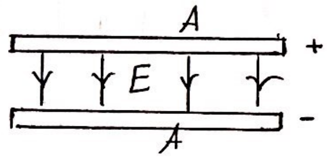
Chapter 25 : Capacitance

- A Capacitor Consists of 2 isolated conductors
- A charged Capacitor, it's plates have charges of $+q, -q$
- net Charge on a Capacitor = 0
- Capacitance :- $C = \frac{q}{V}$ F (it's a constant)   Note:- 1F = 1 C/V
- A fully Charged Capacitor : happens when ΔV between plates becomes equal to ΔV coming from the battery

Calculating the Capacitance (C depends on Geometry only)

↳ A Parallel - Plate Capacitor

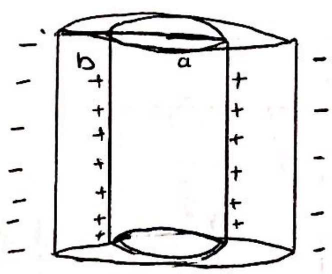
$$C = \frac{\epsilon_0 A}{d} \quad [F]$$



↳ A Cylindrical Capacitor

$$C = \frac{2\pi \epsilon_0 L}{\ln(b/a)} \quad [F]$$

b>a



↳ A spherical Conductor

$$C = \frac{4\pi \epsilon_0 ab}{b-a}$$

If there is only a sphere (meaning that the other sphere is at the infinity we say $b \to \infty$)

So:- $\frac{4\pi\epsilon_0 \, a \, \cancel{b}}{\cancel{b}(1 - \frac{a}{b})}$, $\frac{a}{b} \approx 0$ $\Rightarrow$ $C = 4\pi\epsilon_0 \, a$ or R (An isolated sphere)

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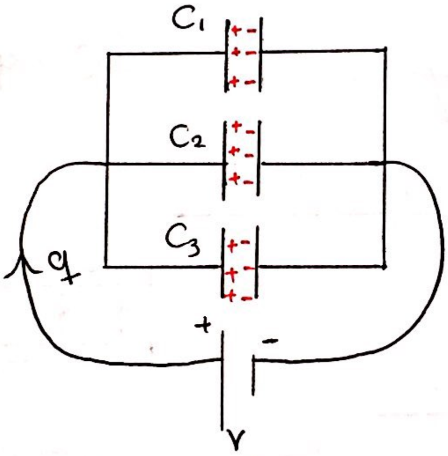
Capacitors in Parallel and series

Parallel:

- V is the same
- $q_{tot} = q_1 + q_2 + q_3$
- Knowing that: $q_1 = C_1 V$
  $q_2 = C_2 V$
  $q_3 = C_3 V$

$$C_{eq} = \frac{q_{tot}}{V} = \frac{C_1 V + C_2 V + C_3 V}{V} = C_1 + C_2 + C_3$$

$$C_{eq} = C_1 + C_2 + C_3$$



series

- q is the same
- $V_{eq} = V_1 + V_2 + V_3$
- Knowing that:

$V_1 = \frac{q}{C_1}$

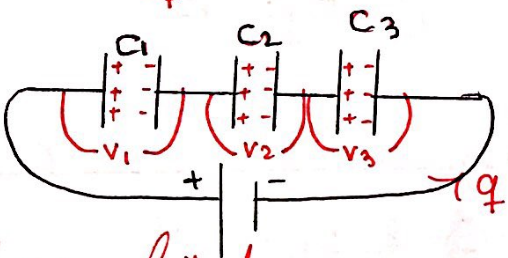
$V_2 = \frac{q}{C_2}$

$V_3 = \frac{q}{C_3}$

$$C_{eq} = \frac{q}{V_{eq}} = \frac{q}{\frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}}$$

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

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



- **Energy stored in an Electric field**

$$\boxed{U = \frac{q^2}{2C} = \frac{1}{2} C V^2}$$

U → Potential energy stored in the capacitor or (the electric field of the capacitor)

it's the same meaning

- **Energy density**

$u = \frac{U}{V}$ → Volume of space between the 2 plates $\Longrightarrow u = \frac{1}{2}\epsilon_0 \left(\frac{V}{d}\right)^2$ J/m3

V → electric potential

$\frac{V}{d} = E$

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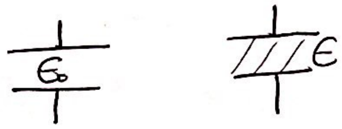
Capacitor with dielectric

$K = \frac{\epsilon}{\epsilon_0} > 1$

$\epsilon_{dielectric} > \epsilon_0$



$C_{dielectric} > C_0$

$C_{diele} = KC$

• You replace ϵ_0 in equations with $K\epsilon_0$

→ so :- • $C = \frac{K\epsilon_0 A}{d}$

• In Gauss's law :- $\oint E \cdot dA = \frac{q}{K\epsilon_0}$

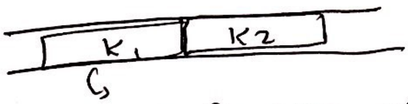
energy density • $u = \frac{1}{2}(K\epsilon_0)E^2$

• Problems solving

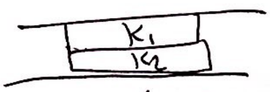
1- two capacitors, one charged and the other isn't
If you charge the second one using the charged capacitor, it will get to an equilibrium point where $\boxed{V_1 = V_2}$ also you can use charge conservation

$\boxed{q_1 + q_2 = q_0}$ → the charge of the first one initially

2- 48)



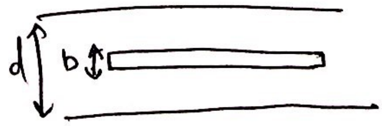
↳ This Becomes on parallel



↳ This Becomes on series

• When a slab is inserted and battery is disconnected
→ q is constant and V changes
The opposite is true

3) 70) New Capacitance



$= \frac{\epsilon_0 A}{d-b}$

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