## 26.3 Combination of capacitors:

In electric circuits, capacitors can be combined in series, parallel, or a combination of both to achieve the desired capacitance. Understanding these combinations is crucial for designing circuits in various applications, including energy storage, filtering, and signal processing.

I- Parallel Combination:

As shown in Figure, two connected capacitors are known as a parallel combination. The figure shows a circuit diagram for this combination of capacitors. A conducting wire connects the capacitors' left plates to the battery's positive terminal. They are, therefore, both at the same electric potential as the positive terminal. Likewise, the right plates are connected to the negative terminal and are, therefore, both at the same potential as the negative terminal. Thus, the individual potential differences across capacitors connected in parallel are all the same and are equal to the potential difference applied across the combination.
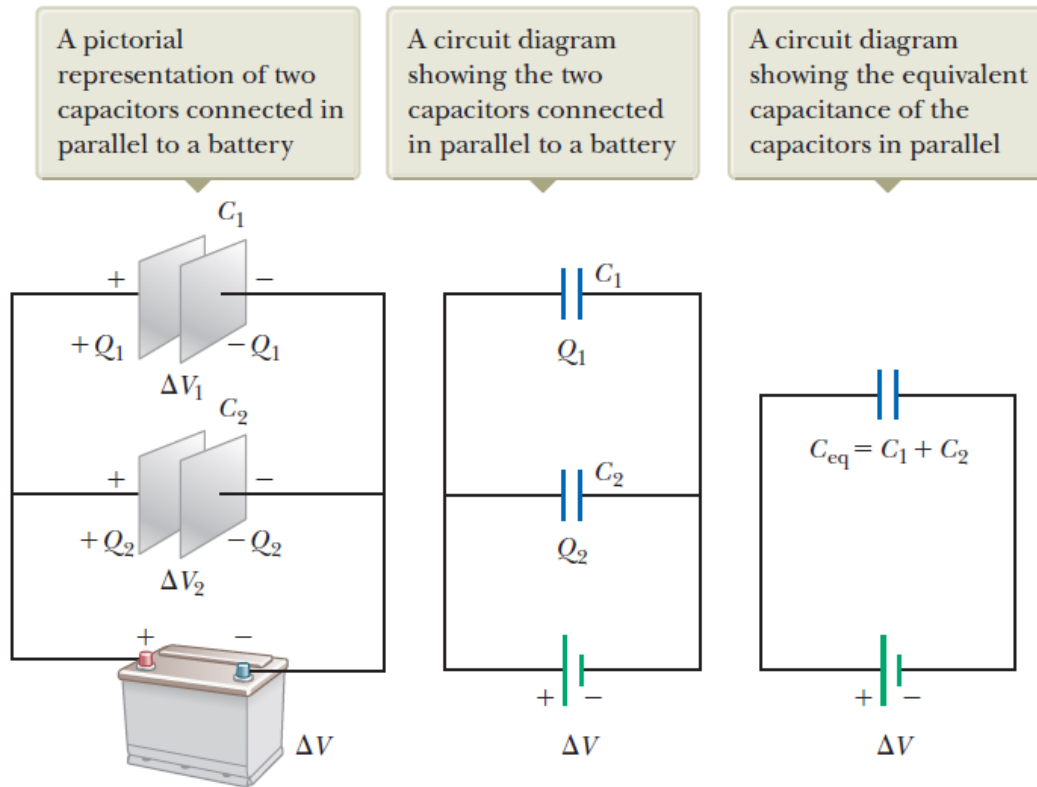
When capacitors are connected **in parallel**, they all experience the **same voltage**, but the total charge is **divided** among them.

$V = V_1 = V_2 = V_3$

$q = q_1 + q_2 + q_3$

$$CV = C_1V + C_2V + C_3V$$
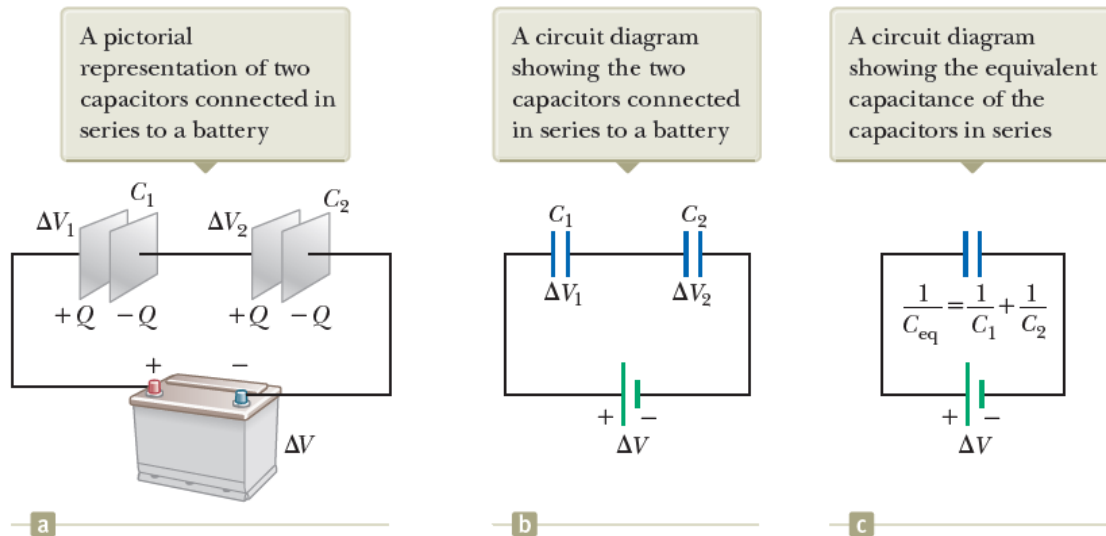
$$CV = (C_1 + C_2 + C_3)V$$

$$C = (C_1 + C_2 + C_3)$$

For ensemble of capacitors:

$$C = \sum_{i=1}^{n} C_1 + C_2 + ... + C_n$$

Characteristics of Parallel Combination:

➢ **Same Voltage**: Each capacitor has the **same potential difference** V.
➢ **Charge Distribution**: The total charge is **split** among capacitors:
➢ **Increased Capacitance**: The equivalent capacitance is **larger than the largest capacitor** in the combination.

II-   Series Combination:

A pictorial representation of two capacitors connected in series to a battery

A circuit diagram showing the two capacitors connected in series to a battery

A circuit diagram showing the equivalent capacitance of the capacitors in series

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

Suppose three initially uncharged capacitors C_1 and C_2 are connected in series, as shown in the figure above. A potential difference ΔV is then applied across both capacitors. The left plate of capacitor 1 is connected to the positive terminal of the battery and becomes positively charged with a charge $+Q$, while the right plate of capacitor 2 is connected to the negative terminal and becomes negatively charged with charge $-Q$ as electrons flow in. What about the inner plates? They were initially uncharged; now the outside plates each attract an equal and opposite charge. So the right plate of capacitor 1 will acquire a charge $-Q$ and the left plate of capacitor $+Q$.

When capacitors are connected **in series**, the same charge QQ is stored on each capacitor, but the total voltage is **divided** among them.

We see that the total potential difference is simply the sum of the two individual potential differences:

$$V = V_1 + V_2$$

$$q = q_1 = q_2$$

Since $V = \dfrac{q}{C}$

$V = V_1 + V_2$

$\dfrac{q}{C} = \dfrac{q}{C_1} + \dfrac{q}{C_2}$

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

For ensemble of capacitors:

$$\dfrac{1}{C} = \sum_{i=1}^{n} \dfrac{1}{C_1} + \dfrac{1}{C_1} \ldots\ldots\ldots + \dfrac{1}{C_n}$$

Characteristics of Series Combination:

➢ **Same Charge**: Each capacitor stores the same charge Q.
➢ **Voltage Division**: The total voltage is **shared** among capacitors:
➢ **Decreased Capacitance**: The equivalent capacitance is **less than the smallest capacitor** in the series.

Examples:

Ex. 1::

Three capacitors ($C_1=4\mu F$, $C_2=6\mu F$, and $C_3=12\mu F$) are connected in **series**.
Find the equivalent capacitance. (2 μF)

Ex. 2:

Three capacitors ($C1=4\mu F$, $C2=6\mu F$, and $C3=12\mu F$) are connected in parallel.
Find the equivalent capacitance.(22 μF)

Ex. 3

Four capacitors are connected as shown in the figure.

(a) Find the equivalent capacitance between points a and b.

(b) Calculate the charge on each capacitor if $\Delta V_{ab} = 15.0$ V.

Solution:

(a) $\dfrac{1}{C_s} = \dfrac{1}{15.0} + \dfrac{1}{3.00}$

$C_s = 2.50 \ \mu F$

$C_p = 2.50 + 6.00 = 8.50 \ \mu F$

$C_{eq} = \left(\dfrac{1}{8.50 \ \mu F} + \dfrac{1}{20.0 \ \mu F} \right)^{-1} = \boxed{5.96 \ \mu F}$

(b) $Q = C \Delta V = (5.96 \ \mu F)(15.0 \ V) = \boxed{89.5 \ \mu C}$ on 20.0 μF

$\Delta V = \dfrac{Q}{C} = \dfrac{89.5 \ \mu C}{20.0 \ \mu F} = 4.47$ V

$15.0 - 4.47 = 10.53$ V

$Q = C \Delta V = (6.00 \ \mu F)(10.53 \ V) = \boxed{63.2 \ \mu C}$ on 6.00 μF

$89.5 - 63.2 = \boxed{26.3 \ \mu C}$ on 15.0 μF and 3.00 μF
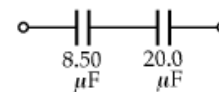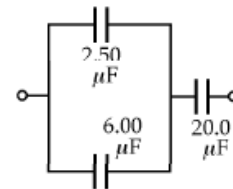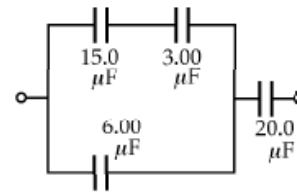
Ex. 4

Find the equivalent capacitance between points a and b for the group of capacitors connected as shown in the figure. Take: C1 = 5.00 µF, C2 = 10.0 µF, and C3 = 2.00 µF.

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$$C_s = \left(\frac{1}{5.00} + \frac{1}{10.0} \right)^{-1} = 3.33 \ \mu F$$

$$C_{p1} = 2(3.33) + 2.00 = 8.66 \ \mu F$$

$$C_{p2} = 2(10.0) = 20.0 \ \mu F$$

$$C_{eq} = \left(\frac{1}{8.66} + \frac{1}{20.0} \right)^{-1} = \boxed{6.04 \ \mu F}$$