Electrostatics of Conductors and Capacitors

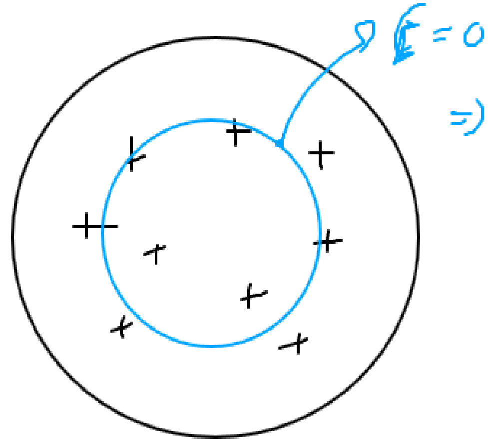
Electrostatics of Conductors

(i) $E = 0$

(ii) $E \perp$ surface

(iii) Equipotential

(iv) All q must reside on the surface

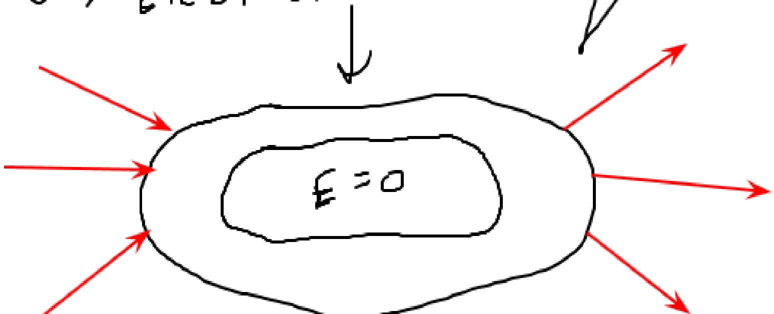


$$\oint \vec{E} \cdot d\vec{s} = \frac{q_{in}}{\varepsilon_0}$$

$$\Rightarrow \quad 0 = \frac{q_{in}}{\varepsilon_0}$$

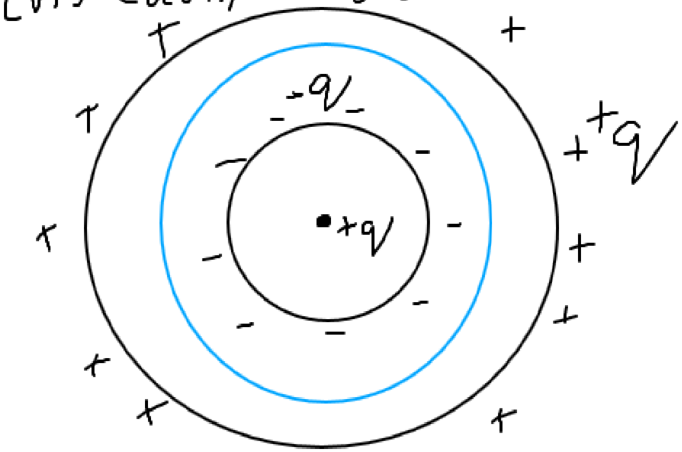
$$q_{in} = 0$$

(v) Electrostatic Shielding



* Helps protect sensitive instruments against Electric Fields

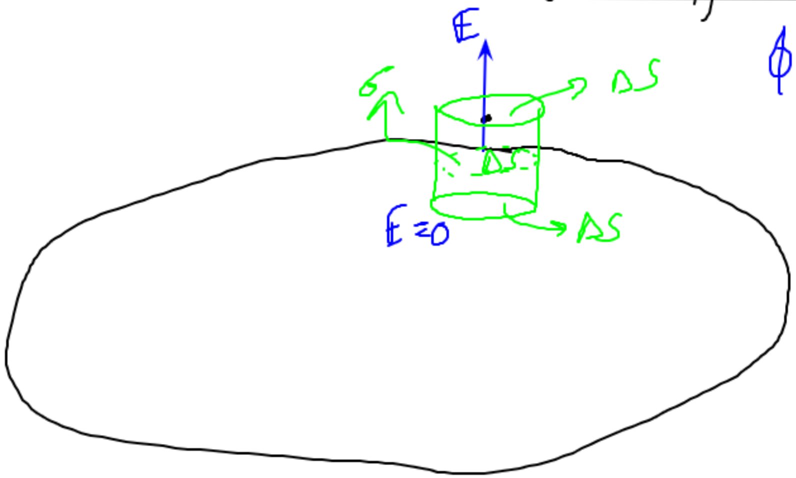
(vi) Cavity in Conductor



$q_{in} = 0$

Assuming Conductor is uncharged initially.

E. Field at the surface of a charged conductor

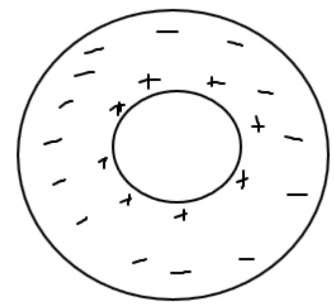


$$\phi = E\Delta S = \frac{\sigma \Delta S}{\varepsilon_0}$$

$$\boxed{E = \frac{\sigma}{\varepsilon_0}}$$

Capacitors

↳ A device used to store charge



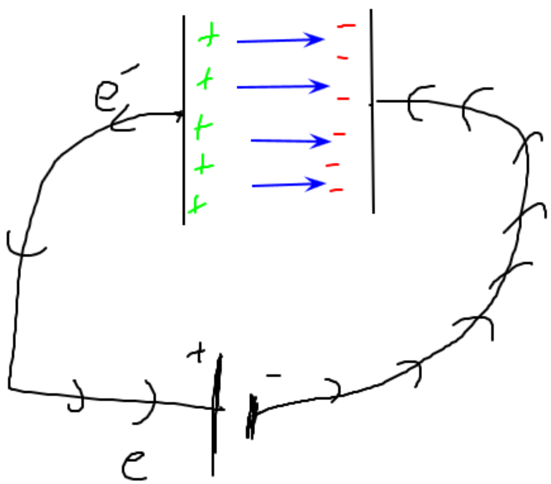
* Capacitance :- Ability to Store Charge

↓ Farad (F)

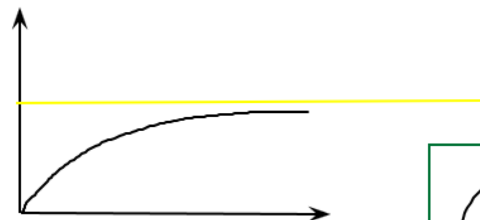
$$C = \frac{Q}{V}$$

C → Dimensions & Geometry

* Parallel-Plate Capacitor



Charging of a Capacitor



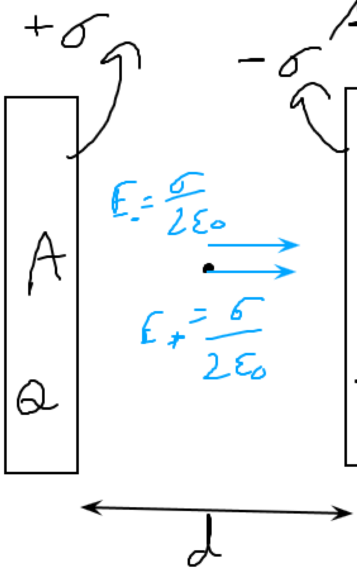
$$Q = CV$$

$$C = \frac{A\varepsilon_0}{d}$$

$$E = \frac{\sigma}{\varepsilon_0}$$

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

Electric Field inside the Capacitor & Capacitance



$$E = \frac{\sigma}{\varepsilon_0}$$

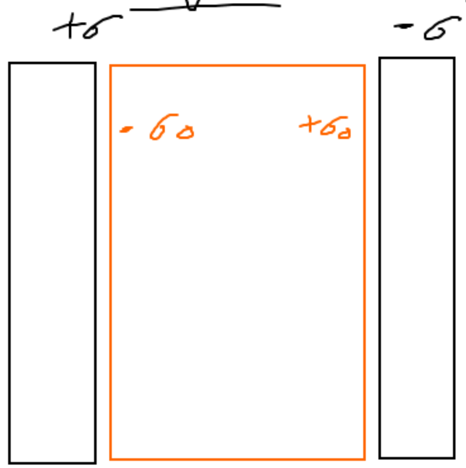
$$V = Ed$$

$$\frac{Q}{C} = Ed$$

$$\frac{\sigma A}{C} = \frac{\sigma}{\varepsilon_0} d$$

$$C = \frac{A\varepsilon_0}{d}$$

Capacitor with a Dielectric



$$E = \frac{\sigma}{\varepsilon_0}$$

After Dielectric

$$E' = \frac{E}{\kappa} = \frac{\sigma}{\kappa \varepsilon_0}$$

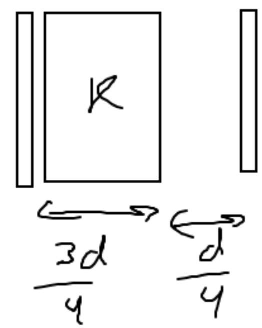
↳ κ: Dielectric constant

$$C = \frac{Q}{V} = \frac{\sigma A}{E' d} = \frac{\kappa A \sigma}{\left(\frac{\sigma}{\varepsilon_0}\right) d}$$

$$\boxed{C = \frac{\kappa A \varepsilon_0}{d} = \kappa C_0}$$

Ex-2.8

$$V = E\frac{d}{4} + \frac{E}{K}\left(\frac{3d}{4}\right) = \frac{Q}{C}$$



$$\frac{A\sigma}{C} = \frac{\sigma d}{4\varepsilon_0} + \frac{3}{4K}\frac{\sigma d}{\varepsilon_0}$$

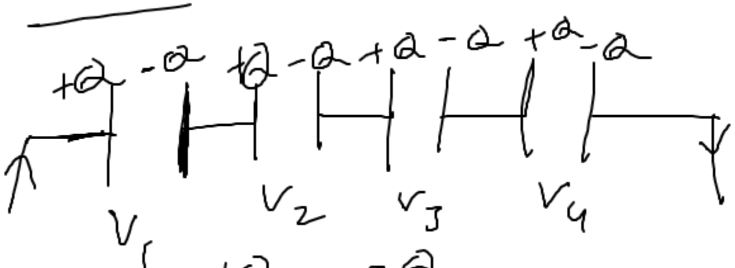
$$C_1 = \frac{K A \varepsilon_0}{\left(\frac{3d}{4}\right)} \qquad C_2 = \frac{A\varepsilon_0}{(d/4)}$$

$$C_{net} = \frac{C_1 C_2}{C_1 + C_2}$$

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

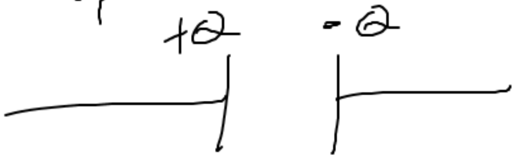
Combination of Capacitors

Series



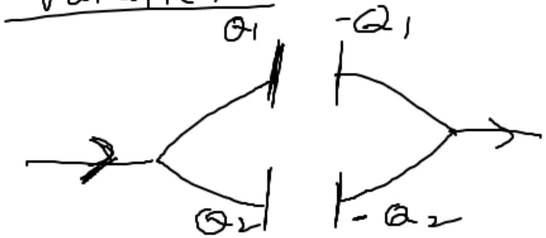
$$V = V_1 + V_2 + V_3 + V_4$$

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} + \frac{Q}{C_4}$$



$$\boxed{\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots}$$

Parallel

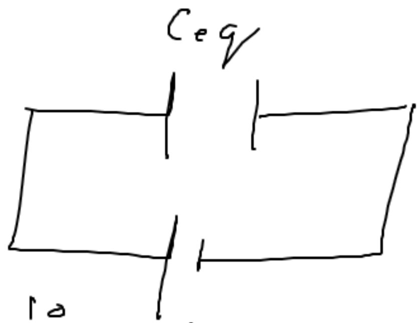


$$Q_1 + Q_2 = C V$$

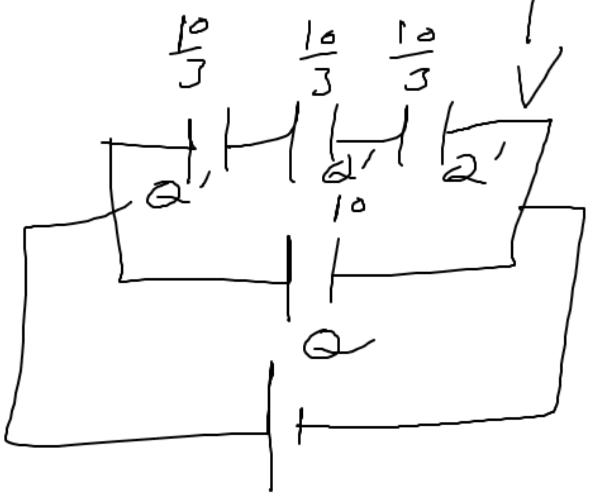
$$C_1 V_1 + C_2 V_2 = C V$$

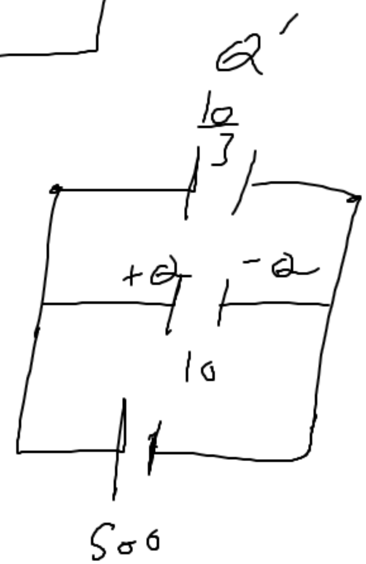
$$\boxed{C = C_1 + C_2 + \cdots}$$

Ex - 2.9



$Q_{Total} = C_{eq} V$





$Q = CV = 5000 \mu C$

$Q' = \left(\frac{10}{3}\right)(500) = \frac{5000}{3} \mu C$

Energy stored in a Capacitor

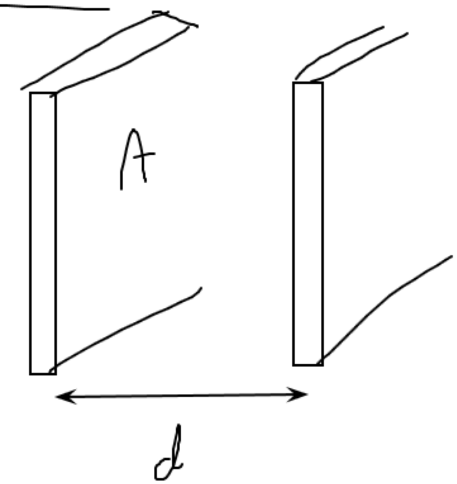
* Electrostatic Energy density

$$\frac{U}{V} = u = \frac{1}{2}\varepsilon_0 E^2$$

V → Volume

$$U = \frac{1}{2}\varepsilon_0 E^2 (Ad)$$

$$U = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(E^2 d^2)$$



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

Thank You