Tutorial N° 2 : CONDUCTORS IN ELECTROSTATIC EQUILIBRIUM AND CAPACITORS

Exercise 1

A hollow metallic conductor (A), initially neutral and isolated, completely surrounds a small spherical metallic conductor (B), carrying an electric charge $Q_B = +6\mu C$. Conductor (B) is placed at the center of the cavity of (A).

1) Explain the phenomenon that occurs when conductor (B) is introduced into the cavity of (A).
2) Determine the electric charges carried by the inner and outer surfaces of conductor (A), then deduce its total charge.
3) Determine the electric field inside the conducting material of (A), then derive its expression outside conductor (A).
4) Calculate the electric potential at the outer surface of (A), knowing that the outer radius of conductor (A) is $R = 10\ cm$.

Exercise 2

A parallel-plate capacitor consists of two flat, parallel metallic plates of surface area S, separated by a vacuum. The distance between the two plates is d. Plate A carries a charge $+Q$ and plate B carries a charge $-Q$. Edge effects are neglected, and the distance between the plates is assumed to be much smaller than their dimensions.

1) Given that the electric field produced by an infinite charged plane with surface charge density σ is given by $= \frac{\sigma}{2\varepsilon_0}$, determine the total electric field between the two plates. Deduce the electric field outside the capacitor.
2) Calculate the potential difference $U = V_A - V_B$ between the two plates as a function of E and d.
3) Determine the expression for the capacitance of a parallel-plate capacitor.
4) Calculate the surface area S of the plates of a capacitor with a capacitance of $1nF$. Given $d = 1mm$, $\varepsilon_0 = 8{,}85 \times 10^{-12}$ F/m

Exercise 3

Consider three capacitors with capacitances $C_1 = 2\mu F$, $C_2 = 3\mu F$, $C_3 = 6\mu F$ and an ideal voltage source supplying a voltage $U = 12V$.

I. Parallel Connection

a) Draw the circuit diagram and calculate the equivalent capacitance of the combination.
b) Connect the combination to the voltage source.

- Calculate the total charge supplied by the voltage source.
- Determine the voltage across each capacitor.
- Determine the electric charge stored on each capacitor.

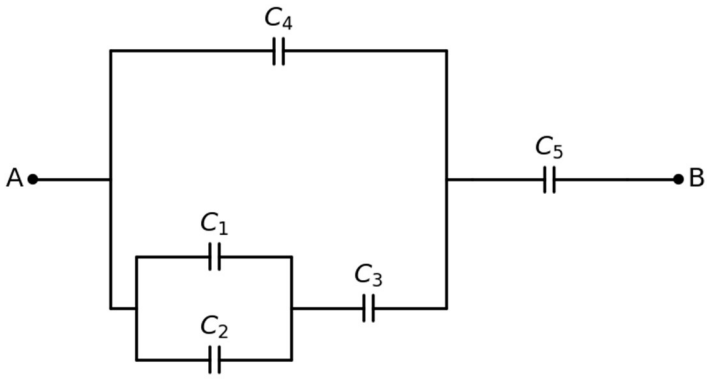
II. Series Connection

Repeat the same questions, considering this time that the three capacitors are connected in series.

Exercise 04

Consider the following electrical circuit consisting of five capacitors with the following capacitances:

$C_1 = 6\mu F, C_2 = 3\mu F, C_3 = 6\mu F, C_4 = 4\mu F, C_5 = 2\mu F$



Calculate the equivalent capacitance of the circuit.

Exercise 05

A capacitor with a capacitance of $C_1 = 10\mu F$ is charged to a voltage $U_0 = 50\ V$.

1) Calculate the initial charge Q_0 stored on this capacitor.
2) Calculate the electrostatic energy W_0 stored in C_1.
3) The capacitor C_1 is disconnected from the voltage source. It is then connected in parallel with a second capacitor $C_2 = 15\mu F$ which is initially uncharged.
   a) Determine the new voltage U' across the combination once electrostatic equilibrium has been reached.
   b) Determine the new charges Q_1' and Q_2' stored on capacitors C_1 and C_2 respectively?
4) Calculate the new total energy W' of the system.
   Compare W' with W_0. Where has the missing energy gone?