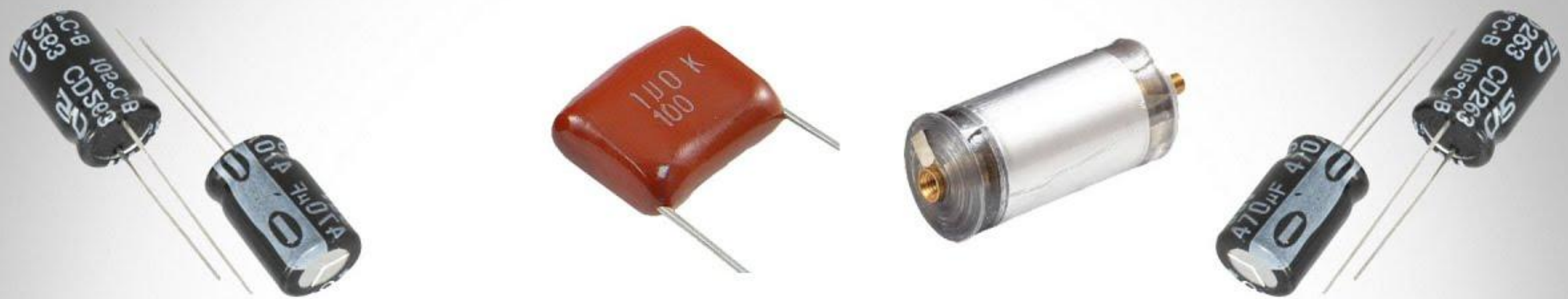
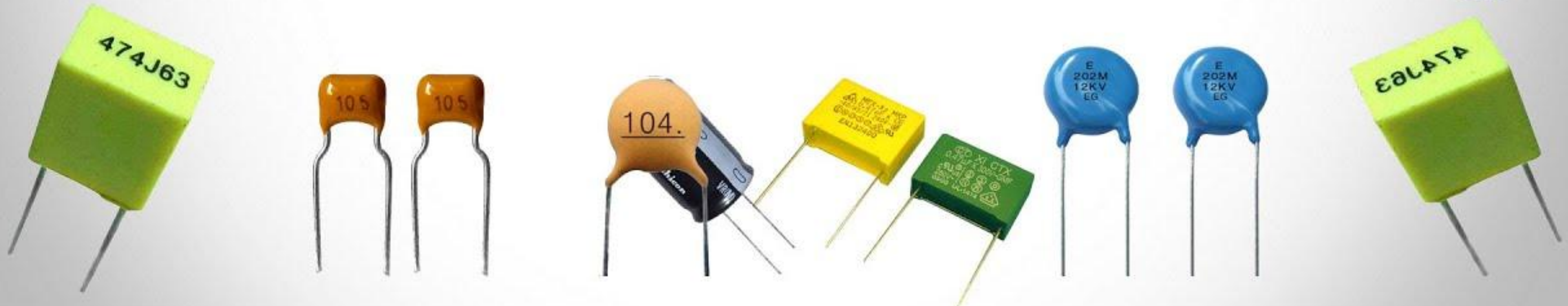


Grade 11 S – Physics

Chapter 13: Capacitor



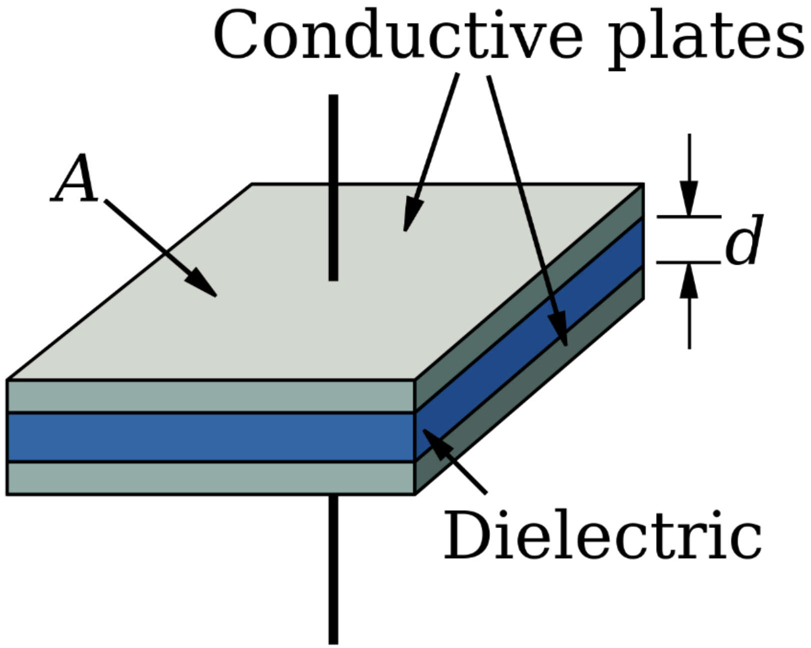
OBJECTIVES

1 **Definition of a capacitor.**

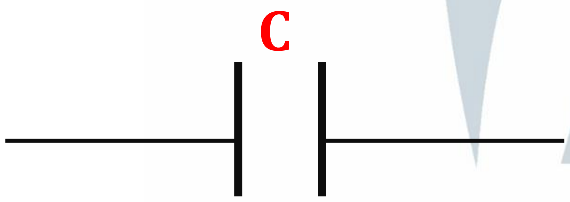
2 **Capacitance of a capacitor**

Definition of capacitor

capacitor: **It is an electric device formed of two conducting parallel plates (armatures) separated by an insulator called dielectric which can be: vacuum, air, glass, ceramic…**



In an electrical circuit, a capacitor is represented by:

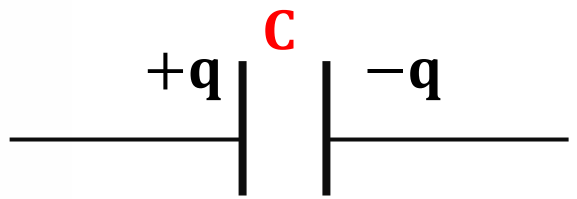


Symbol of Capacitor

Definition of capacitor

The capacitor is manufactured to store electric energy and returns it to the circuit whenever required

The capacitors in the electronic circuits allows to store opposite electrical charges, negative and positive, and of identical values $q_A = -q_B$



When the plates are not charged, we say that the capacitor is neutral.

Capacitor is founded and used in computers, camera flash, alarms

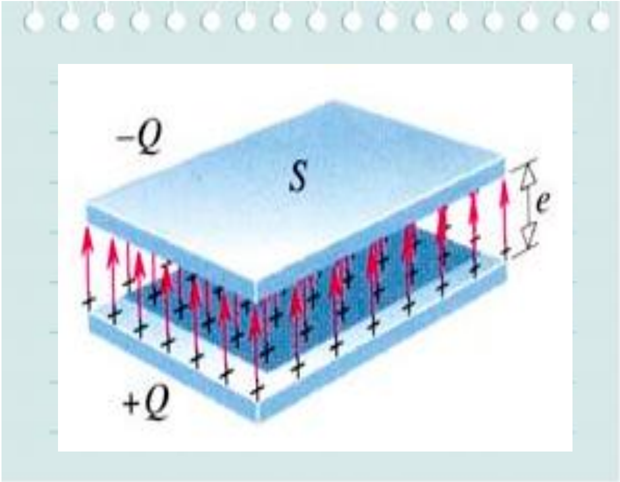
Types of capacitor

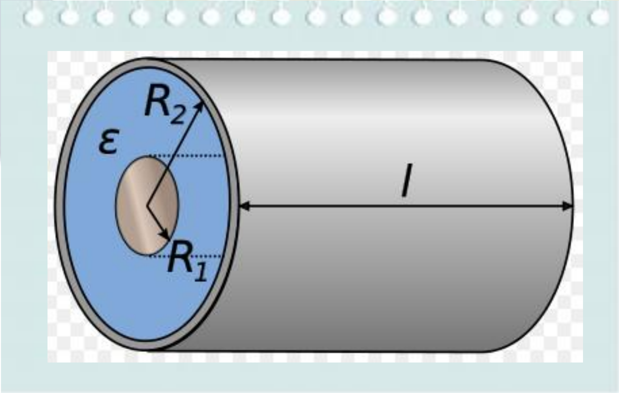
Types of capacitor

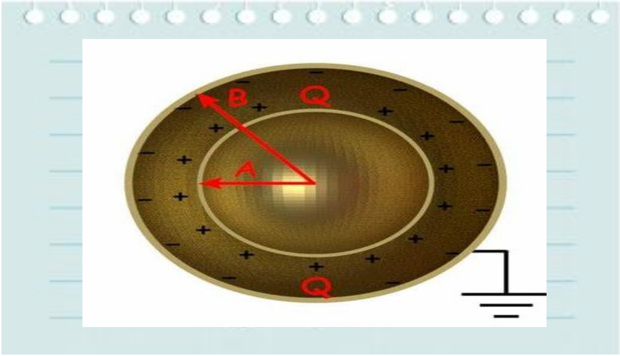
Plan capacitor:
This capacitor is formed by two plane and parallel plates.

Cylindrical capacitor:
This capacitor is formed by two cylindrical and parallel plates.

Spherical capacitor:
This capacitor is formed by two spherical and parallel plates.





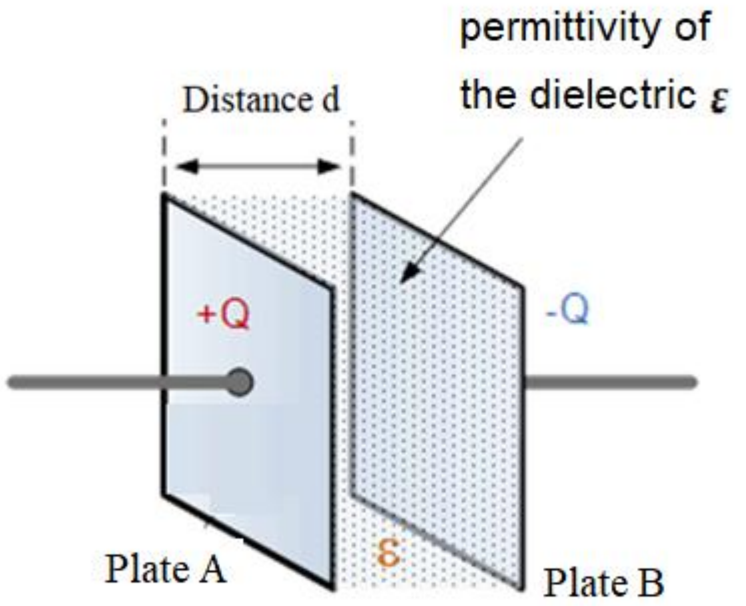


Capacitance of capacitor

Capacitance: The capacitance "C" is the ability to store electric energy inside it.

The capacitance of a parallel plate capacitor is given by:

$$C = \varepsilon \frac{S}{d}$$



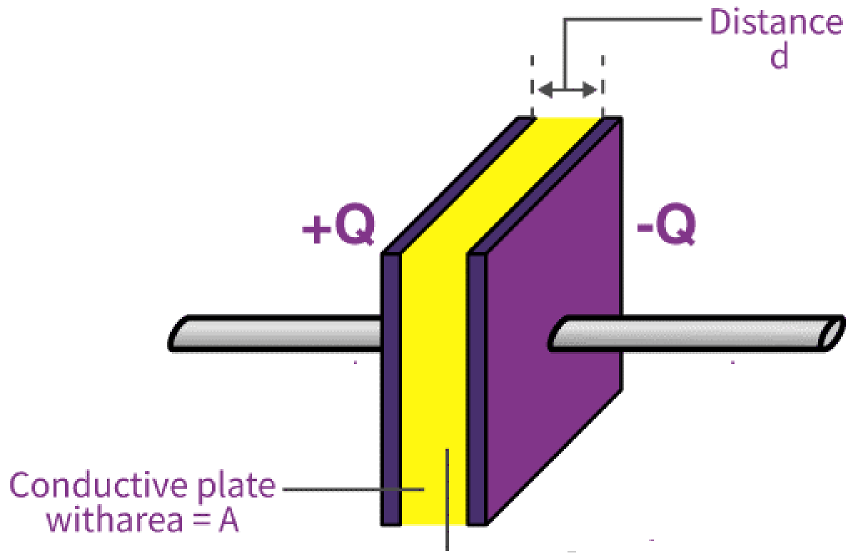
- d: distance between the plates (m).
- S or A: common surface of the plates (m^2)
- ε: permittivity of the dielectric (F/m). Where $\varepsilon = \varepsilon_0 \varepsilon_r$
- C: capacitance of the capacitor in farad (F).

$\varepsilon_0 = 8.85 \times 10^{-12} F/$: permittivity of vacuum

ε_r: relative permittivity of substance

Capacitance of capacitor

Application 1: An air-filled capacitor is made from two flat parallel plates 1mm apart. The inside area of each plate is $8\,cm^2$. The permittivity of free space $\varepsilon_0 \approx 8.85 \times 10^{-12} F/m$ & $\varepsilon_r = 1$ Calculate the capacitance C_0 of this parallel plane capacitor.



The capacitance "C_0" of an air-filled capacitor is determined by:

$$C_0 = \varepsilon \frac{S}{d} = \varepsilon_0 \varepsilon_r \frac{S}{d}$$

$$C_0 = \frac{1 \times 8.85 \times 10^{-12} \times 8 \times 10^{-4}}{10^{-3}}$$

$$C_0 = 7.08 \times 10^{-12}\ F$$

Capacitance of capacitor

The sub units od capacitance:

Milli-farad (mF):	$\times 10^{-3}$ →	F
Micro-farad (μF):	$\times 10^{-6}$ →	F
Nano-farad (nF):	$\times 10^{-9}$ →	F
pico-farad (pF):	$\times 10^{-12}$ →	F

Capacitance of capacitor

Application 2: An air-filled capacitor is made from two flat parallel plates separated by a distance d apart. The inside area of each plate is S. The permittivity of free space $\varepsilon_0 \approx 8.85 \times 10^{-12} F/m$.
Find a relation between C_0 and the capacitance C' if the distance is doubled.

The capacitance C_0 of an air-filled capacitor is determined by:

$$C_0 = \varepsilon_0 \frac{S}{d}$$

When the distance is doubled:

$$C' = \varepsilon_0 \frac{S}{2d}$$

$$\frac{C_0}{C'} = \frac{\varepsilon_0 \frac{S}{d}}{\varepsilon_0 \frac{S}{2d}} \Rightarrow \frac{C_0}{C'} = 2$$

$$\Rightarrow C_0 = 2C'$$

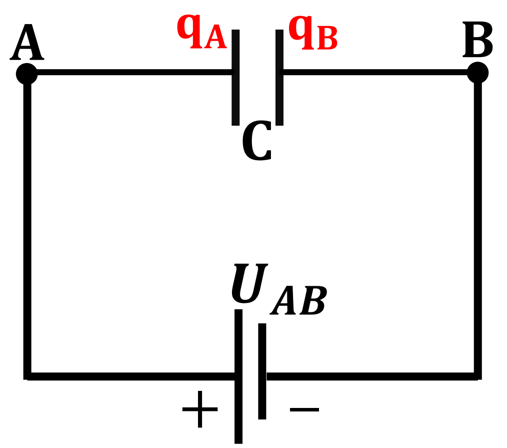
Capacitance of capacitor

The charge carried by the capacitor is $q = q_A = -q_B$

The quantity of electric charge q is measured in *coulomb*(C).

The charge q stored in a capacitor is proportional to the voltage U_{AB} between its terminals:

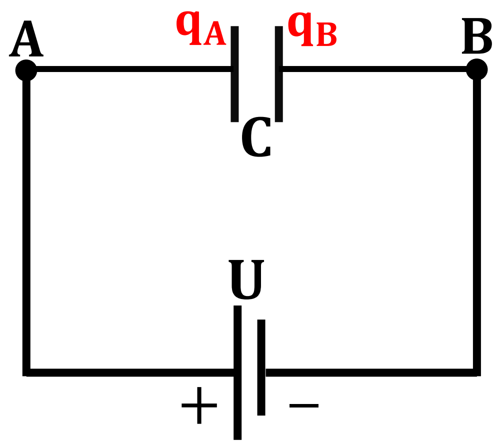
$$q = C.U_{AB}$$



- **U:** Voltage, in SI volts "V"
- **C:** capacitance of a capacitor, in farads "F"
- **q:** quantity of charge , in coulombs "C"

Capacitance of capacitor

Application 3: A capacitor is made up of two parallel flat plates 0.4 mm apart.



The electric charge stored in the capacitor is 0.02 μC when it is fed by a potential difference of 250 V.
Given air permittivity $\varepsilon_0 \approx 8.85 \times 10^{-12}$ F/m.

1. Calculate the capacitance of the capacitor.
2. Calculate the surface area of each plate.
3. Calculate the charge of the plates when the potential difference is 500 V.

Capacitance of capacitor

Given: d=0.4mm; q=0.02µC; 250 V; $\varepsilon_0 \approx 8.85 \times 10^{-12}$F/m.

1. Calculate the capacitance of the capacitor.

$$C = \frac{q}{U} = \frac{0.02 \times 10^{-6}}{250}$$

$$\Rightarrow C = 8 \times 10^{-11}\ F$$

2. Calculate the surface area of each plate.

$$C_0 = \frac{\varepsilon_0 S}{d} \Rightarrow S = \frac{C.d}{\varepsilon_0}$$

$$\Rightarrow S = \frac{8 \times 10^{-11} \times 0.4 \times 10^{-3}}{8.85 \times 10^{-12}}$$

$$\Rightarrow S = 3.6 \times 10^{-3}\ \mathrm{m}^2$$

Capacitance of capacitor

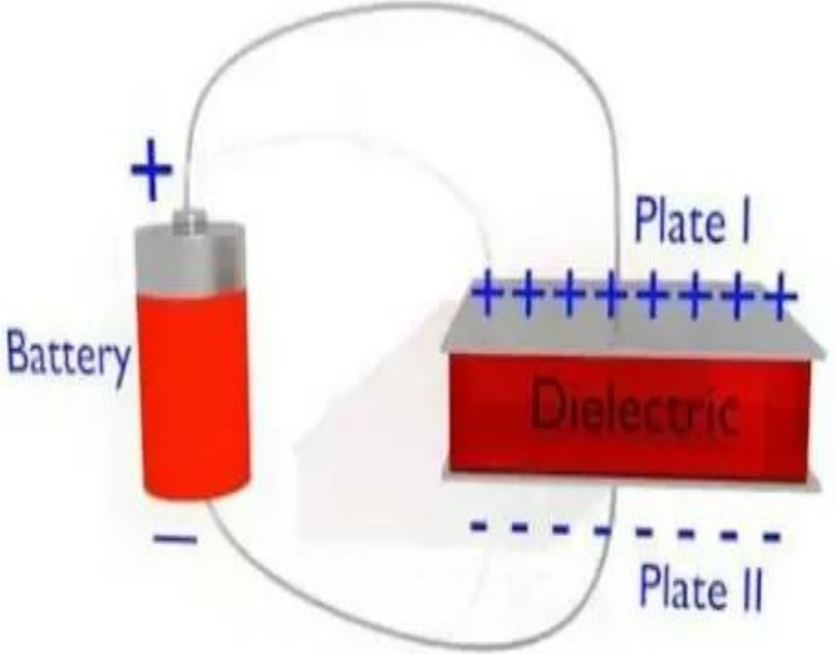
Given: d=0.4mm; q=0.02μC; 250 V; $\varepsilon_0 \approx 8.85 \times 10^{-12}$F/m.

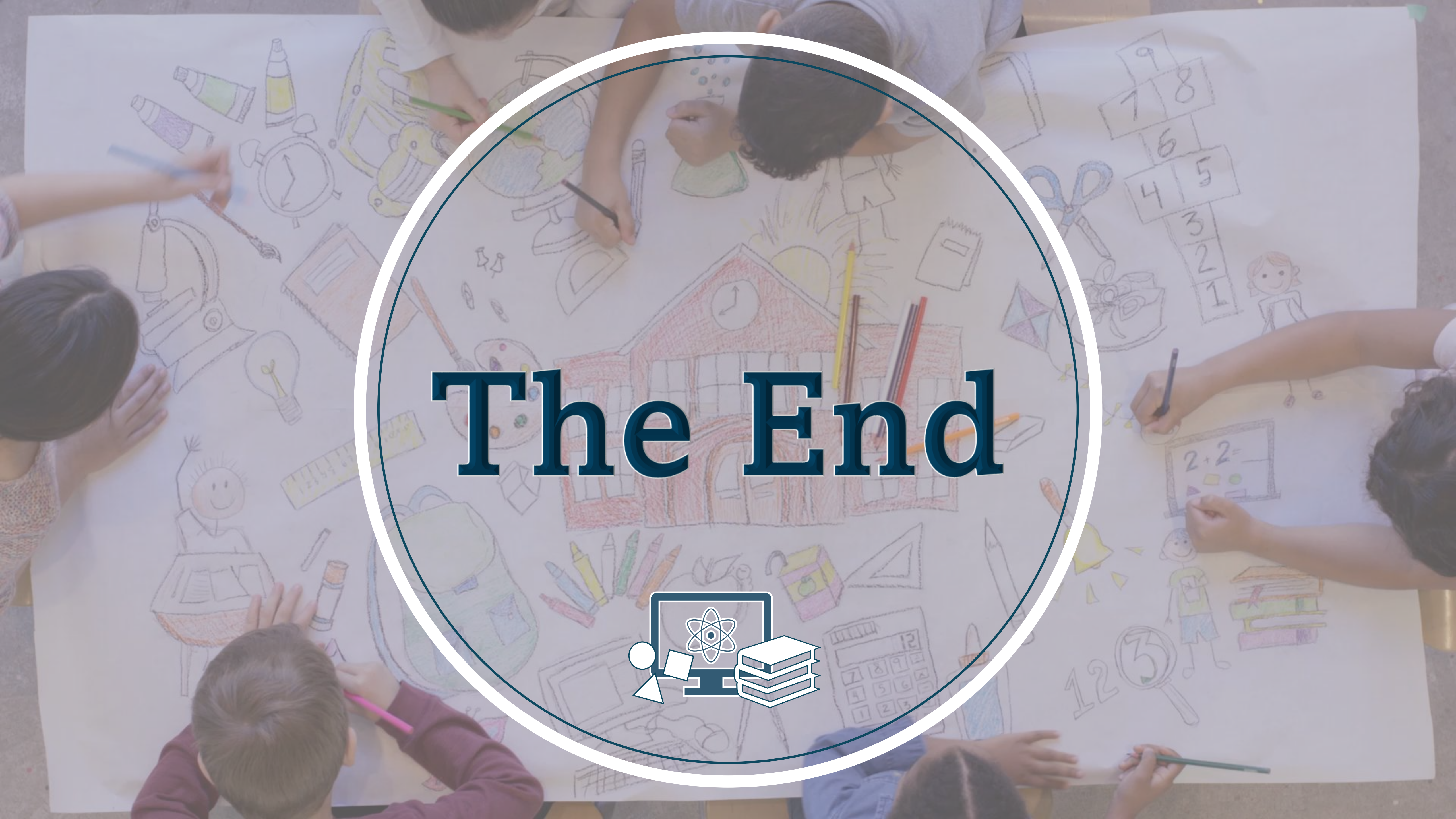
3. Calculate the charge of the plates when the potential difference is 500 V

$$q = C.U = 8 \times 10^{-11} \times 500$$

$$q = 4 \times 10^{-8}\ C$$

$$q = 0.04\ \mu C$$

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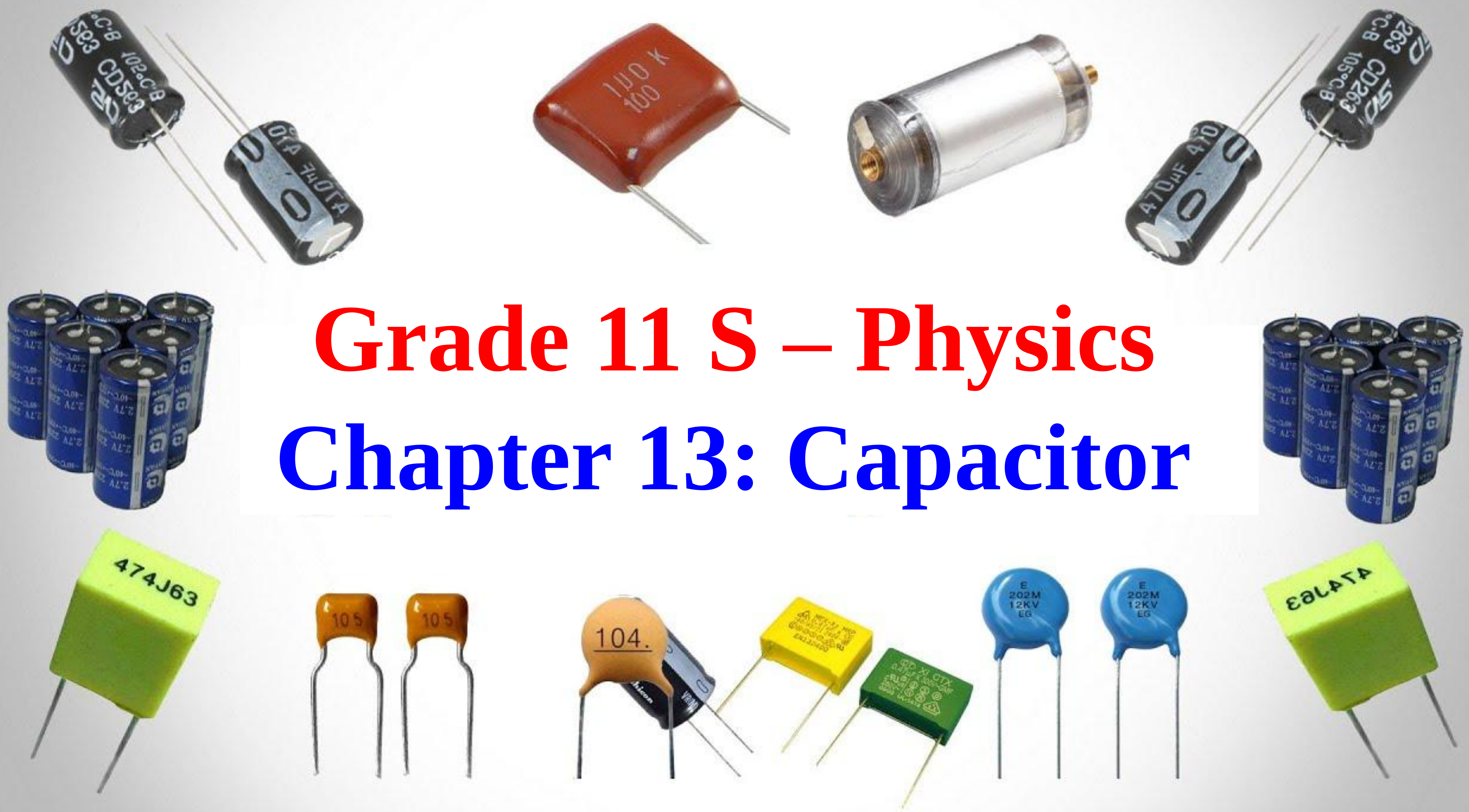
Grade 11 S – Physics

Chapter 13: Capacitor

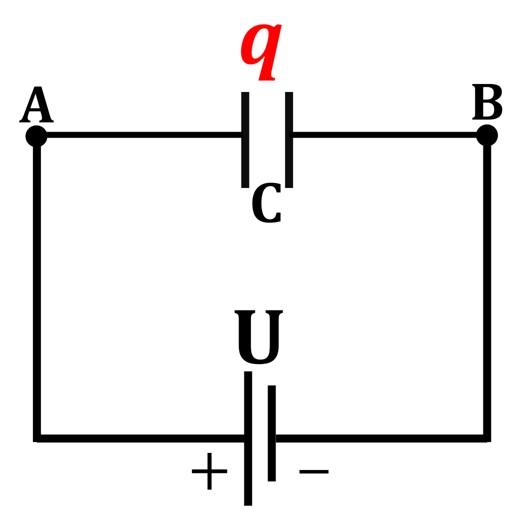


OBJECTIVES

1. Determine the energy stored in a capacitor.
2. Grouping of capacitors in series
3. Grouping of capacitors in parallel

Electrical Potential Energy

The electrical potential energy is the energy stored in a capacitor, is related to, charge of the capacitor "q" and the voltage "U" between the terminals of the capacitor is given by:



$$w = \frac{1}{2}CU^2$$

C: The capacitance of the capacitor, in (F)

U: voltage across the capacitor, in (V)

W: energy stored in the capacitor, in (J)

Application 3:

A capacitor with a capacity of 5000µF is charged under a voltage of 12 V. Calculate the accumulated charge and the energy stored in this capacitor.

The accumulated charge stored in the capacitor is:

$$Q = CU$$

$$Q = 5000 \times 10^{-6} \times 12$$

$$Q = 6 \times 10^{-3} C$$

The energy stored in the capacitor is:

$$W = \frac{1}{2} qU$$

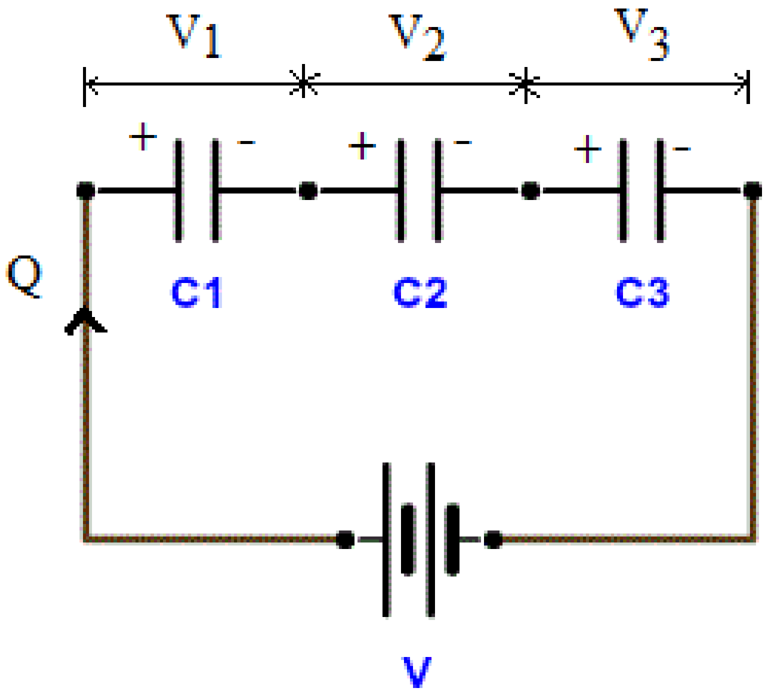
$$W = \frac{1}{2} \times (6 \times 10^{-2} C) \times 12.$$

$$W = 36 \times 10^{-2} J$$

Grouping of capacitors/ in series

Series connections produce less total capacitance than any of the individual capacitors. Equivalent capacitance can be determined as:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$



Law of addition of voltage in series:

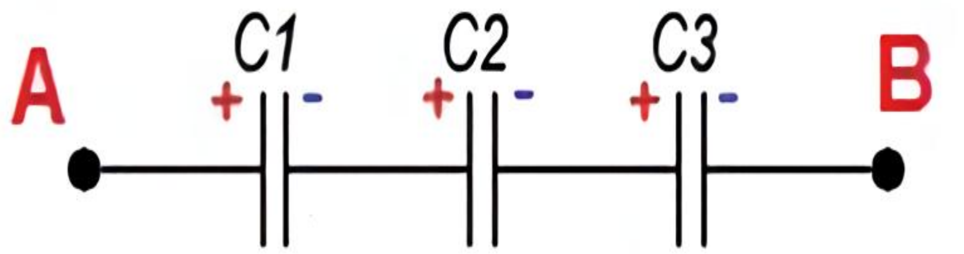
$$\mathrm{V} = V_1 + V_2 + \cdots$$

Law of uniqueness of charges in series:

$$\mathrm{Q} = \mathrm{Q}_1 = \mathrm{Q}_2 = \cdots$$

Grouping of capacitors/ in series

Application 4: **Three capacitors each of capacitance 9 pF are connected in series as shown in figure.**



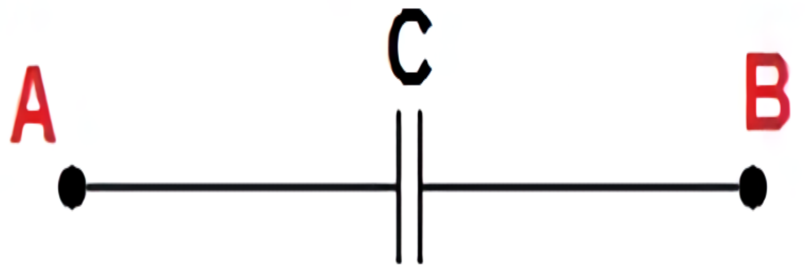
1) **Calculate the equivalent capacitance of the circuit.**

Since C_1, C_2 and C_3 are connected in series then:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \Rightarrow \frac{1}{C_{eq}} = \frac{1}{9} + \frac{1}{9} + \frac{1}{9}$$

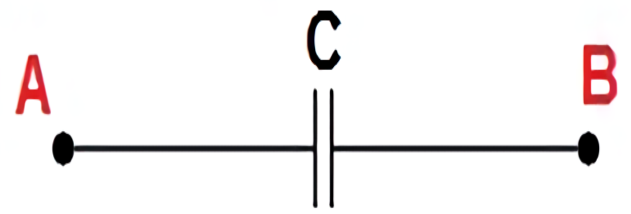
$$\Rightarrow \frac{1}{C_{eq}} = \frac{3}{9}$$

$$\Rightarrow C_{eq} = 3pF$$



Grouping of capacitors/ in series

2) **Knowing that : U_{AB} = 36 V. Calculate the charge and the voltage of each capacitor in the circuit.**



The total charge is: $Q = C_{eq} \times U_{AB}$

➡ $Q = 3 \times 10^{-12} \times 36$ ➡ $Q = 108 \times 10^{-12} C$

Since C_1, C_2 and C_3 are connected in series then:

$$Q = Q_1 = Q_2 = Q_1 = 108 \times 10^{-12} C$$

$$U_1 = \frac{Q_1}{C_1} = \frac{108 \times 10^{-12}}{9 \times 10^{-12}} = 12V$$

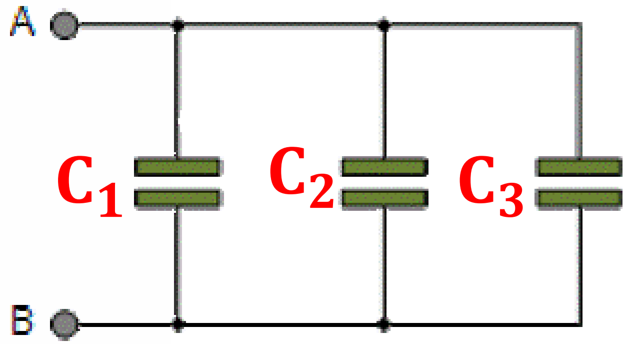
$$U_2 = \frac{Q_2}{C_2} = \frac{108 \times 10^{-12}}{9 \times 10^{-12}} = 12V$$

$$U_3 = U - (U_1 + U_2) = 12V$$

Grouping of capacitors/ in parallel

The equivalent capacitor has a capacitance more than any individual capacitors. Equivalent capacitance can be determined as:

$$C_{eq} = C_1 + C_2 + C_3 + \cdots C_n$$

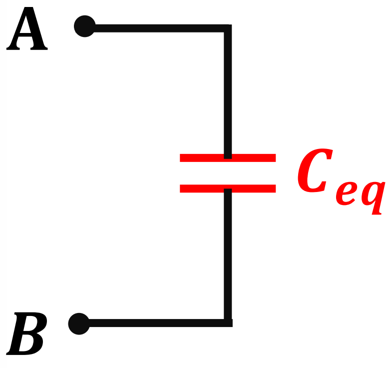


Law of addition of charges in series:

$$Q = Q_1 + Q_2 + \cdots Q_n$$

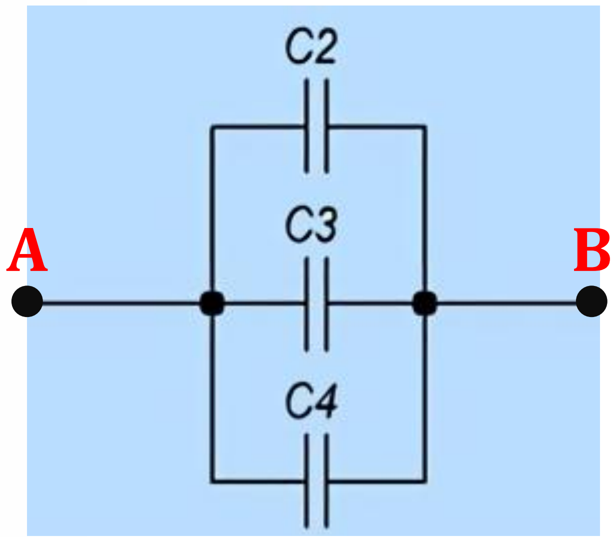
Law of uniqueness of voltage in parallel:

$$U = U_1 = U_2 + \cdots U_n$$



Grouping of capacitors/ in parallel

Application 5: **Three capacitors are connected in parallel as shown in the figure. $C_1 = 2\mu F$; $C_2 = 4\mu F$; $C_3 = 6\mu F$.**



1) **Calculate the equivalent capacitance of the circuit.**

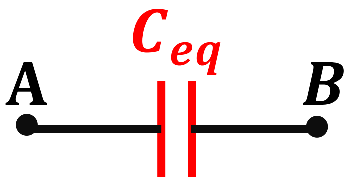
Since C_1, C_2 and C_3 are connected in parallel then:

$$C_{eq} = C_1 + C_2 + C_3 \Rightarrow C_{eq} = 2\mu F + 4\mu F + 6\mu F$$

$$\Rightarrow C_{eq} = 12pF$$

Grouping of capacitors/ in parallel

2) Knowing that : $U_{AB} = 6V$. Calculate the charge and the voltage of each capacitor in the circuit.



The total charge is: $Q = C_{eq} \times U_{AB}$

$Q = 12 \times 10^{-6} \times 6$ ⟹ $Q = 72 \times 10^{-6} C$

Since C_1, C_2 and C_3 are connected in parallel then:

$U_{AB} = U_1 = U_2 = U_3 = 6V$

$Q_1 = C_1 \times U_1 = 2 \times 10^{-6} \times 6$

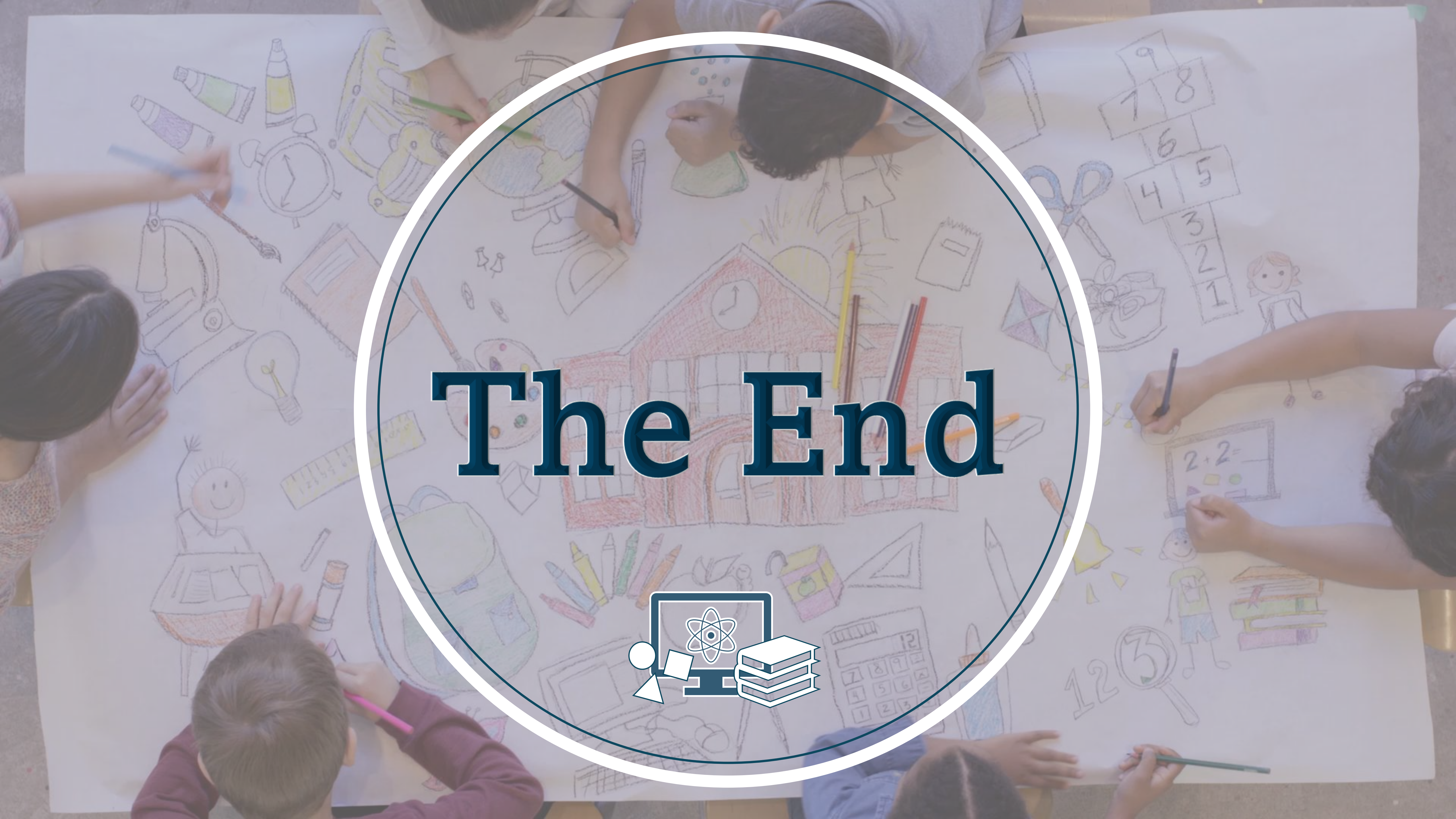
$Q_1 = 12 \times 10^{-6} C$

$Q_2 = C_2 \times U_2 = 4 \times 10^{-6} \times 6$

$Q_2 = 24 \times 10^{-6} C$

$Q_3 = C_3 \times U_3 = 6 \times 10^{-6} \times 6$

$Q_2 = 36 \times 10^{-6} C$



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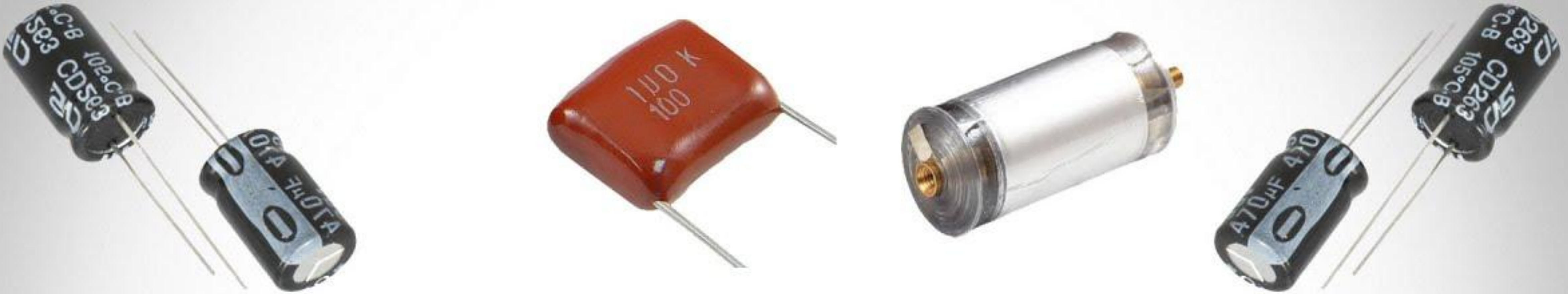
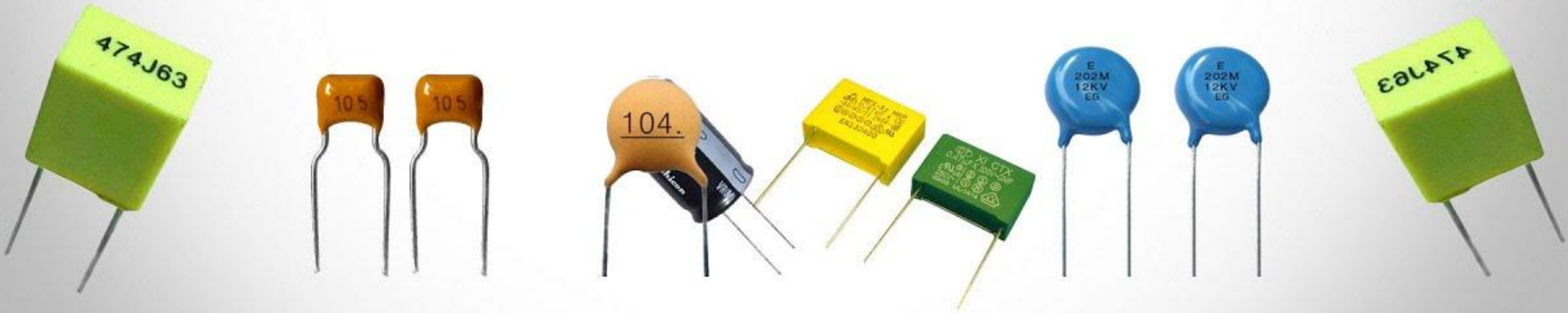


Grade 11 S – Physics

Chapter 13: Capacitor

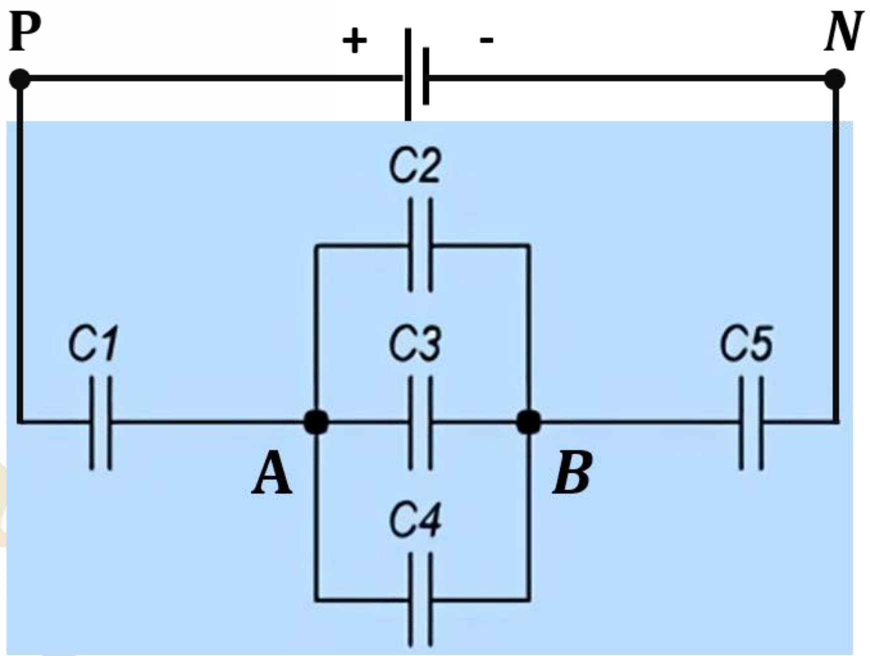


OBJECTIVES

1	**Grouping of capacitors complex circuit(series and parallel)**
1	**Electric equilibrium**

Grouping of capacitors / series & parallel

Application 7: Consider five capacitors of capacitance $C_1 = C_5 = 6\mu F$, $C_2 = C_3 = C_4 = 2\mu F$ a dry cell of voltage $U_{PN} = 12V$ are connected as shown in the adjacent figure.



1) Calculate the equivalent capacitance C_{eq} between P and N.
2) Deduce the quantity of total charge.
3) Calculate the charge and the voltage across each capacitor

Grouping of capacitors / series & parallel

Solution: $C_1 = C_5 = 6\mu F, C_2 = C_3 = C_4 = 2\mu F; U_{PN} = 12V$

1)Calculate the equivalent capacitance C_{eq} between P and N.

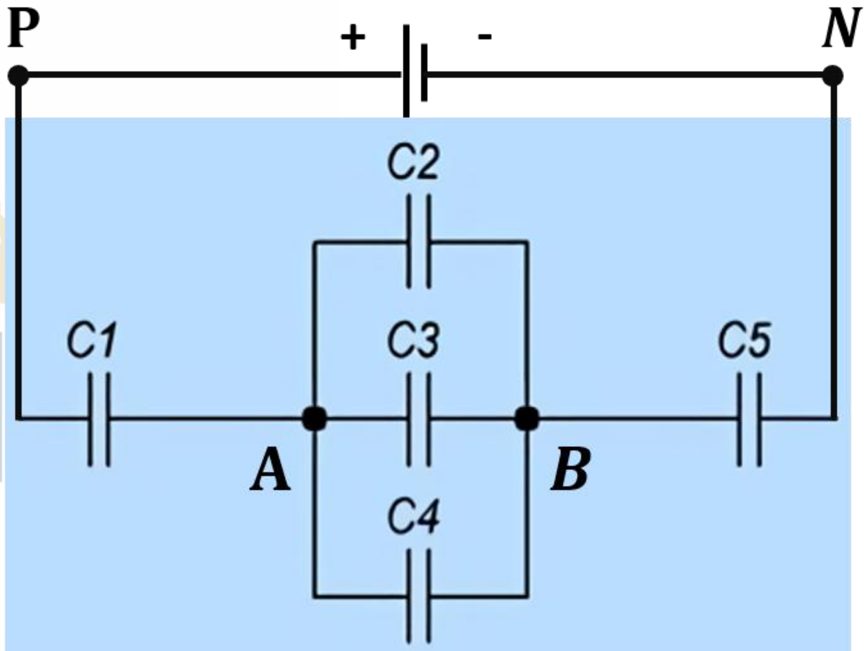
C_2, C_3, C_4 are in parallel then:

$$C_{2,3,4} = C_2 + C_3 + C_4 = 2\mu + 2\mu + 2\mu = 6\mu F$$

C_1, $C_{2,3,4}$ & C_5 are in series then:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_{2,3,4}} + \frac{1}{C_5} = \frac{1}{6} + \frac{1}{6} + \frac{1}{6} = \frac{3}{6}$$

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



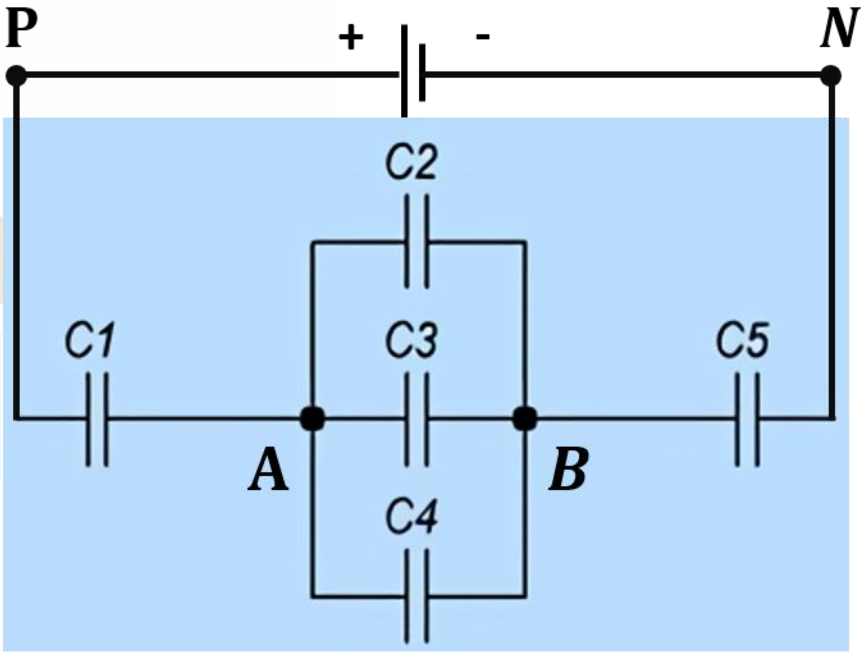
Grouping of capacitors / series & parallel

Solution: $C_1 = C_5 = 6\mu F, C_2 = C_3 = C_4 = 2\mu F; U_{PN} = 12V$

2) Deduce the quantity of total charge.

$$Q_{eq} = C_{eq} \times U_{PN} = 2 \times 10^{-6} \times 12 = 24 \times 10^{-6} C$$

3) Calculate the charge and the voltage across each capacitor.



C_1, $C_{2,3,4}$ & C_5 are in series then:

$$Q_{eq} = q_1 = q_{2,3,4} = q_5 = 24 \times 10^{-6} C$$

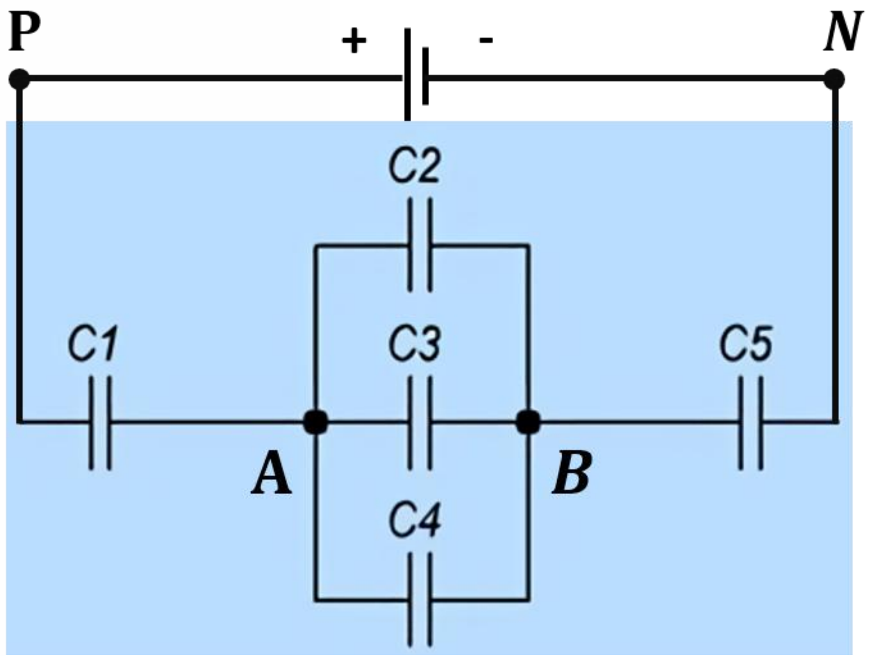
Grouping of capacitors / series & parallel

$$Q_{eq} = q_1 = q_{2,3,4} = q_5 = 24 \times 10^{-6} C$$

$$U_1 = \frac{q_1}{C_1} = \frac{24 \times 10^{-6}}{2 \times 10^{-6}} = 12V$$

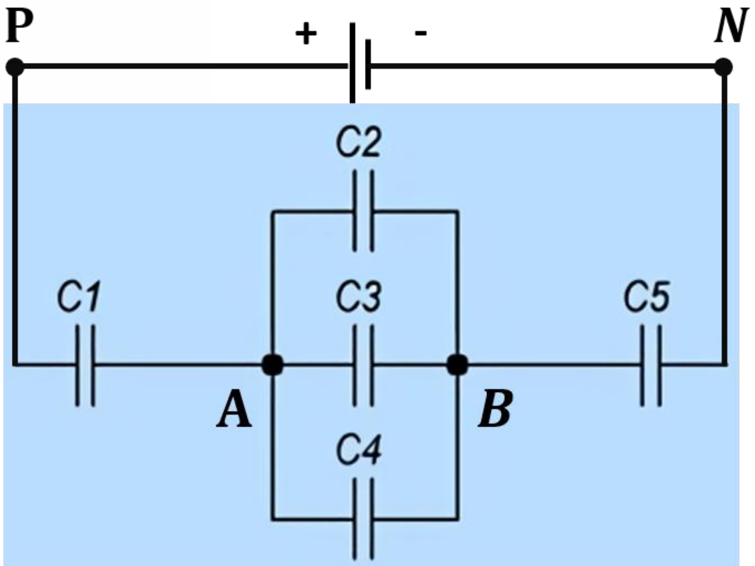
$$U_{2,3,4} = \frac{q_{2,3,4}}{C_{2,3,4}} = \frac{24 \times 10^{-6}}{6 \times 10^{-6}} = 4V$$

$$U_5 = \frac{q_5}{C_5} = \frac{24 \times 10^{-6}}{6 \times 10^{-6}} = 4V$$



Grouping of capacitors / series & parallel

C_2, C_3, C_4 are in parallel then:



Apply law of uniqueness of voltage:

$$U_2 = U_3 = U_4 = U_{2,3,4} = 4V$$

$$q_2 = C_2 \times U_2 = 2 \times 10^{-6} \times 4V = 8 \times 10^{-6} C$$

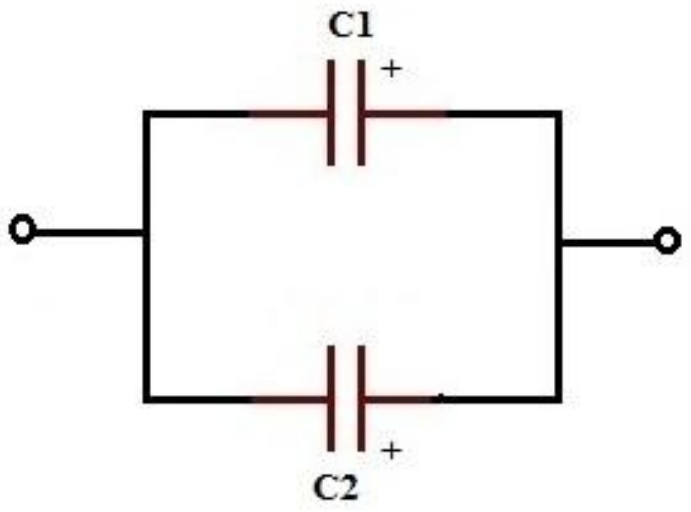
$$q_3 = C_3 \times U_3 = 2 \times 10^{-6} \times 4V = 8 \times 10^{-6} C$$

$$q_4 = C_4 \times U_4 = 2 \times 10^{-6} \times 4V = 8 \times 10^{-6} C$$

Conservation of total quantity of charge

We connect a capacitor of capacitance C_1 and of charge Q_1 to a capacitor of capacitance C_2 and of charge Q_2 as shown in the adjacent figure.

At electric equilibrium the capacitor C_1 become have Q'_1 and the capacitor C_2 become have new charge Q'_2



$$Q_{total\ initial} = Q_{total\ final}$$

$$Q_1 + Q_1 = Q'_1 + Q'_2$$

At electric equilibrium:

$$U'_1 = U'_2$$

Application 8:

Two capacitors of capacitances $C_1 = 6\mu F$ and $C_2 = 2\mu F$ carry the respective charges $Q_1 = 1.5mC$ and $Q_2 = 2mC$.

1. Calculate the electric energy stored in each capacitor.

$$W = \frac{1}{2}CU^2$$

$$q = C \times U \Rightarrow U = \frac{q}{C}$$

$$W = \frac{1}{2}C\left[\frac{q}{C}\right]^2$$

$$W = \frac{1}{2}C\left[\frac{q}{C}\right]^2$$

$$W = \frac{1}{2}C\frac{q^2}{C^2}$$

$$W = \frac{1}{2}\frac{q^2}{C}$$

Conservation of total quantity of charge

Two capacitors of capacitances $C_1 = 6\mu F$ and $C_2 = 2\mu F$ carry the respective charges $Q_1 = 1.5mC$ and $Q_2 = 2mC$.

$$W_1 = \frac{1}{2}\frac{{q_1}^2}{C_1}$$

$$W_1 = \frac{1}{2}\frac{(1.5 \times 10^{-3})^2}{6 \times 10^{-6}}$$

$$W_1 = 0.1875J$$

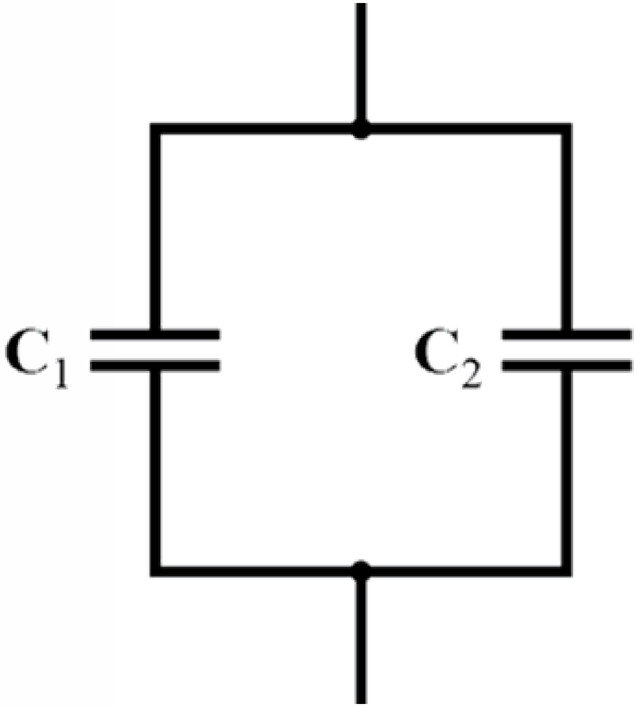
$$W_2 = \frac{1}{2}\frac{{q_2}^2}{C_2}$$

$$W_2 = \frac{1}{2}\frac{(2 \times 10^{-3})^2}{2 \times 10^{-6}}$$

$$W_2 = 1J$$

Conservation of total quantity of charge

2)We join the armatures of the same sign of each of the capacitors together.



a) Calculate the voltage of each capacitor at electric equilibrium.

$$q_1 + q_2 = q'_1 + q'_2$$

$$q_1 + q_2 = C_1 U'_1 + C_2 U'_2$$

$$U'_1 = U'_2 = U'$$

$$q_1 + q_2 = C_1 U' + C_2 U'$$

$$q_1 + q_2 = U'(C_1 + C_2)$$

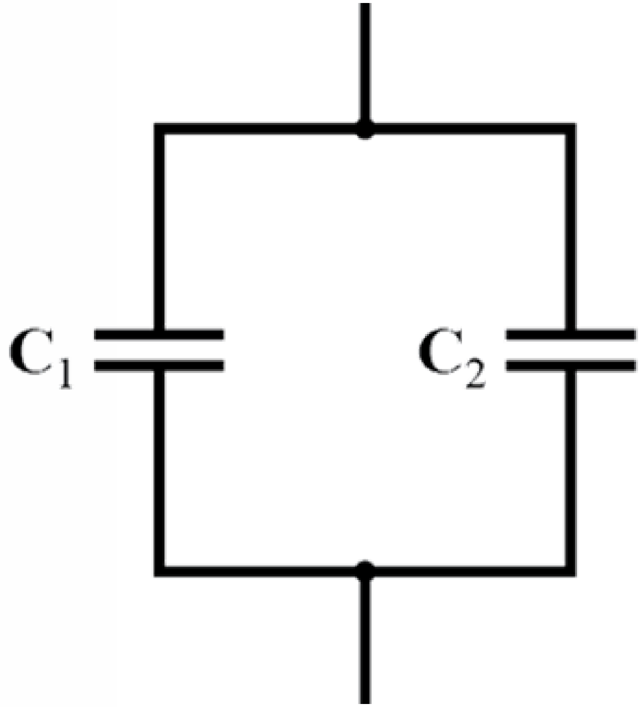
Conservation of total quantity of charge

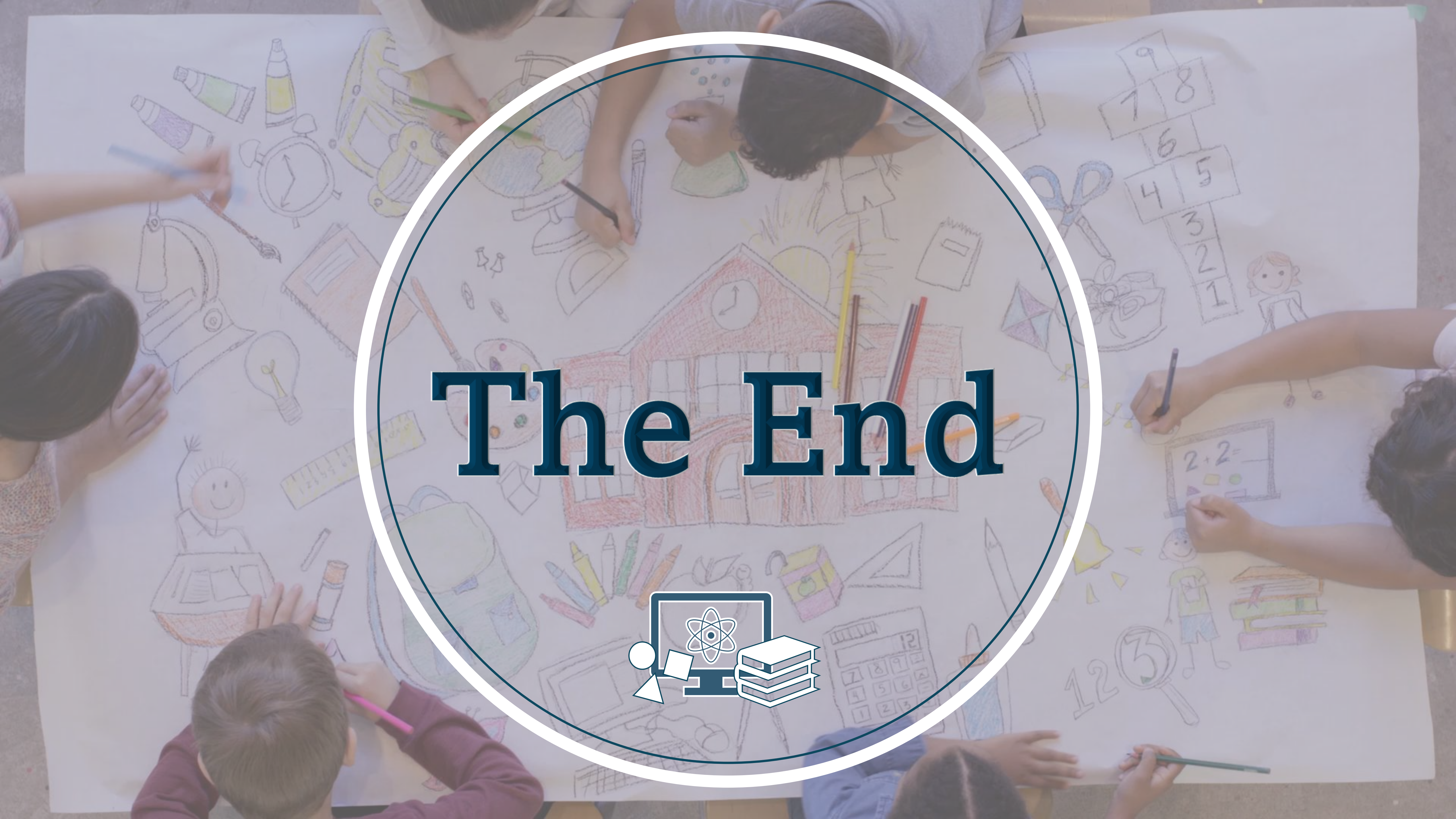
$$q_1 + q_2 = U'(C_1 + C_2)$$

$$U' = \frac{q_1 + q_2}{(C_1 + C_2)}$$

$$U' = \frac{(1.5 + 2) \times 10^{-3}}{(6 + 2) \times 10^{-6}}$$

$$U' = 437.5V$$





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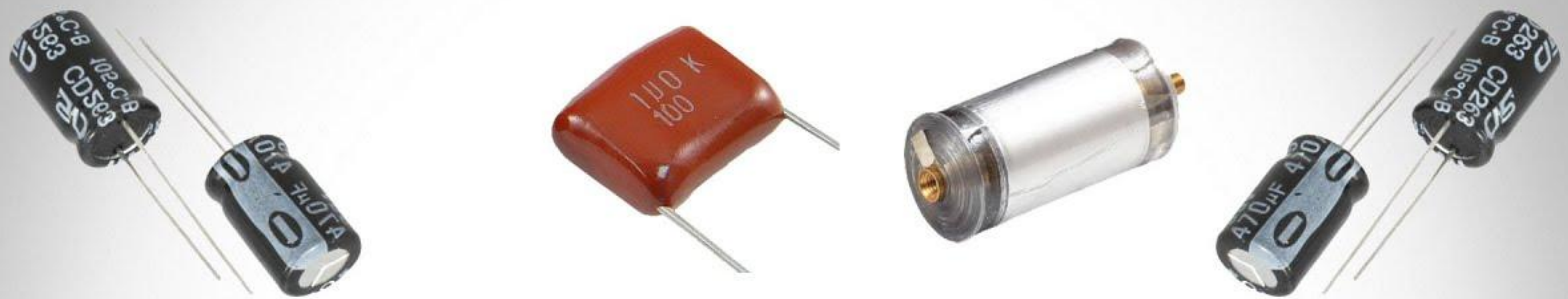
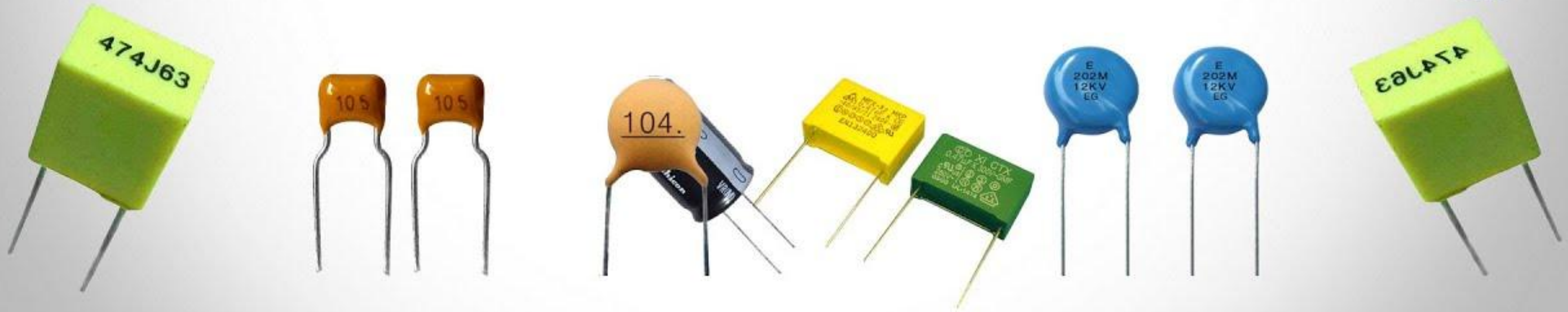


Grade 11 S – Physics

Chapter 13: Capacitor

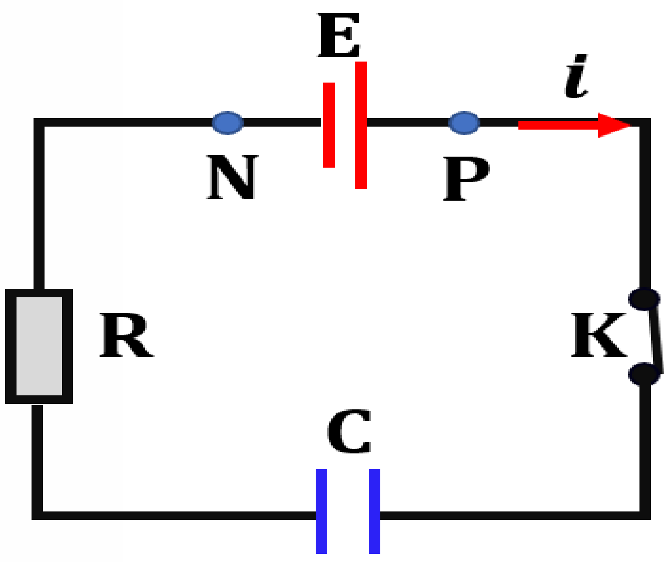


OBJECTIVES

1 **Study the Charging of a capacitor.**

Charging of capacitor

A neutral capacitor of capacitance C and a resistor of resistance R are connected in series across ideal generator delivering a constant voltage $U_G = E$ as shown in the following circuit.



At an instant $t = 0$, the switch K is closed, then the charging process of the capacitor starts .

Charging of capacitor

The value of the voltage (u_C), the charge (q) and the current (i) are studied.

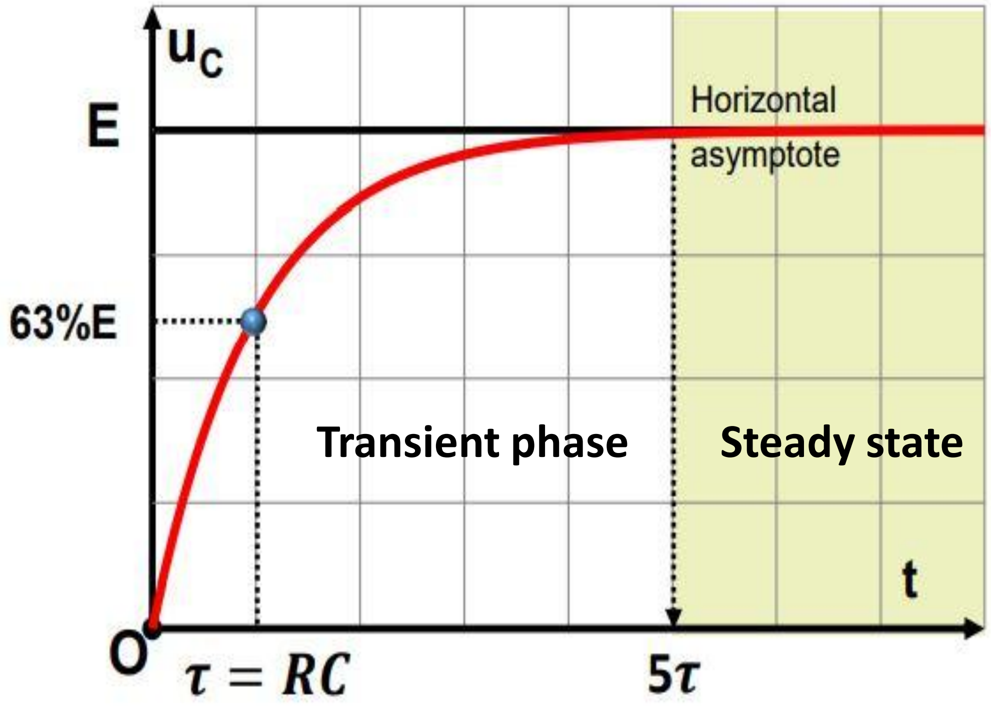
The voltage across the capacitor (u_C):

- At t=0 $u_C = 0$
- At $t = \tau = RC$ the voltage across the capacitor (u_C) reaches 63% out of the maximum value at steady state.

$$u_C = 63\%E \rightarrow u_C = 0.63 \times E$$

- For $t = 5\tau$ the capacitor is Practically full charged then:

$$u_C = E$$



$t = \tau$: is the time needed to charge the capacitor by 63% out of the maximum value (E)

Charging of capacitor

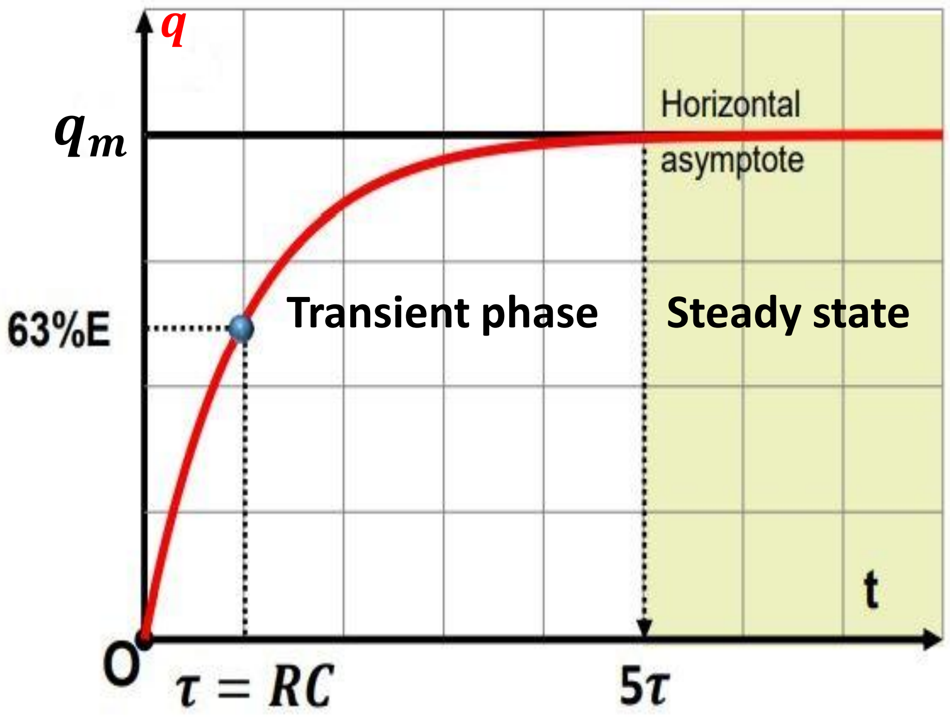
The charge across the capacitor (q):

- **At t=0** $q = 0$
- **At $t = \tau = RC$** the charge across the capacitor (q) reaches 63% out of the maximum value at steady state ($q_m = CE$).

$$q = 63\% q_m \rightarrow q = 0.63 \times C.E$$

- **For $t = 5\tau$** the capacitor is Practically full charged then:

$$q = q_m \rightarrow q = C.E$$



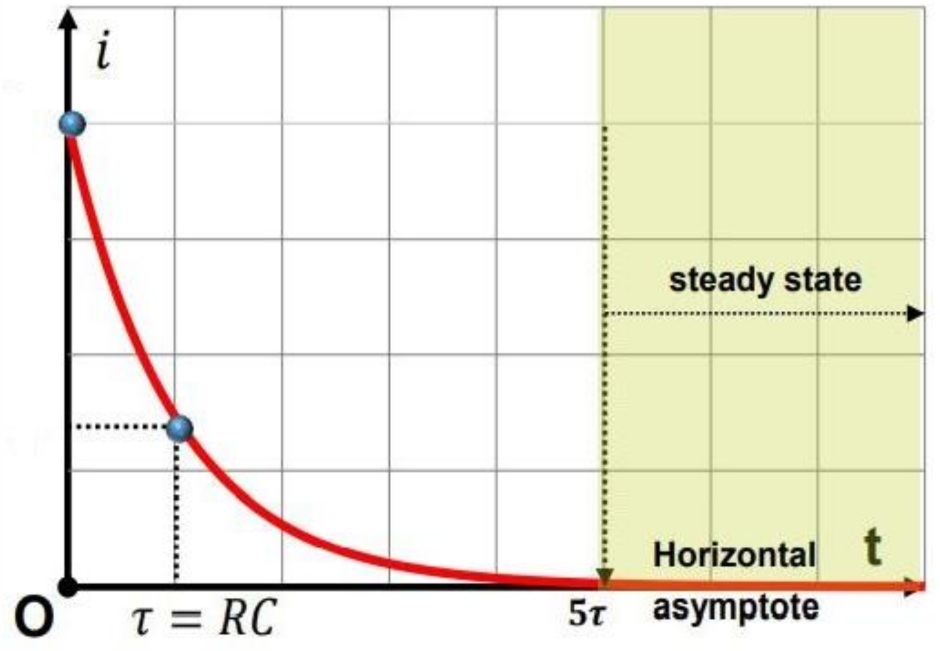
$t = \tau$: is the time needed to charge the capacitor by 63% out of the maximum value (C.E)

Charging of capacitor

The current crossing the capacitor (i):

- At t=0 $\quad \text{I} = I_m = \frac{E}{R}$
- At $t = \tau = RC$ the current cross the capacitor (i) reaches 37% out of the maximum value (I_m).

$$i = 37\% I_m \rightarrow i = 0.37 \times I_m$$



- For $t = 5\tau$ the current cross the capacitor become zero then:

$$i = 0$$

$t = \tau$: is the time needed to charge the capacitor by 63% out of the maximum value (C.E)

Summary of charging process

t(s)	$t = 0$	$t = \tau = RC$	$t = 5\tau$
u_C	0	0.63E	E
q	0	$0.63q_m$	$q_m = CE$
i	$I_m = \frac{E}{R}$	$0.37I_m$	0
u_R	E	$0.37\frac{E}{R}$	0

Charging of capacitor

How to calculate the time constant (τ):

First method by calculation: Given: $R = 1k\Omega, C = 2.5\mu F$

Using the formula: $\tau = RC$ → $\tau = 1000 \times 2.5 \times 10^{-6}$

→ $\tau = 2.5 \times 10^{-3} sec$

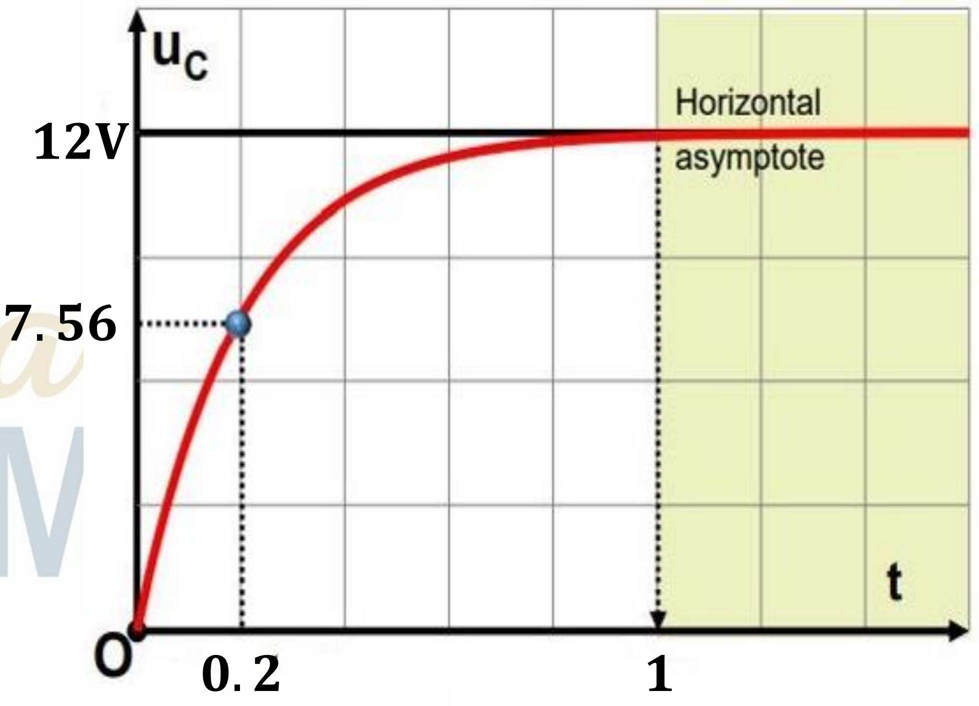
Charging of capacitor

How to calculate the time constant (τ):

Second method by definition: Given: $R = 5\Omega$, $C = ??$

Determine the value of time constant τ. Deduce C.

τ: is the time needed to charge the capacitor by 63% out of the maximum value (C.E)



$$u_C = 0.63E$$

$$u_C = 0.63 \times 12$$

$$u_C = 7.56\text{V}$$

Then $\tau = 0.2s$

$$\tau = RC$$

$$0.2 = 5 \times C$$

$$C = 0.04F$$

Charging of capacitor

How to calculate the time constant (τ):

Third method by tangent:

Given: $R = ??, C = 200\mu F$

Determine the value of time constant τ. Deduce R.

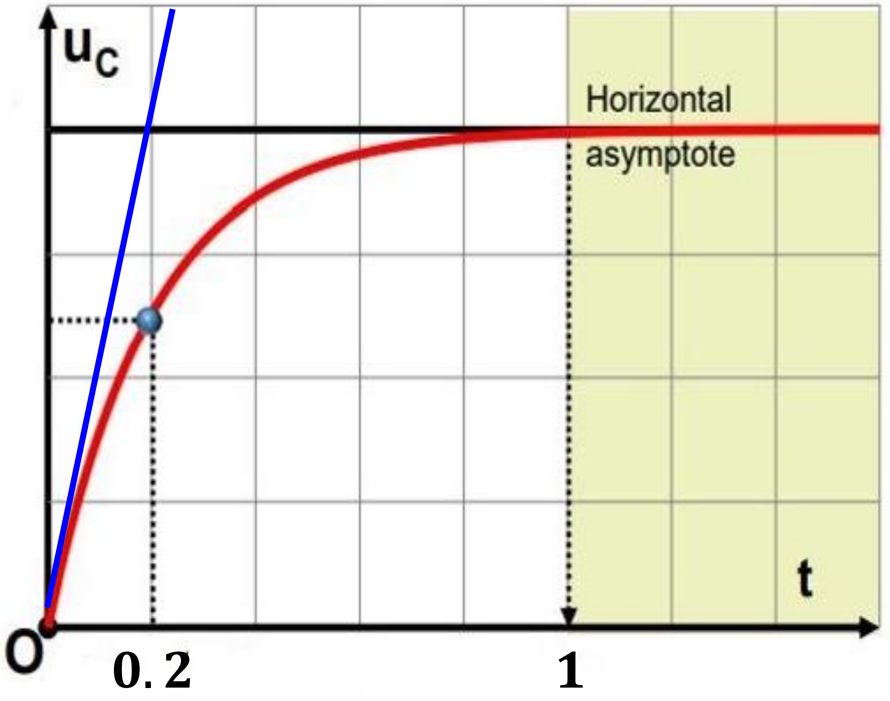
The abscissa of point of intersection between the horizontal asymptote and the tangent at $t_0 = 0$ is the time constant (τ):

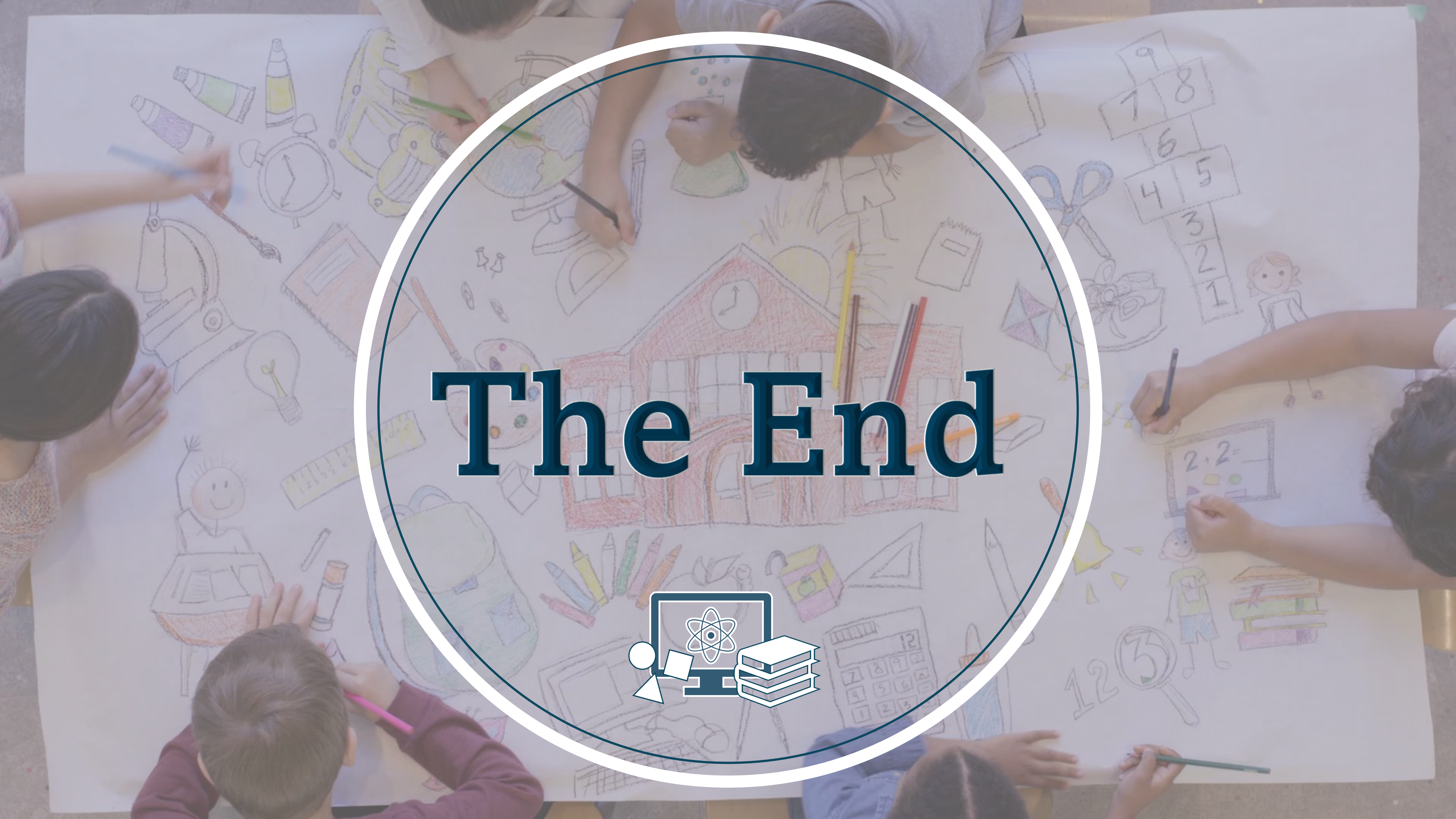
$\tau = 0.2 sec$

$\tau = RC$

$0.2 = R \times 200 \times 10^{-6}$

$R = 1000\Omega$





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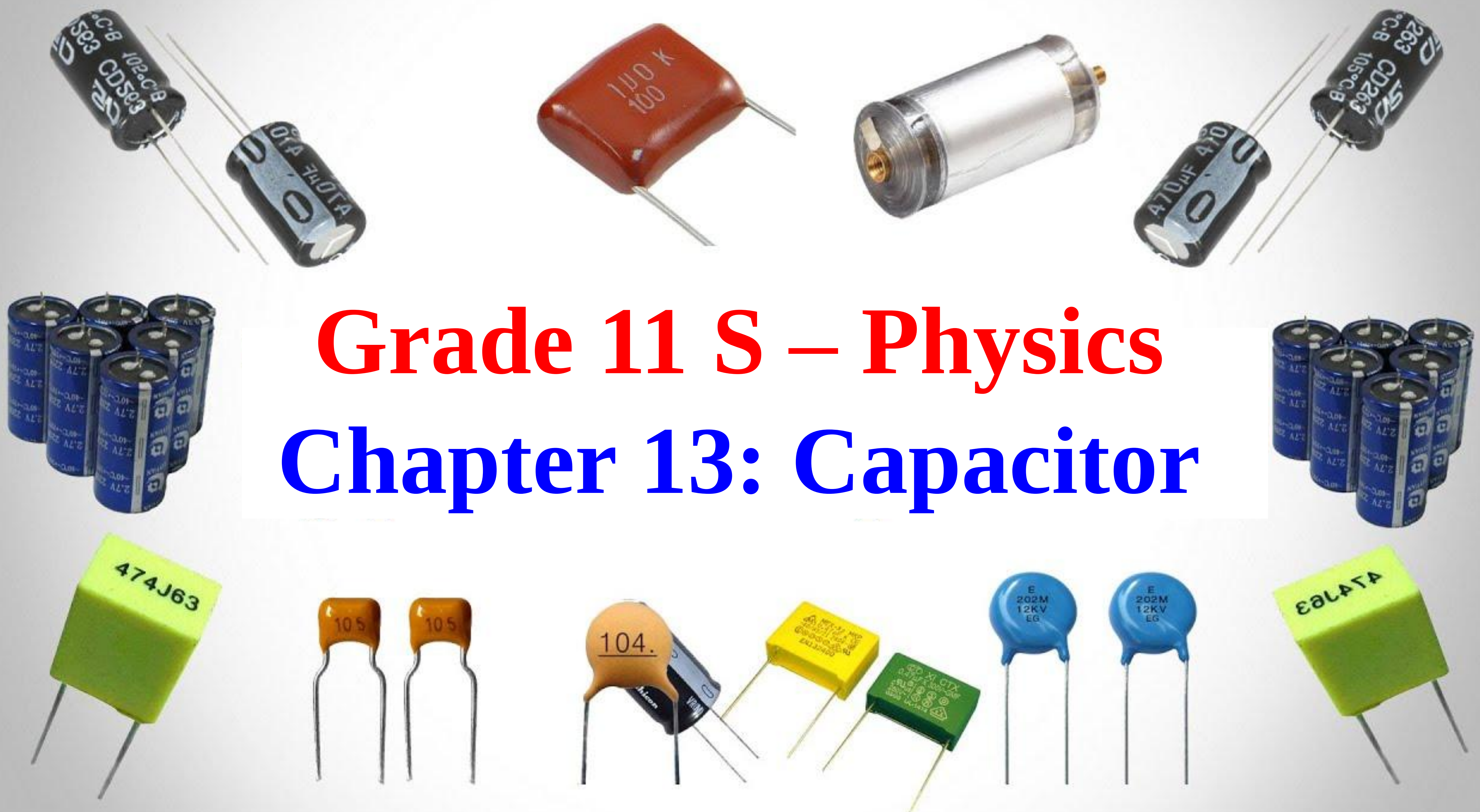
Grade 11 S – Physics

Chapter 13: Capacitor

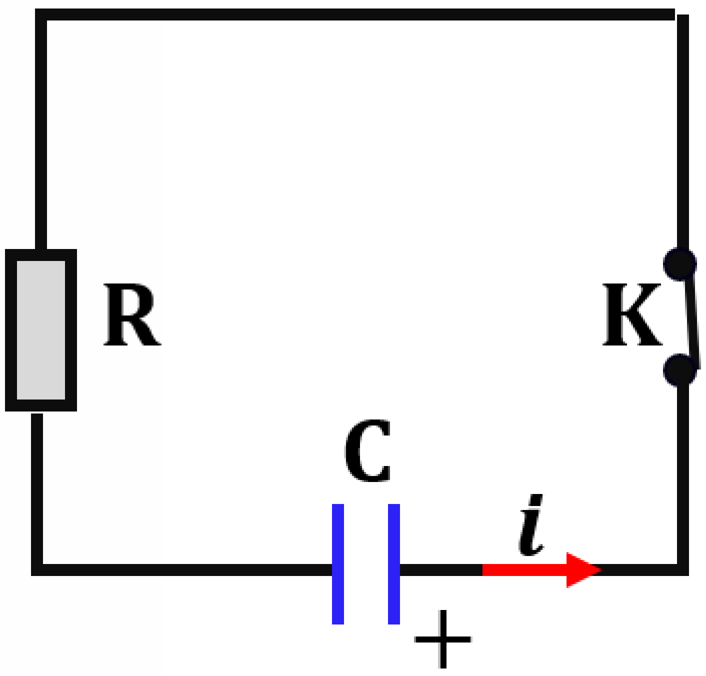


OBJECTIVES

1 **Study the Discharging of a capacitor.**

Discharging of capacitor

The charged capacitor of capacitance C is disconnected from the generator and connected to a resistor of resistance R, delivers the current to the circuit from its positive armature then discharging process takes place.



Discharging of capacitor

The value of the voltage (u_C), the charge (q) and the current (i) are studied.

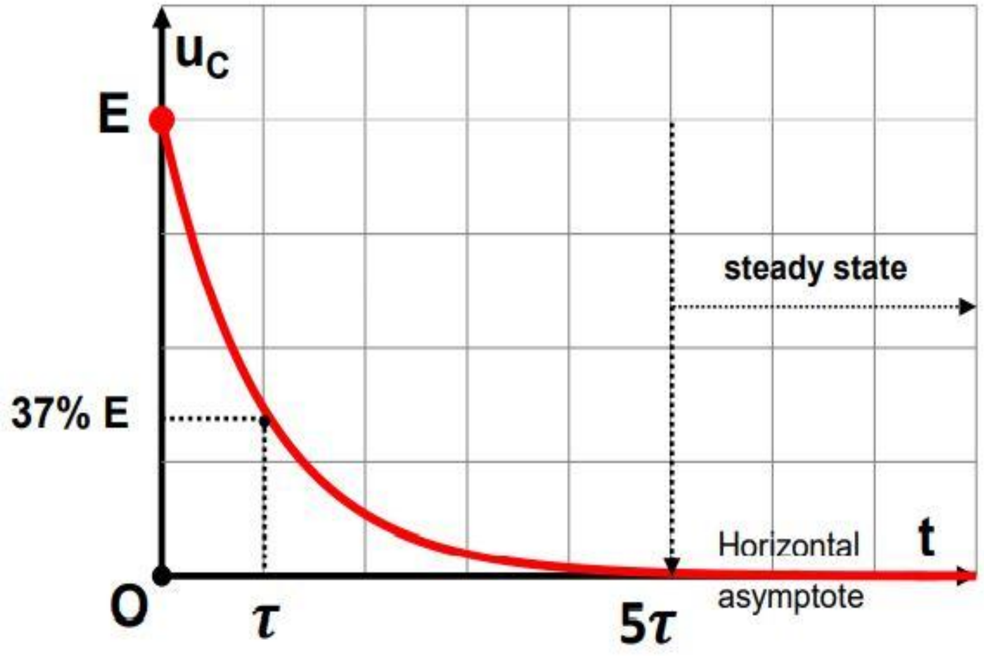
The voltage across the capacitor (u_C):

- At t=0 $u_C = E$
- At $t = \tau = RC$ the voltage across the capacitor (u_C) reaches 37% out of the maximum value at steady state.

$$u_C = 37\%E \rightarrow u_C = 0.37 \times E$$

- For $t = 5\tau$ the capacitor is Totally discharged then:

$$u_C = 0$$



τ : is the time needed to discharge the capacitor by 63% out of the maximum value (E)

Discharging of capacitor

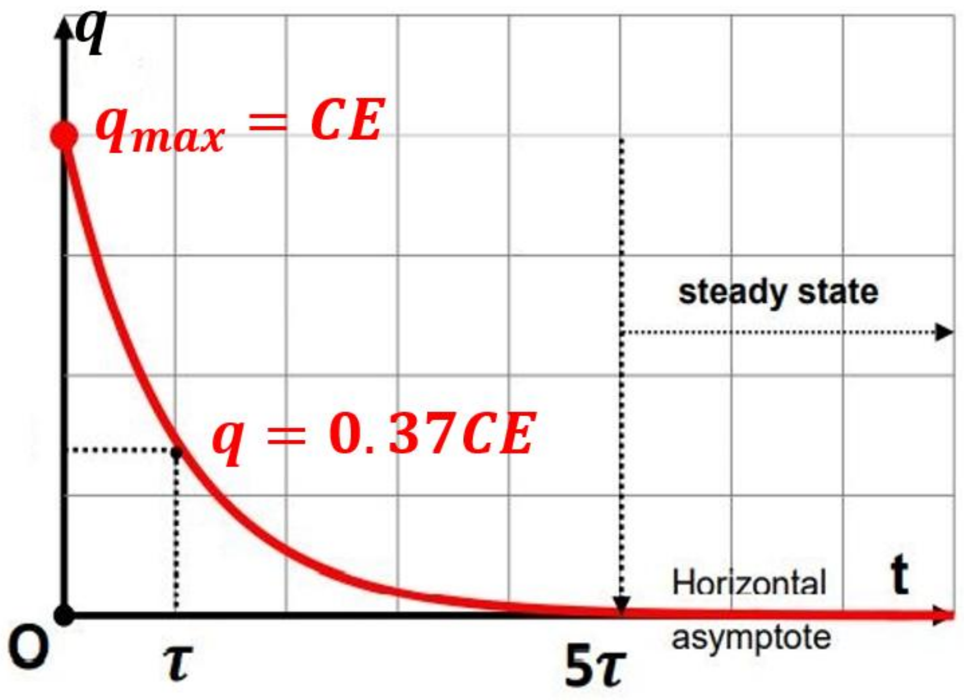
The charge across the capacitor (q):

- **At t=0** $q = C.E$
- **At $t = \tau = RC$** the charge across the capacitor (q) reaches 37% out of the maximum value at steady state ($q_m = CE$).

$$q = 37\% q_m \rightarrow q = 0.37 \times C.E$$

- **For $t = 5\tau$** the capacitor is Totally discharged then:

$$q = 0$$



Discharging of capacitor

The current crossing the capacitor (i):

- **At t=0**

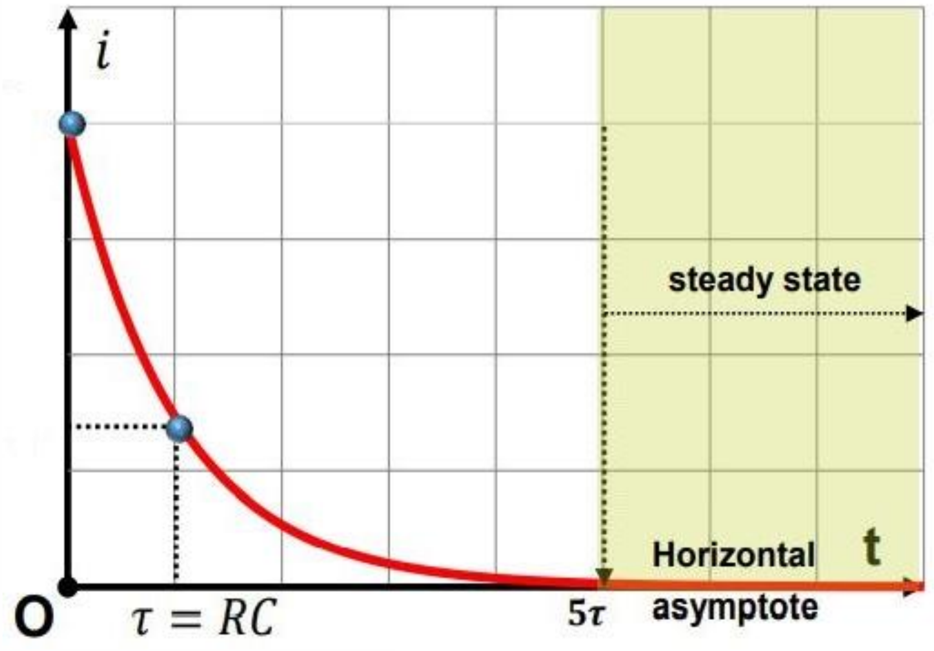
$$I = I_m = \frac{E}{R}$$

- **At $t = \tau = RC$** the current cross the capacitor (i) reaches 37% out of the maximum value (I_m).

$$i = 37\% I_m \rightarrow i = 0.37 \times I_m$$

- **For $t = 5\tau$** the current cross the capacitor become zero then:

$$i = 0$$



Summary of Discharging process of a capacitor

t(s)	0	$\tau = RC$	$t = 5\tau = 5RC$
u_C	E	$u_C = 0.37E$	$u_C = 0$
q	$q = q_{max} = CE$	$q = 0.37q_{max}$	$q = 0$
i	$I = I_m = \frac{E}{R}$	$I = 0.37I_m$	$i = 0$
u_R	E	$u_C = 0.37E$	$u_R = 0$

Discharging of capacitor

How to calculate the time constant (τ):

First method by calculation: Given: $R = 1k\Omega, C = 2.5\mu F$

Using the formula: $\tau = RC$ → $\tau = 1000 \times 2.5 \times 10^{-6}$

→ $\tau = 2.5 \times 10^{-3} sec$

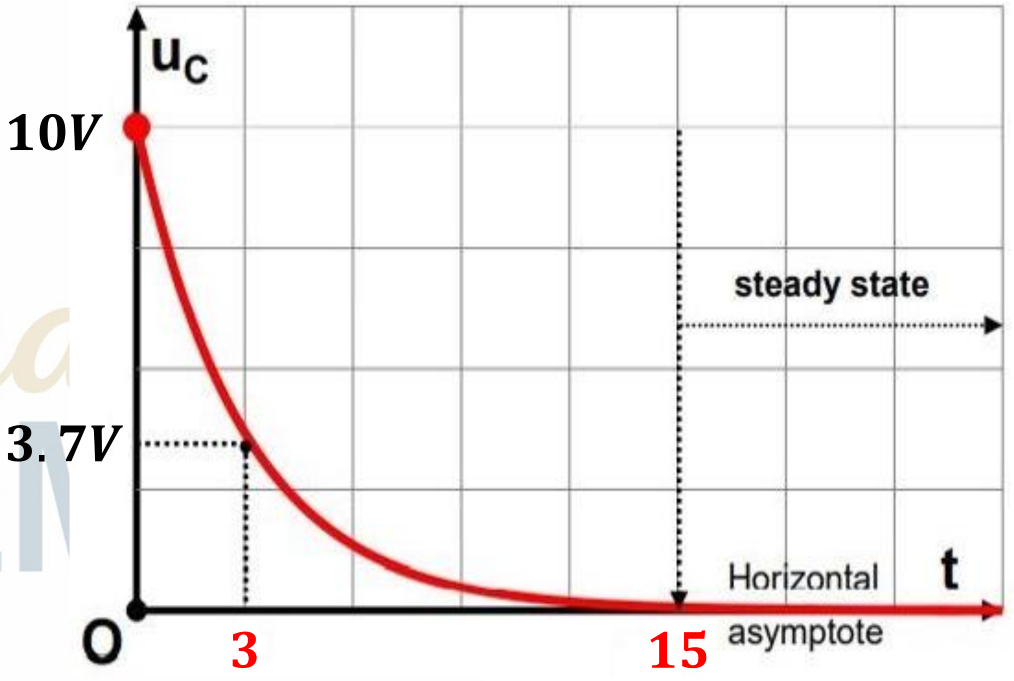
Discharging of capacitor

How to calculate the time constant (τ):

Second method by definition: Given: $R = 10\Omega$, $C = ??$

Determine the value of time constant τ. Deduce C.

τ: is the time needed to discharge the capacitor by 63% out of the maximum value (C.E)



$$u_C = 0.37E \Rightarrow \tau = RC$$

$$u_C = 0.37 \times 10 \Rightarrow 3 = 10 \times C$$

$$u_C = 3.7\text{V} \Rightarrow C = 0.3F$$

Then $\tau = 3s$

Discharging of capacitor

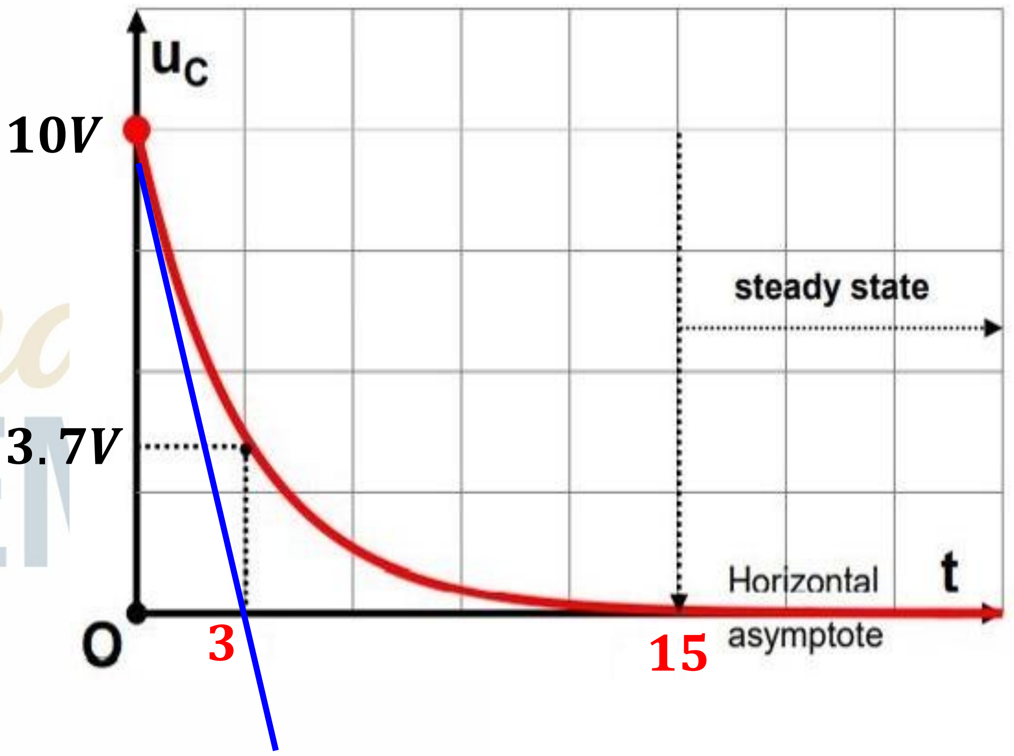
How to calculate the time constant (τ):

Third method by tangent:

Given: $R = ??,\ C = 200\mu F$

Determine the value of time constant τ. Deduce R.

The intersection between the horizontal asymptote and the tangent at $t_0 = 0$ is the time constant (τ):

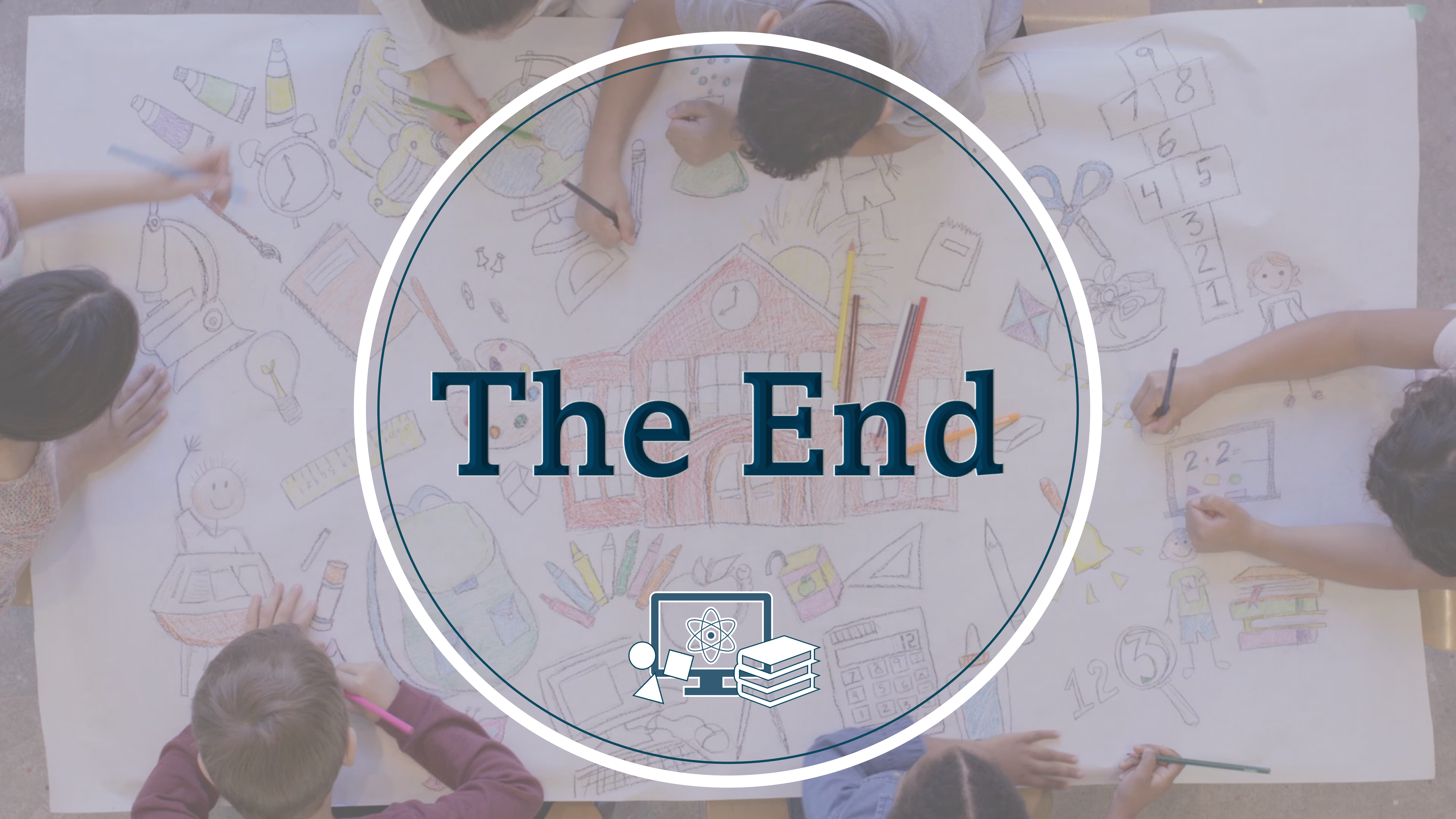


$$\tau = 3sec$$

$$\tau = RC$$

$$3 = R \times 200 \times 10^{-6}$$

$$R = 15000\Omega$$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