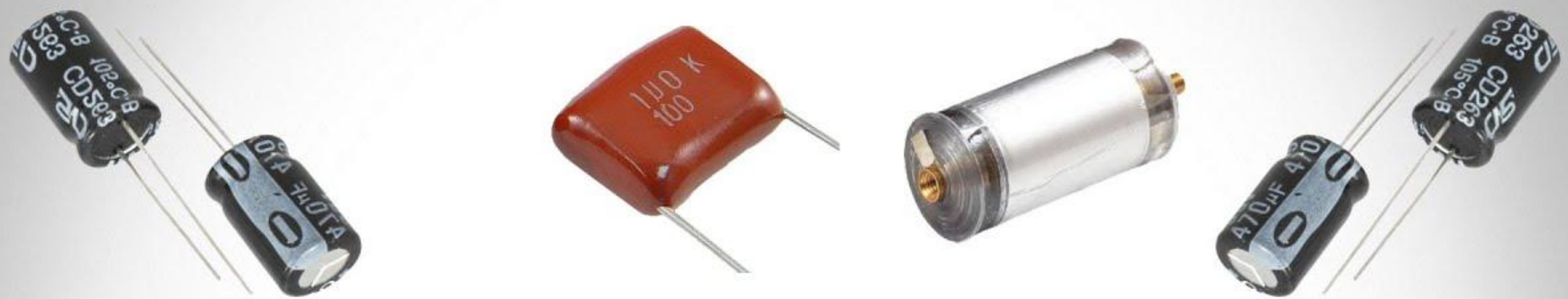
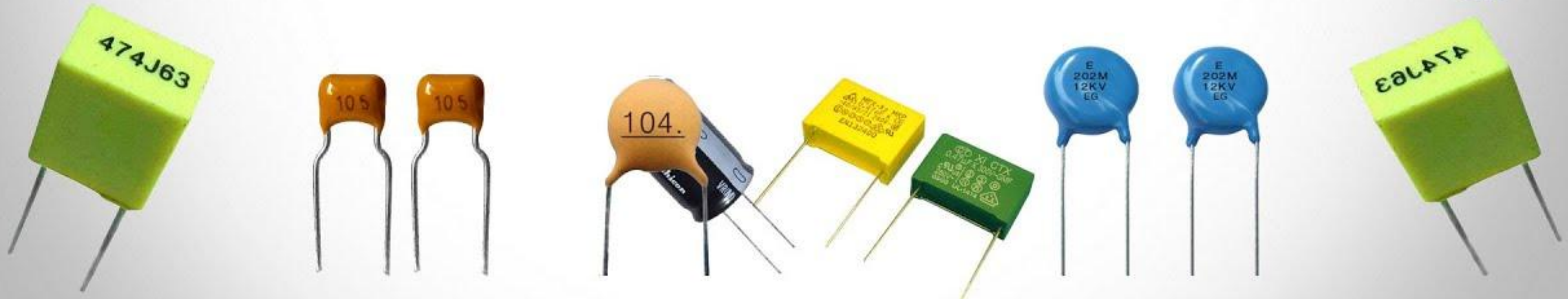
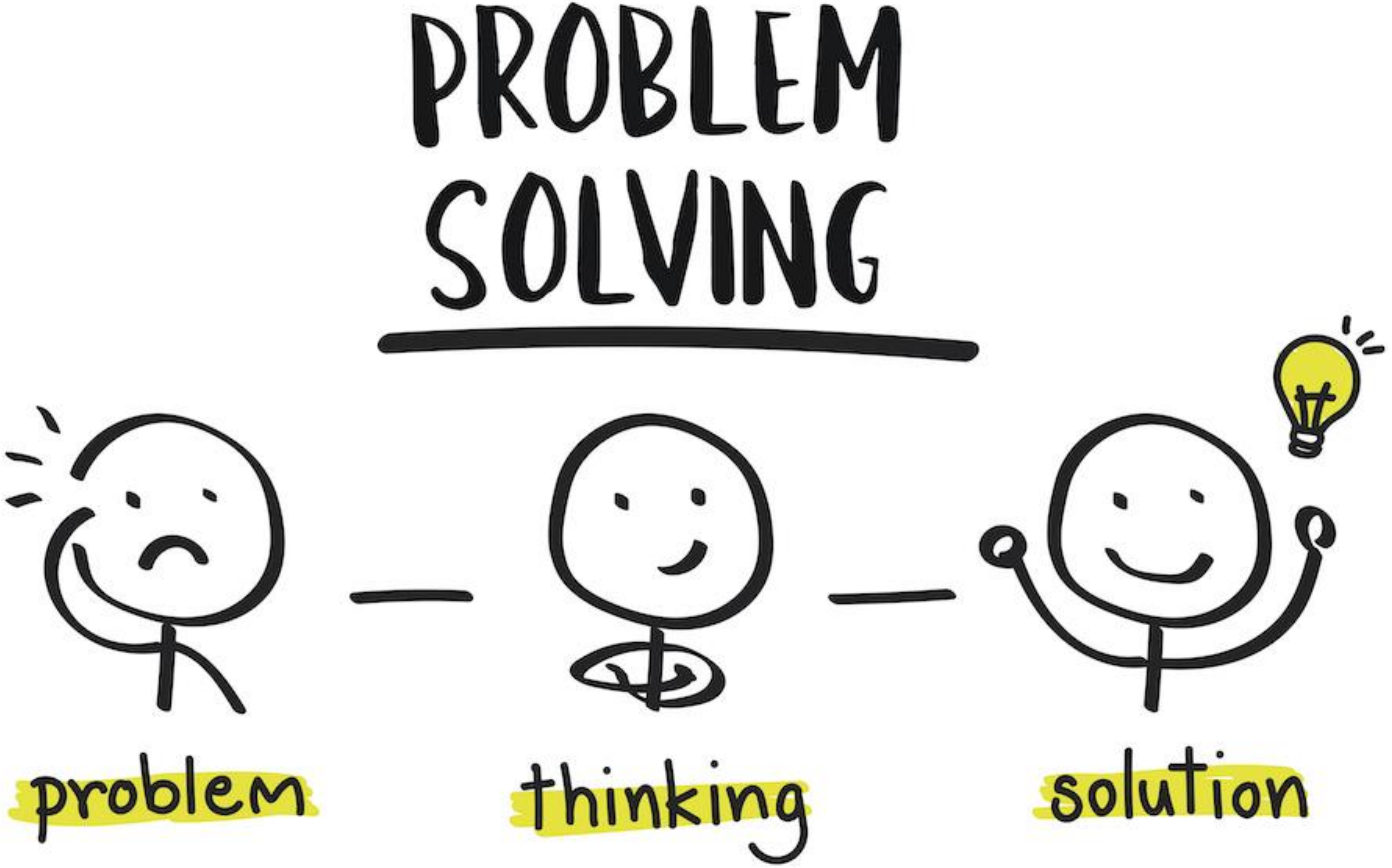


Grade 11 S – Physics

Chapter 13: Capacitor




PROBLEM SOLVING
problem
thinking
solution

Exercise 1

A parallel plate capacitor of capacitance $C_1 = 48nF$consists of two identical parallel conducting plates of common area $S = 1000cm^2$. The two plates are separated by a distance $d = 0.1\ mm$. An insulating material of relative permittivity ε_r is used to separate the two plates. The following table gives the values of ε_r of some mediums: Given $\varepsilon_0 = 8.85 \times 10^{-12} F/m$

Medium	Vacuum	*Paraffin*	*Mica*	*Porcelain*
ε_r	1	4.5	5.4	6.5

1. Calculate the value of ε_r. Deduce the nature of the insulating medium.
2. The capacitor is being charged under a voltage of U=24V.
   a. Calculate the quantity of the electric charge q on the capacitor C_1.
   b. Calculate the electric energy stored by the capacitor when it is completely charged.

Exercise 1

$C_1 = 48nF; S = 1000cm^2; d = 0.1\,mm; \varepsilon_0 = 8.85 \times 10^{-12} F/m$

Medium	Vacuum	*Paraffin*	*Mica*	*Porcelain*
ε_r	1	4.5	5.4	6.5

1. Calculate the value of ε_r. Deduce the nature of the insulating medium.

$$C = \varepsilon_0 \varepsilon_r \frac{S}{d} \Rightarrow 48 \times 10^{-9} = 8.85 \times 10^{-12} \varepsilon_r \frac{1000 \times 10^{-4}}{0.1 \times 10^{-3}}$$

$$\Rightarrow 48 \times 10^{-9} = 8.85 \times 10^{-9} \varepsilon_r$$

$$\Rightarrow \varepsilon_r = 5.4$$

Referring to the table insulating medium is Mica

Exercise 1

$C_1 = 48nF; S = 1000cm^2; d = 0.1\,mm; \varepsilon_0 = 8.85 \times 10^{-12} F/m$

1. The capacitor is being charged under a voltage of U=24V.

   a. Calculate the quantity of the electric charge q on the capacitor C_1.

$q = C \times U \Rightarrow q = 48 \times 10^{-9} \times 24 \Rightarrow q = 1.152 \times 10^{-6} C$

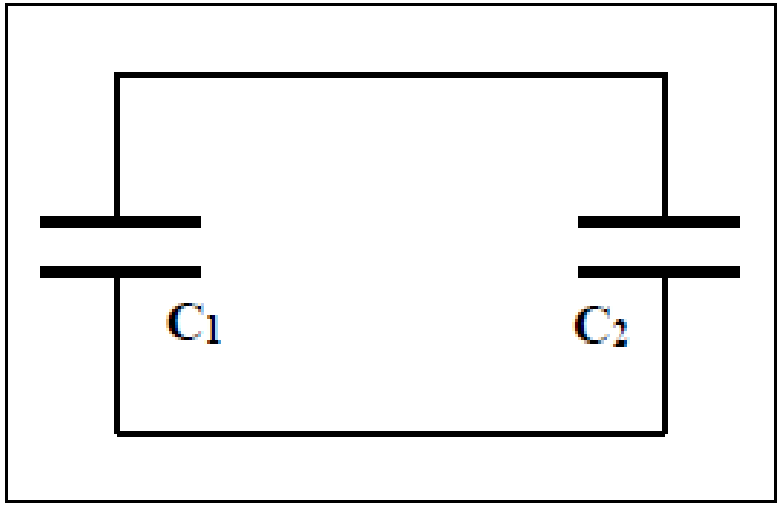
   b. Calculate the electric energy stored by the capacitor when it is completely charged.

$w = \frac{1}{2} CU^2 \Rightarrow w = 0.5 \times 48 \times 10^{-9} \times 24^2$

$\Rightarrow w = 1.3824 \times 10^{-5} J$

Exercise 1

3. The capacitor C_1 being completely charged is now connected across another uncharged one of capacitance $C_2 = 4C_1$ as indicated in the adjacent figure. At electric equilibrium, the electric charges on C_1 and C_2 are respectively q_1 and q_2.



3.1) Write a relation between q_1 , q_2 and q.

3.2) Deduce the voltage U' across each capacitor at electric equilibrium and the charges q_1 and q_2.

Exercise 1

$C_1 = 48nF$; $C_2 = 192nF$(uncharged); equilibrium, C_1 have q_1 and C_2 have q_2.

3.1) Write a relation between q_1 , q_2 and q.

$Q_{total\ initial} = Q_{total\ final}$ ⇨ $q + 0 = q_1 + q_2$ ⇨ $q = q_1 + q_2$

3.2) Deduce the voltage U' across each capacitor at electric equilibrium and the charges q_1 and q_2.

$$q + 0 = q_1 + q_2$$

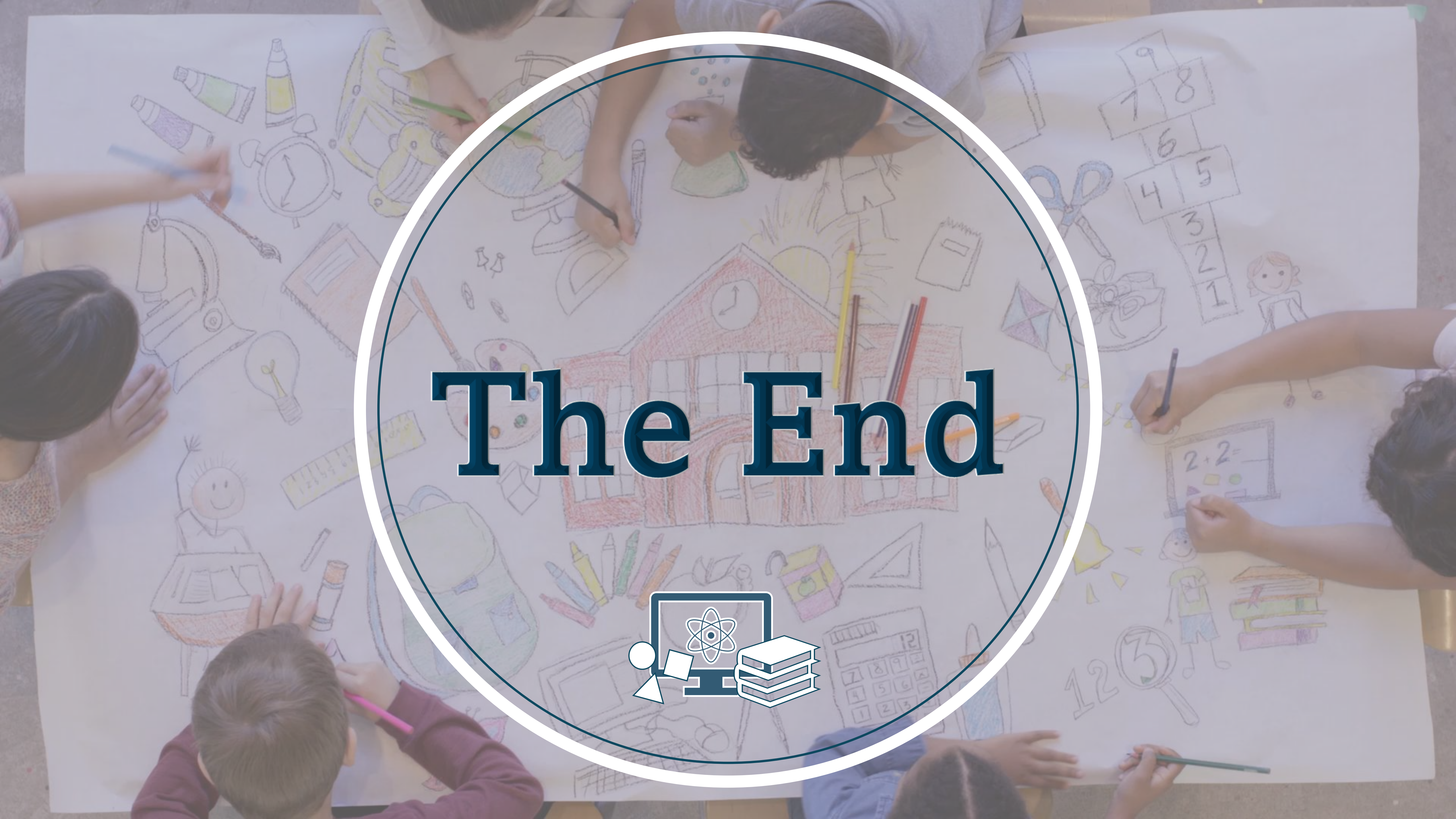
$$q = C_1 \times U' + C_2 \times U'$$

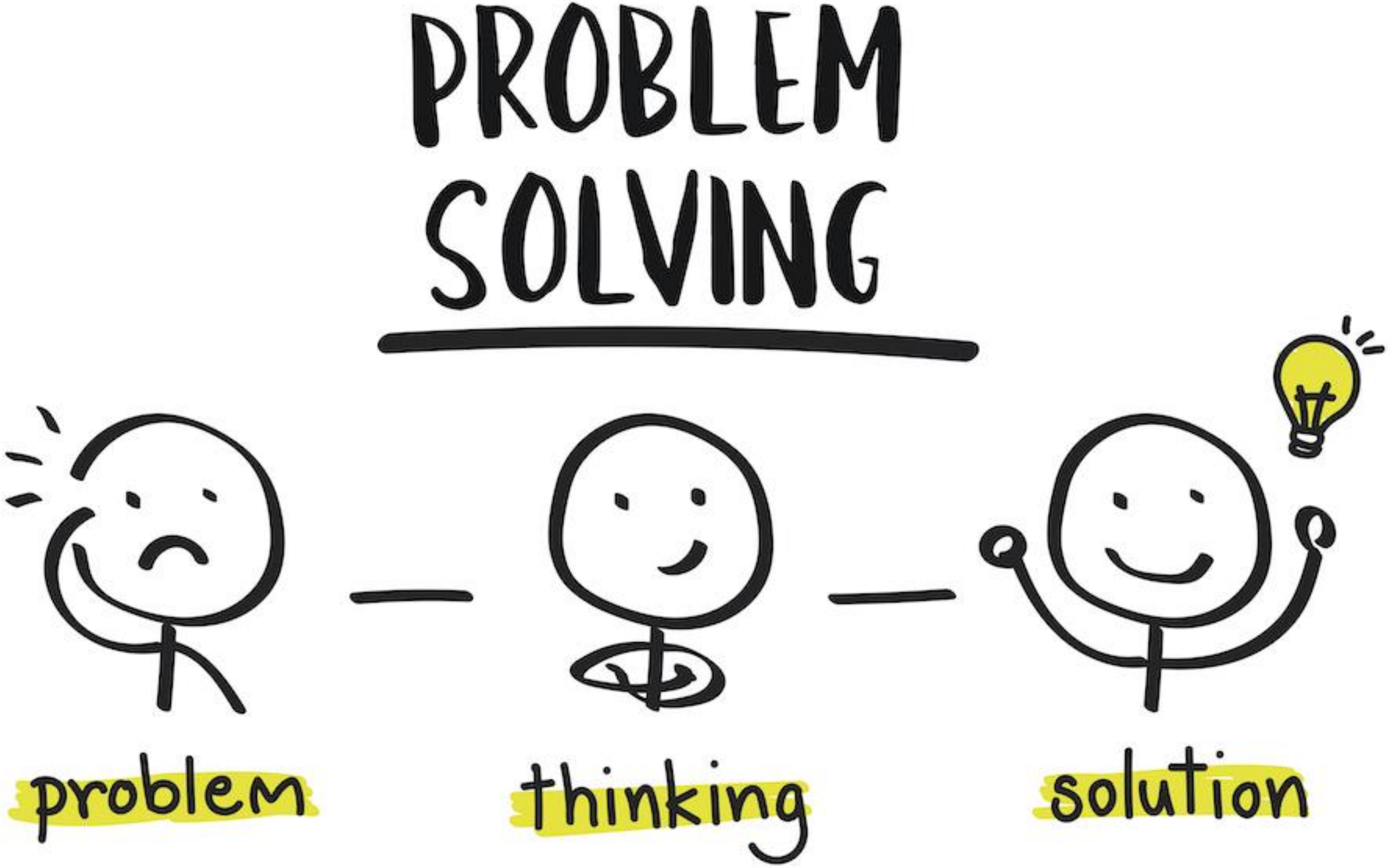
$$q = U'(C_1 + C_2)$$

$$q = U'(C_1 + C_2)$$

⇨ $1.152 \times 10^{-6} = U'(48 + 192) \times 10^{-9}$

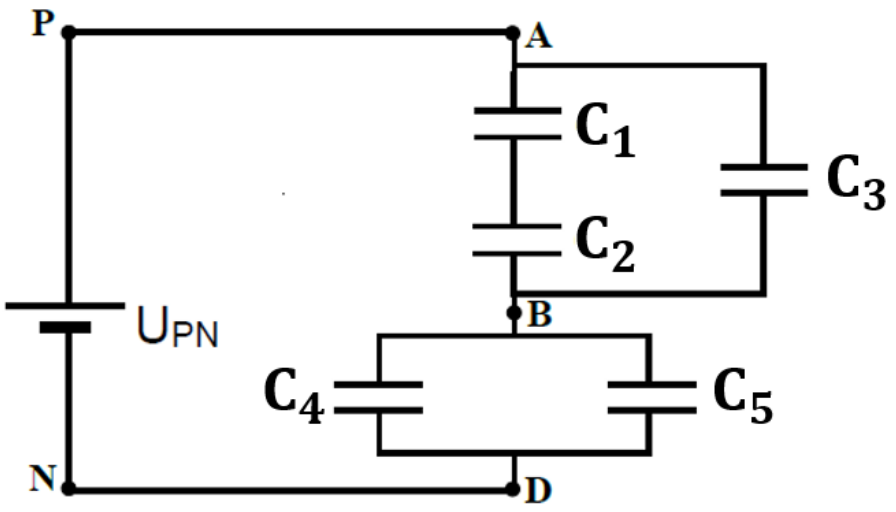
⇨ $U' = 4.8V$


The End


PROBLEM SOLVING
problem
thinking
solution

Exercise 2

Consider five capacitors of capacitance $C_1 = C_2 = 2\mu F$, $C_3 = 2\mu F$ and $C_4 = C_5 = 1.5\mu F$ are connected to a dry cell of voltage U_{PN} as shown in the adjacent figure. Given that: $U_{BD} = 5V$.



1)Calculate the equivalent capacitance C_{eq} between A and D.

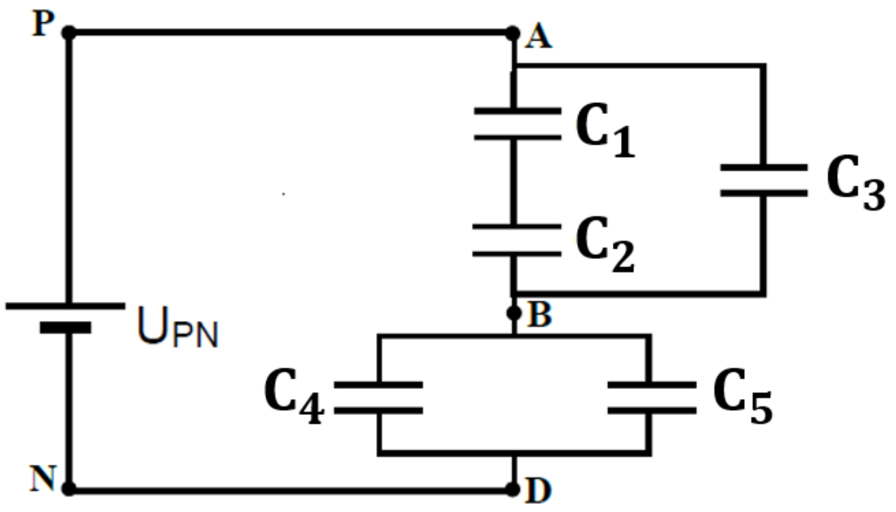
2)Calculate the charge Q_{BD}. Deduce the charge Q_{eq} of C_{eq}.

3)Deduce the voltage U_{PN}.

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

Exercise 2

$C_1 = C_2 = 2\mu F,\ C_3 = 2\mu F$ and $C_4 = C_5 = 1.5\mu F;\ U_{BD} = 5V.$



1)Calculate the equivalent capacitance C_{eq} between A and D.

C_1 and C_2 are in series: $C_{1,2} = \dfrac{C_1 \times C_2}{C_1 + C_2}$

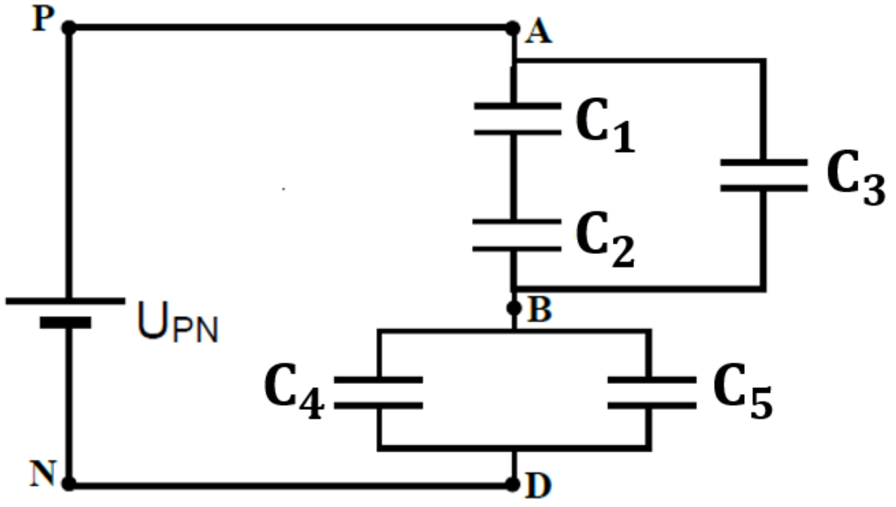
$$C_{1,2} = \frac{2 \times 2}{2+2} = \frac{4}{4} = 1nF$$

$C_{1,2}$ and C_3 are in parallel: $C_{1,2,3} = C_{1,2} + C_3$

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

Exercise 2

$C_1 = C_2 = 2\mu F,\ C_3 = 2\mu F$ and $C_4 = C_5 = 1.5\mu F;\ U_{BD} = 5V.$



C_4 and C_5 are in parallel: $C_{4,5} = C_4 + C_5$

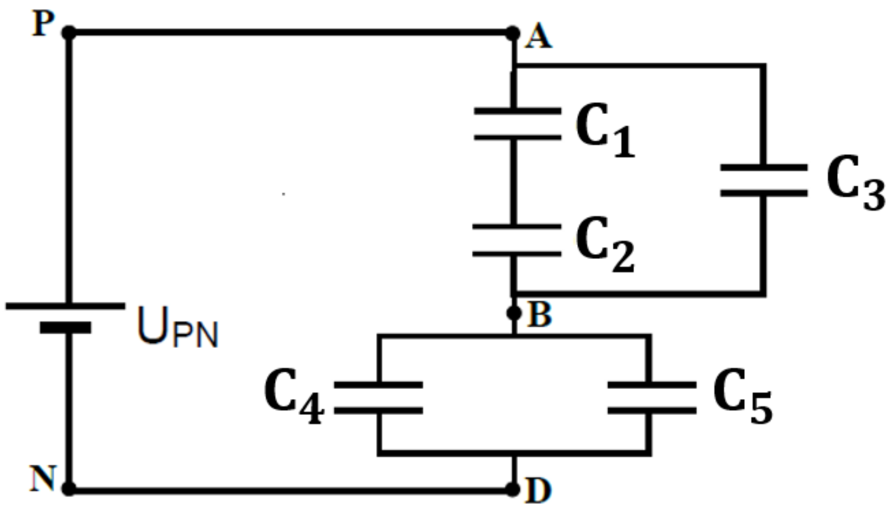
$\Rightarrow C_{4,5} = 1.5 + 1.5 \Rightarrow C_{4,5} = 3\mu F$

$C_{1,2,3}$ and $C_{4,5}$ are in series:

$$C_{eq} = \frac{C_{1,2,3} \times C_{4,5}}{C_{1,2,3} + C_{4,5}} = \frac{3 \times 3}{3 + 3} = \frac{9}{6} \Rightarrow C_{1,2,3} = 1.5\mu F$$

Exercise 2

$C_1 = C_2 = 2\mu F,\ C_3 = 2\mu F$ and $C_4 = C_5 = 1.5\mu F;\ U_{BD} = 5V.$



2) Calculate the charge Q_{BD}. Deduce the charge Q_{eq} of C_{eq}.

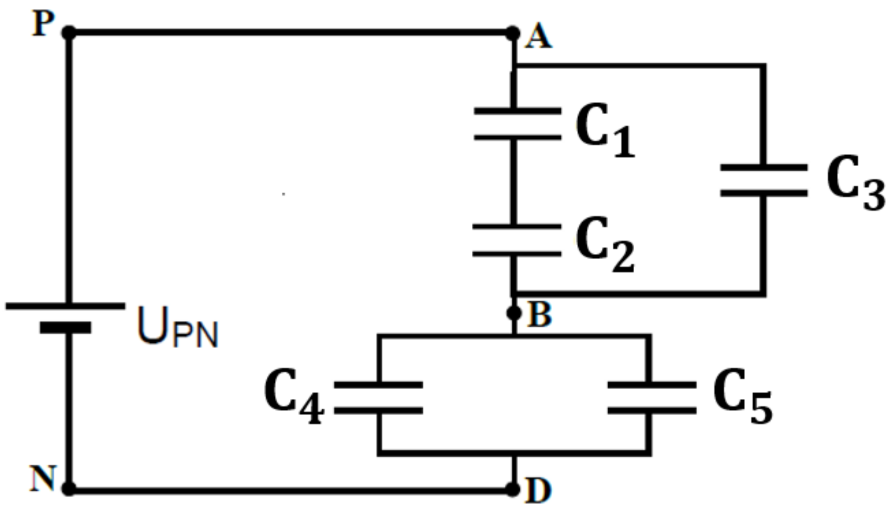
$Q_{BD} = C_{4,5} \times U_{BD}$ ➡ $Q_{BD} = 3nF \times 5$

➡ $Q_{BD} = 15\mu C$

$Q_{BD} = Q_{AB} = Q_{eq} = 15\mu C$ Law of uniqueness of charges in series

Exercise 2

$C_1 = C_2 = 2\mu F,\ C_3 = 2\mu F$ and $C_4 = C_5 = 1.5\mu F;\ U_{BD} = 5V.$



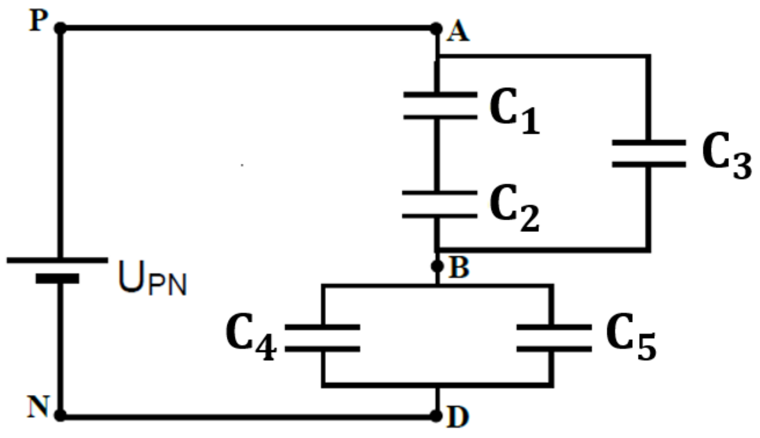
3) Deduce the voltage U_{PN}.

$$Q_{eq} = C_{eq} \times U_{PN} \Rightarrow U_{PN} = \frac{Q_{eq}}{C_{eq}}$$

$$\Rightarrow U_{PN} = \frac{15 \times 10^{-6}}{1.5 \times 10^{-6}} \Rightarrow U_{PN} = 10V$$

Exercise 2

$C_1 = C_2 = 2\mu F,\ C_3 = 2\mu F$ and $C_4 = C_5 = 1.5\mu F;\ U_{BD} = 5V.$



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

C_4 and C_5 are in parallel then: $U_4 = U_5 = U_{BD} = 5V$

$Q_4 = C_4 \times U_4$

$\Rightarrow Q_4 = 1.5\mu F \times 5V$

$\Rightarrow Q_4 = 7.5\mu C$

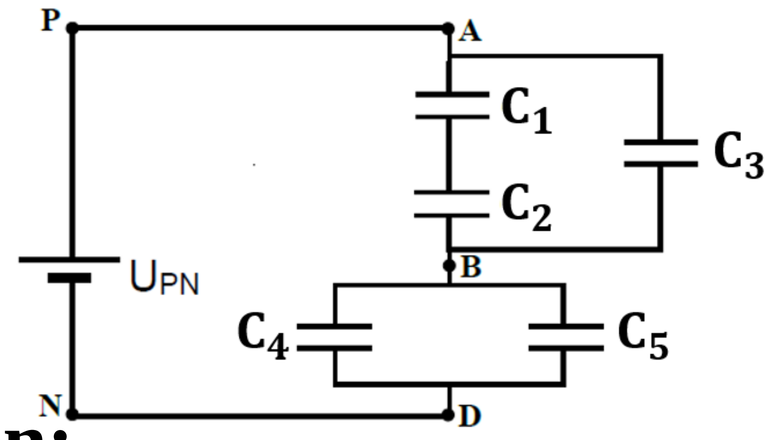
$Q_5 = C_5 \times U_5 = 1.5\mu F \times 5V = 7.5\mu C$

$\Rightarrow Q_5 = 1.5\mu F \times 5V$

$\Rightarrow Q_5 = 7.5\mu C$

Exercise 2

$C_1 = C_2 = 2\mu F,\ C_3 = 2\mu F$ and $C_4 = C_5 = 1.5\mu F;\ U_{BD} = 5V.$



$C_{1,2}$ and C_3 are in parallel then:

$U_{1,2} = U_3 = U_{AB} = 5V$

$Q_3 = C_3 \times U_3$

$\Rightarrow Q_3 = 2\mu F \times 5V$

$\Rightarrow Q_3 = 7.5\mu C$

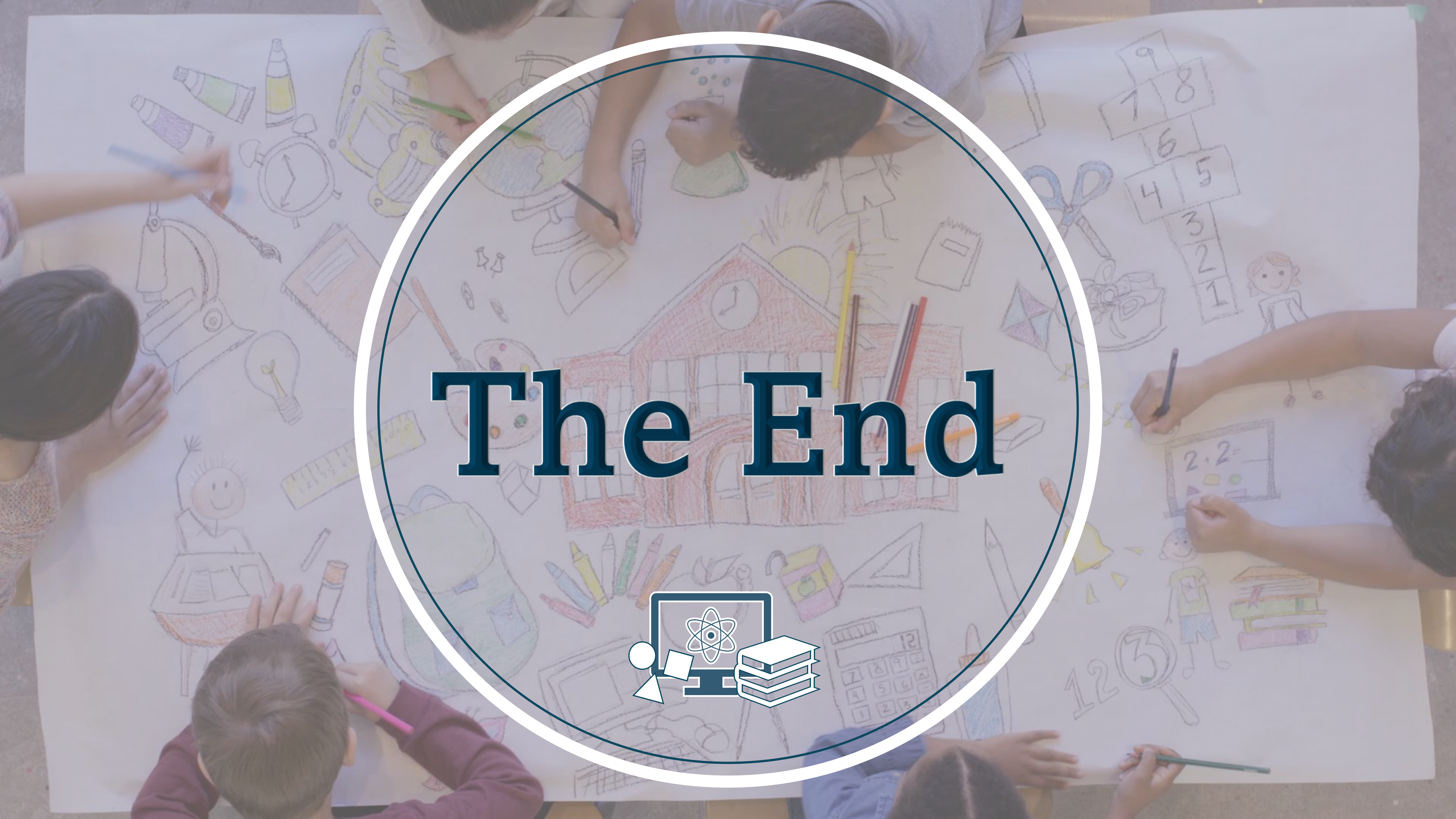
C_1 and C_2 are in series then:

$Q_{1,2} = C_{1,2} \times U_{1,2} = 1\mu F \times 5V = 5\mu C$

$\Rightarrow Q_1 = Q_2 = Q_{1,2} = 5\mu C$

$\Rightarrow U_1 = \frac{Q_1}{C_1} = \frac{5\mu C}{2\mu F} = 2.5V.$

$\Rightarrow U_2 = \frac{Q_2}{C_2} = \frac{5\mu C}{2\mu F} = 2.5V.$


The End