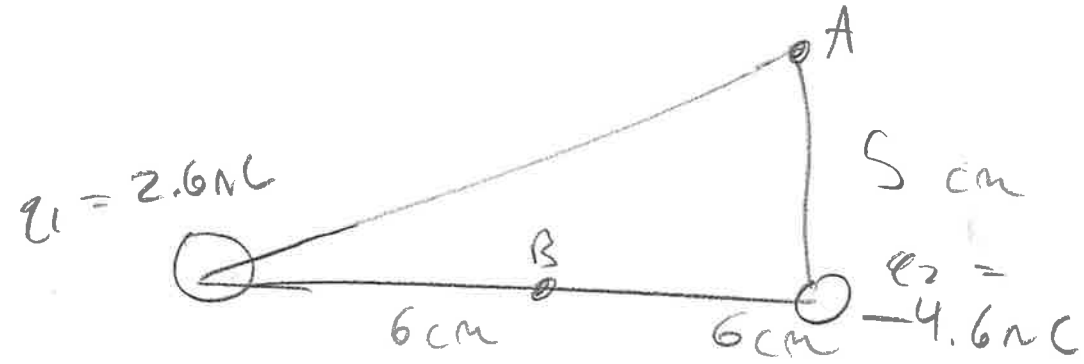
Warm Up Problem



Find the potential difference $V_B - V_A$.

$$V_B = V_1 + V_2$$

$$V_B = \frac{kq_1}{r_1} + \frac{kq_2}{r_2}$$

$$V_B = k\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

$$V_B = -300\,V$$

$$V_A = V_1 + V_2$$

$$V_A = \frac{kq_1}{r_1} + \frac{kq_2}{r_2}$$

$$V_A = k\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

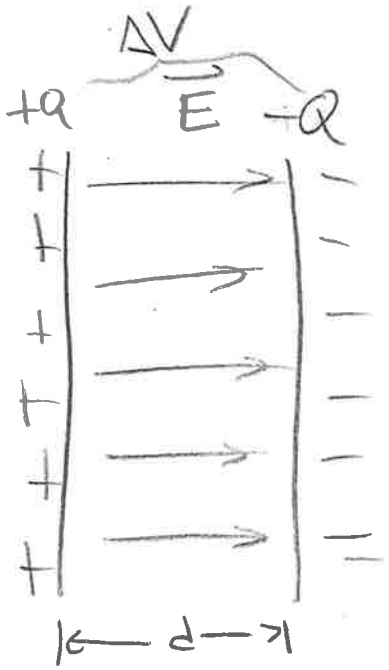
$$V_A = -648\,V$$

$$V_B - V_A = -300 - (-648)$$

$\Delta V = 348\,V$

Capacitors

- Electronic devices used to store charge.



Parallel plate capacitor

$\vec{E}$ field strength scales with Q

$$E \propto Q$$

Electrical potential between plates scales with $\vec{E}$.

$$E \propto V$$

charge on one plate scales with voltage

$$Q \propto V$$

Insert constant of proportionality

$$Q = CV$$

rearrange for C

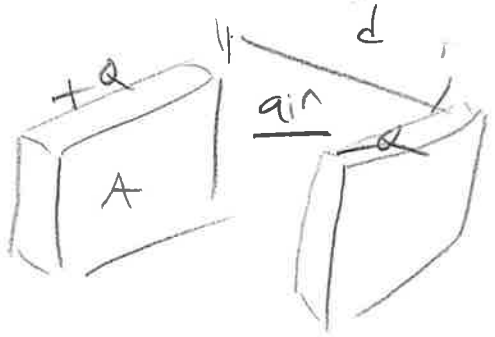
$$C = \frac{Q}{V}$$

Capacitance equation

C – capacitance (F)

$$1\,F = \frac{1\,C}{1\,V}$$

Returning to parallel plates



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

C – capacitance (F)

ε_0 – electric permittivity of free space

(C^2/Nm^2 or F/m)

$$\varepsilon_0 = 8.85 \times 10^{-12}\ F/m$$

A – plate area (m^2)

d – separation between plates (m)

Capacitance problem

What is the capacitance of a parallel plate capacitor with plates of $1\ m^2$ separated by 1mm?

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

$$C = (8.85 \times 10^{-12}\ F/m)\ \frac{(1\ m^2)}{1 \times 10^{-3}\ m}$$

$$C = 8.85 \times 10^{-9} F$$

or $8.85\ nF$

Dielectric

- If we want to store more charge, more V, more $\vec{E}$. This can cause unwanted transfer of charge.
- Use material that withstand high $\vec{E}$ fields ⟶ dielectric material.

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

K – dielectric constant of material.

- Dielectric table

Dielectric example

A capacitor is constructed using $1m^2$ parallel plates separated by a 1mm gap.

a) What is the maximum charge the capacitor can hold if the gap is filled with air?

b) What is the maximum charge on this capacitor if it is instead filled with Teflon? (6)

a) $C = K\varepsilon_0 \frac{A}{d}$

$K = 1$

$C = 8.85\ n\ E$

max $E = 3 \times 10^6$ V/m

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

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

$V = Ed$

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

$Q = EdC$

$Q = Ed\left[K\varepsilon_0 \frac{A}{d}\right]$

$$Q = K \varepsilon_0 E A$$

$K = 1$

$E = 3 \times 10^6 \text{ V/m}$

$A = 1 \text{ m}^2$

$$Q = 2.655 \times 10^{-5} \text{ C}$$

$$\boxed{Q = 26.6 \ \mu\text{C}}$$

b) Now teflon

$$Q = K \varepsilon_0 E A$$

$$Q = 1.11 \times 10^{-3} \text{ C}$$

$$\boxed{Q = 1.11 \text{ mC}}$$