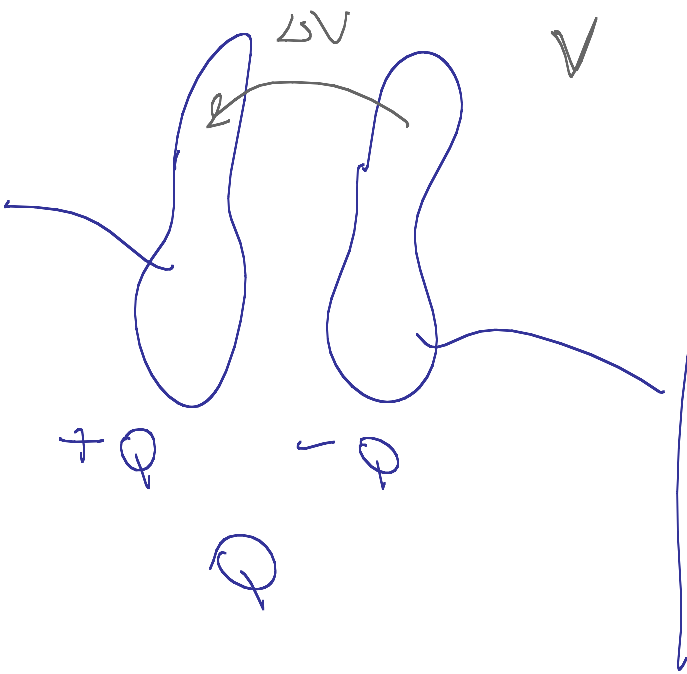
Phys 2120-4 9/17/12

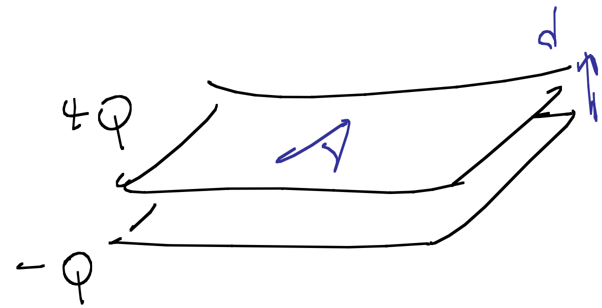
Note Title 9/17/2012

Chap 23 Capacitors, Elec. energy



Most common:

Parallel plates

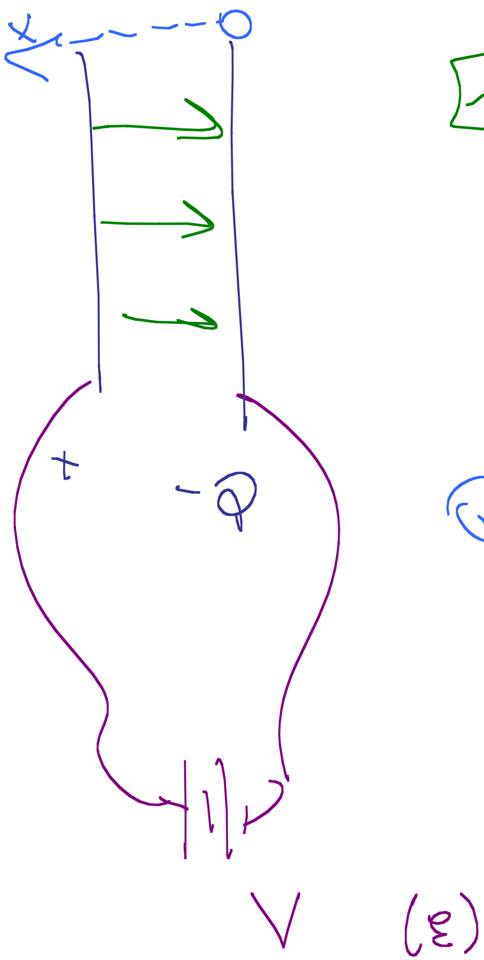


$$E_{inside} = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A}$$

Generally,

$d \ll \sqrt{A}$

∞ plates.



$$E_x = \frac{Q}{\epsilon_0 A}$$

$$V = -\int_0^d E_x \, dx = E d$$

$$= \frac{Qd}{\epsilon_0 A}$$

$$Q = \frac{\epsilon_0 A}{d} V$$

$$Q \propto V$$

$$C = \frac{\epsilon_0 A}{d}$$

$$Q = CV$$

Capacitance: $\frac{\text{Coul}}{\text{Volt}} =$ Farad $\quad \epsilon_0 \cdots \; F/m$

$1\ m^2$

$1\ mm$

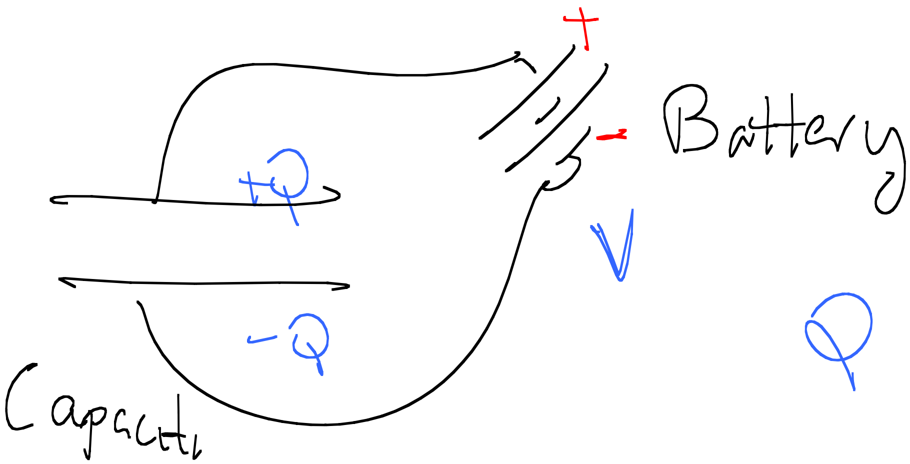
$$C = \frac{\epsilon_0 A}{d}$$

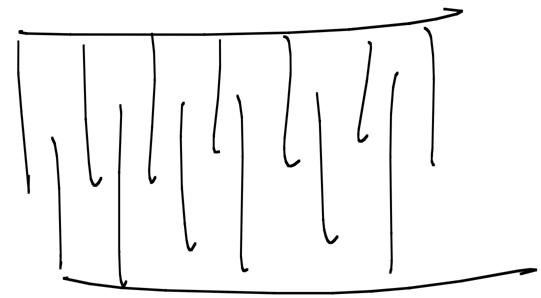
1 F capacitors exist !!!

small # Farad

pF, nF, μF

Other geometries: Ganged capacitors:





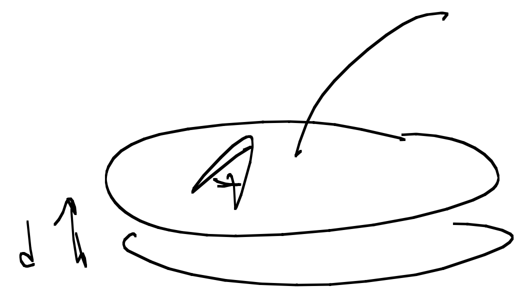
$$Q = CV$$

23.21 A capacitor's plates hold $1.3\,\mu C$ when charged to $60\,V$. What's its capacitance?

$$C = \frac{Q}{V} = \frac{1.3 \times 10^{-6}\,C}{60\,V} = 2.17 \times 10^{-8}\,F$$

$$= 21.7\,nF$$

23.25 Find the capacitance of parallel-plate cap. with circ. plates 20 cm in radius sep. by 1.5 mm.

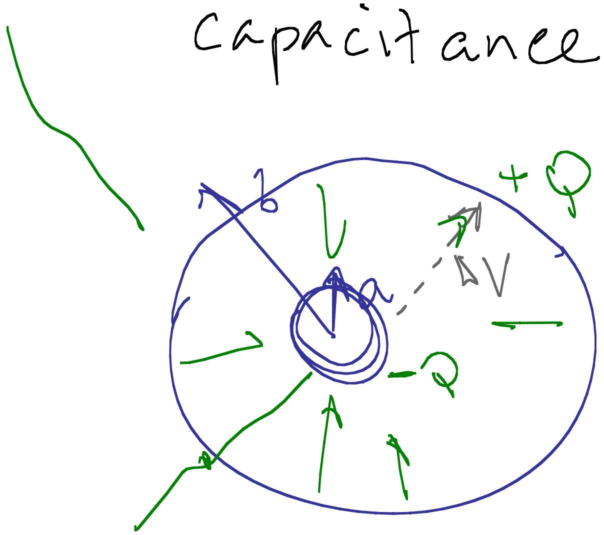


$$A = \pi r^2 = 1.26\times 10^{-1}\ m^2$$

$$C = \frac{\epsilon_0 A}{d} = \frac{\left(8.85\times 10^{-12}\ \frac{F}{m}\right)\left(1.26\times 10^{-1}\ m^2\right)}{\left(1.5\times 10^{-3}\ m\right)} = 7.43\times 10^{-10}\ F$$

$$= 743\ pF$$

23.41 A capacitor consists of a conducting sphere of radius a, surrounded by concentric conducting shell radius b. Show that its capacitance is $C = \frac{ab}{k(b-a)}$ $\qquad k = \frac{1}{4\pi\epsilon_0}$



Find ΔV between the spheres

$E_r = k\frac{Q}{r}$

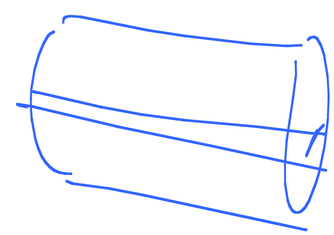
For potential, use $-kQ/r = V(r)$

$$\Delta V = -kQ\left(\frac{1}{b} - \frac{1}{a}\right) = -kQ\left(\frac{a-b}{ba}\right)$$

$$= kQ\frac{(b-a)}{ba} = V \qquad V \propto Q$$

$$Q = \frac{Vab}{k(b-a)} \qquad C$$

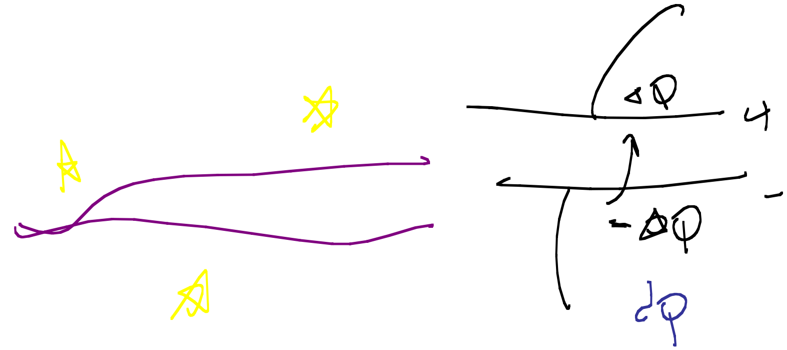
$$C = \frac{ab}{k(b-a)}$$



Energy

Cap. stores energy

Imagine magic tweezers



Plates already have charge Q, V

$$dW = (dQ)\,V = dQ\,\frac{Q}{C}$$

work

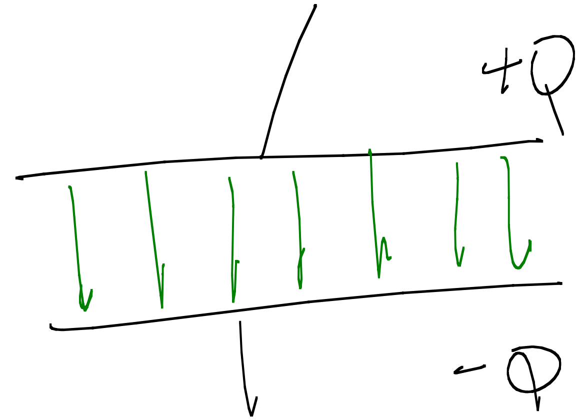
$$Q = CV \qquad V = \frac{Q}{C}$$

$$W = \int_0^Q \frac{Q'}{C}\,dQ' = \frac{1}{C}\,\frac{1}{2}\,Q'^2\Big|_0^Q = \frac{1}{2}\frac{Q^2}{C}$$

sub

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

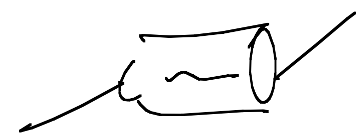
$$E_{stored} = \frac{1}{2}CV^2 = U$$



Where is this energy?

Between plates!

$$U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{(\sigma A)^2\, d}{2\epsilon_0 A} \qquad E = \sigma/\epsilon_0$$



so

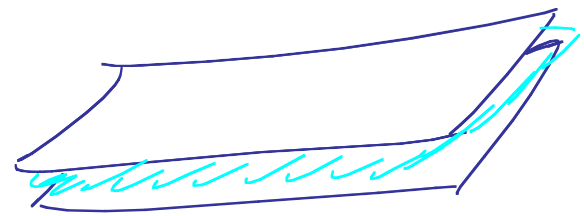
$$= \left(\frac{1}{2}\epsilon_0 E^2\right) \underbrace{Ad}_{\text{Volume between plates}}$$

Energy per volume $= u_0$

$$= \frac{1}{2}\epsilon_0 E^2$$

u = energy density .. stored in electric

$= \frac{1}{2} \epsilon_0 E^2$



Capacitors

Rolled up

w/ plastic between sheets

stuff between

Increases capacitance.

Dielectric

Insulator.

$C = \frac{\epsilon_0 A}{d}$

Now

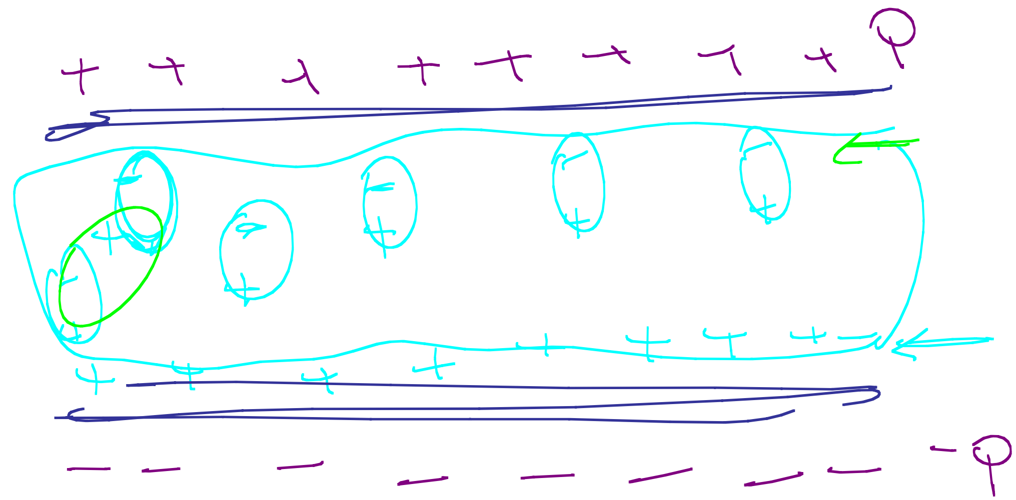
$C = K \frac{\epsilon_0 A}{d}$

Dielectric constant.

$Q = CV$

Mat'l	K
Air	1.0006
Glass	5.6
Polyethylene	2.3
Teflon	2.1

Why do we get larger capacitance



Reduces E field

$$E_{diel} = E_0/K$$

$$V_{diel} = \frac{V_0}{K}$$

$$C_{diel} = \frac{Q}{V_{diel}} = \frac{KQ}{V_0} = K\underset{\text{air}}{C_0} = K\frac{\epsilon_0 A}{d}$$

Connect capacitors