frac{1.2 \times 10^{-3}}{100}$$

$\therefore$ $\boxed{C_2 = 1.2 \times 10^{-5} Farad}$ OR $\boxed{C_2 = 12\ \mu F}$

Capacitance of the second capacitor is ***12 μF***.

***Q.No.11*: Two capacitors of 2 μF and 4 μF are connected in series to a 40 volt battery.**

**Calculate the charge of these capacitors and potential difference across each.** (***2019 Karachi Board***)

***Data*:**

$C_1 = 2\mu F = 2 \times 10^{-6} F$, $C_2 = 4\mu F = 4 \times 10^{-6} F$ C=?

V = 40 volt $Q_1$ =? $Q_2$ =? $V_1$ =? $V_2$ =?

***Solution*:**

$C_1$ and $C_2$ are connected in series

$$\therefore \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \quad \therefore \frac{1}{C} = \frac{1}{2} + \frac{1}{4}$$

$$\frac{1}{C} = \frac{2+1}{4} = \frac{3}{4} \quad \boxed{C = 1.33\ \mu F}$$

Total charge stored = charge stored on C:

$Q = C V = 1.33 \times 10^{-6} \times 40 = 5.33 \times 10^{-5}$ coulomb

$C_1$ and $C_2$ are connected in series, therefore charge on each capacitor will be equal

Hence, $\boxed{Q_1 = Q_2 = 5.33 \times 10^{-5}\ coulomb}$

$$V_1 = \frac{Q_1}{C_1} = \frac{5.33 \times 10^{-5}}{2 \times 10^{-6}} \quad \boxed{V_1 = 26.67\ volt.}$$

$$V_2 = \frac{Q_2}{C_2} = \frac{5.33 \times 10^{-5}}{4 \times 10^{-6}} \quad \boxed{V_2 = 13.33\ volt.}$$

***Q.No.12*: Four capacitors each of 2 μF are connected in such a way that the total capacitance is also 2 μF. Show what combination gives this value.**

(***2013 Hyderabad Board***)

***Data*:**

Capacitances $= C_1 = C_2 = C_3 = C_4 = 2\ \mu F$

Total capacitance $C_e = 2\ \mu F$.

***Solution*:**

Let $C_1$ and $C_2$ be connected **in series** to each other, their total capacitance will be

$$\frac{1}{C_{e1}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{2} + \frac{1}{2} = \frac{2}{2} = 1$$

$\therefore$ $\mathbf{C_{e1} = 1\ \mu F}$

Similarly, if $C_3$ & $C_4$ are also connected **in series** to each other their total capacitance $C_{e2}$ will also be **1 μF**. Now if these two series combinations are connected **in parallel** to each other their total capacitance is given by:

$$C_e = C_{e1} + C_{e2} = 1 + 1 = \mathbf{2\ \mu F}$$

Therefore, two given capacitors connected in series and the two series combinations are then connected in parallel to each other will give total capacitance of **2 μF**.

***Q.No.12*: A parallel plate capacitor consists of two plates with area of 0.1 m² each, separated by 0.002 m. The capacitor is filled with a dielectric material having a relative permittivity "$\varepsilon_r$" of 4. Calculate the capacitance of the capacitor. ($\varepsilon_o = 8.85\times10^{-12}$ C²/N-m²)**

(***2025 Karachi Board***)

***Data*:**

Area of plates $A = 0.1\ m^2$

Separation of plates $d = 0.002$ m.

Relative permittivity $\varepsilon_r = 4$

Permittivity of free space $\varepsilon_o = 8.85\times10^{-12}\ C^2/Nm^2$

Capacitance $C = ?$

***Solution*:**

Capacitance of a dielectric filled capacitor is given by:

$$C = \frac{A\,\varepsilon_o\,\varepsilon_r}{d} = \frac{0.1\times8.85\times10^{-12}\times 4}{0.002}$$

$$\mathbf{C = 1.77\times10^{-9}\ F}$$