Physics 142 - September 27, 2005

Capacitors, electrostatic Energy

Exam I - Thursday, Oct. 6, 2005
0800 B+L 109
yes, we will have lecture that day

Yikes!

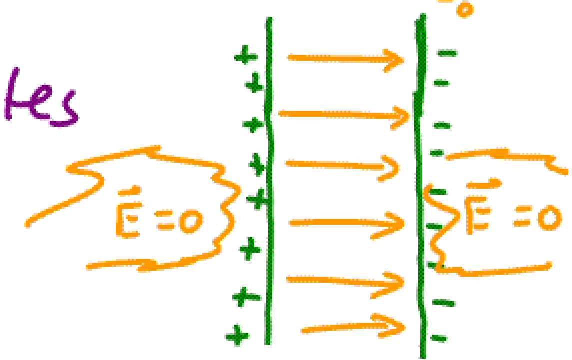
Last Time -

- Potential due to continuous charge distribution -

$$V_P = \int_{\text{distribution}} \frac{k\,dQ}{r}$$

- Looked at $\vec{E}$ between // plates

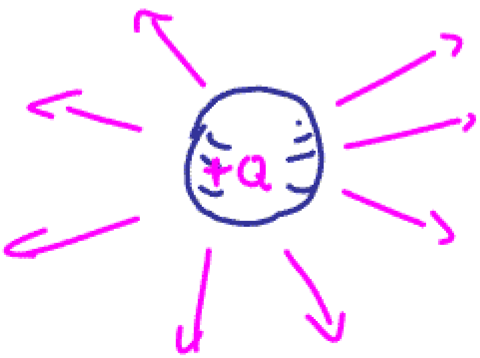
$$|\vec{E}| = \sigma/\epsilon_0$$



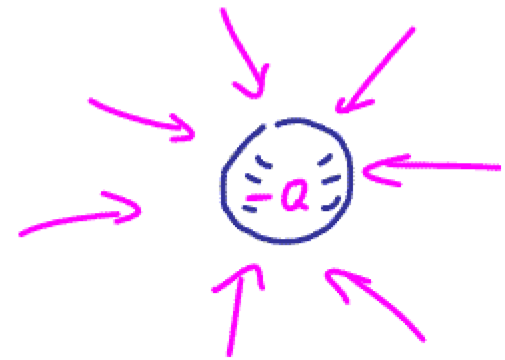
- electron-Volt unit of energy and mass

$$1\,\text{eV} = 1.6 \times 10^{-19}\ \text{Joules}$$

- Began looking at Capacitance



2 chgd spheres
far apart
radius R



$$V_+ = \frac{kQ}{R} \qquad\qquad V_- = -\frac{kQ}{R}$$

$$\Delta V \sim \frac{2kQ}{R}$$

$$V_{+-} \equiv V_+ - V_-$$

$$V_+ \propto Q \qquad \Delta V \propto Q \qquad V_- \propto Q$$

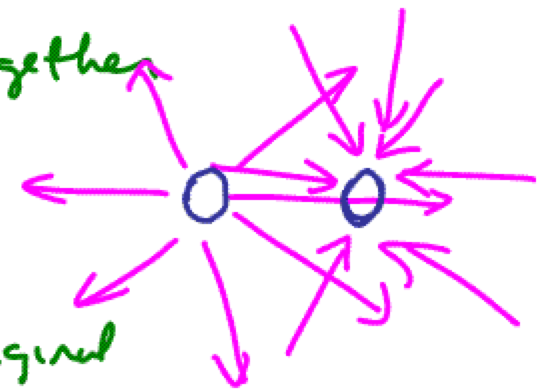
define Capacitance as the constant of proportionality $\equiv C$

$Q = C_+ V_+ \qquad Q = C_{+-} V_{+-} \qquad Q = C_- V_-$

now bring two spheres close together

V_{+-} is reduced

$$(V_{+-})_{new} < (V_{+-})_{original}$$



Think of Work Necessary to bring chg from ∞

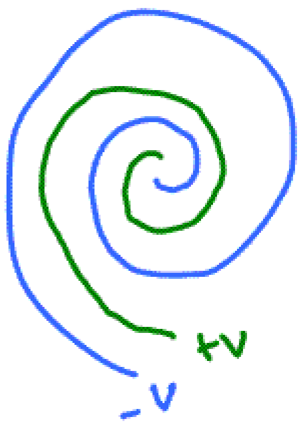
$$Q = (C_{+-})_{new} (V_{+-})_{new}$$

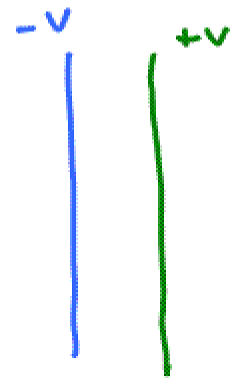
Capacitance quantifies Amount of charge that can be held by system

→ Depends only on geometry

$Q = CV$

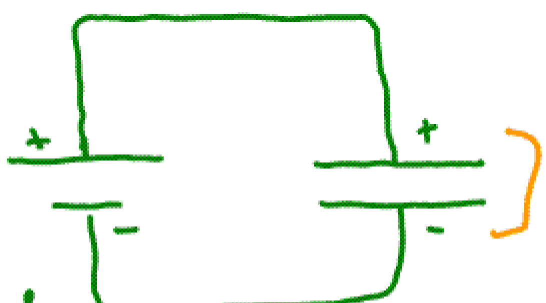
$$C = \frac{Q}{V} = \frac{\text{Coul}}{\text{Volt}} \equiv \text{Farad}$$





Capacitors act as resevoirs of chg in electric circuits

Battery



capacitor

EMF
≡
Electromotive force = maintains const pot. diff between terminals

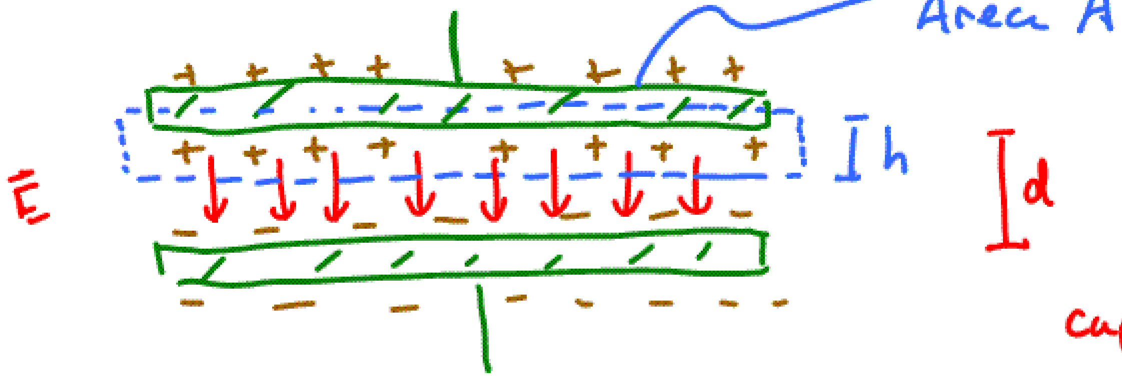
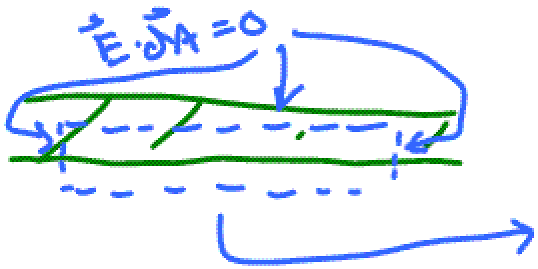


plate separation

capacitive plates w/ charge $+Q$ and $-Q$

CAN we find expression for capacitance of system?

Gauss' Law



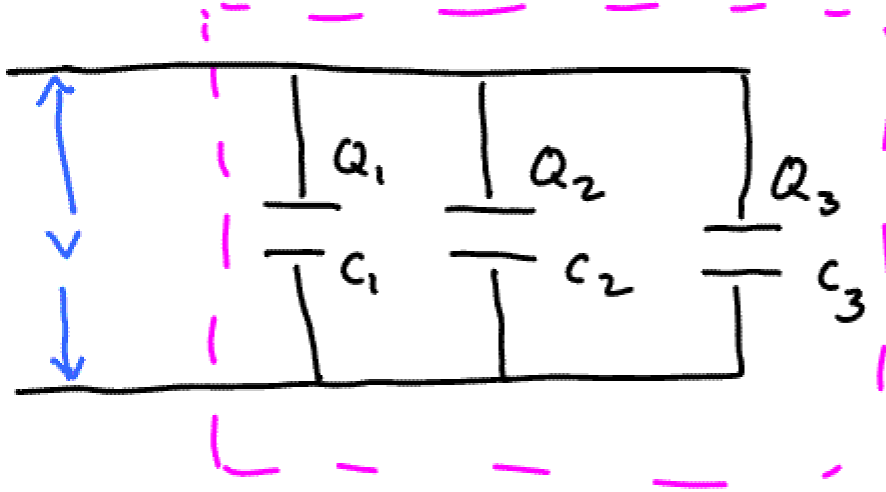
$$\int_{surf} \vec{E}\cdot\vec{dA} = \frac{Q_{encl}}{\epsilon_0}$$

$$|\vec{E}|\,A = \frac{Q}{\epsilon_0} \qquad Q = |\vec{E}|\,A\,\epsilon_0$$

$$V = \frac{W}{q} = \frac{Fd}{q} = Ed$$

$$Q = CV \qquad C = \frac{Q}{V} = \frac{|\vec{E}|A\epsilon_0}{|\vec{E}|d} = \frac{A\epsilon_0}{d}$$

Pure geometry



Capacitors are in parallel

Box w/

Total $Q = Q_1 + Q_2 + Q_3$

capacitance C

$$Q = CV$$

$$Q_1 = C_1 V$$
$$Q_2 = C_2 V$$
$$Q_3 = C_3 V$$

$$Q = Q_1 + Q_2 + Q_3$$

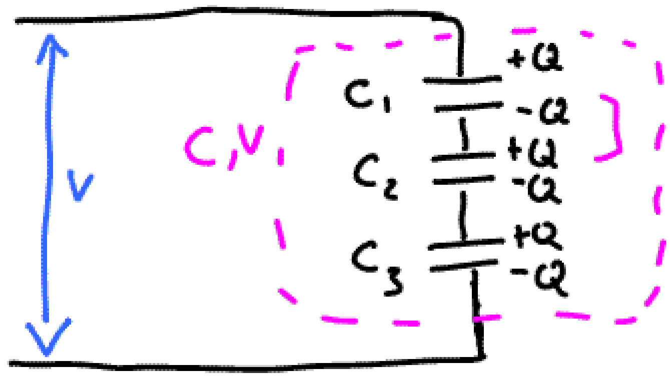
$$CV = C_1 V + C_2 V + C_3 V$$

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

Important

capacitors in ||

$$C_{TOTAL} = \sum_i C_i$$



Capacitors in series

$Q = C_1 V_1$

$Q = C_2 V_2$

$Q = C_3 V_3$

$$V = V_1 + V_2 + V_3$$

$$V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

Important

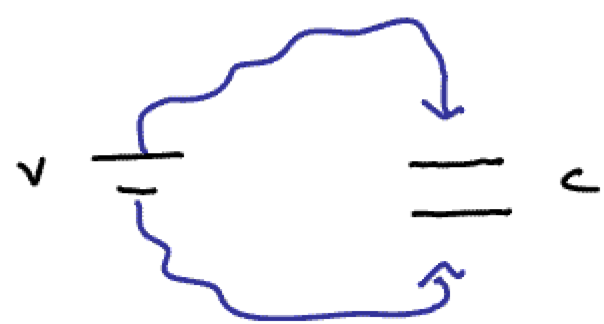
$$\frac{1}{C} = \sum_i \frac{1}{C_i}$$

for capacitors in series

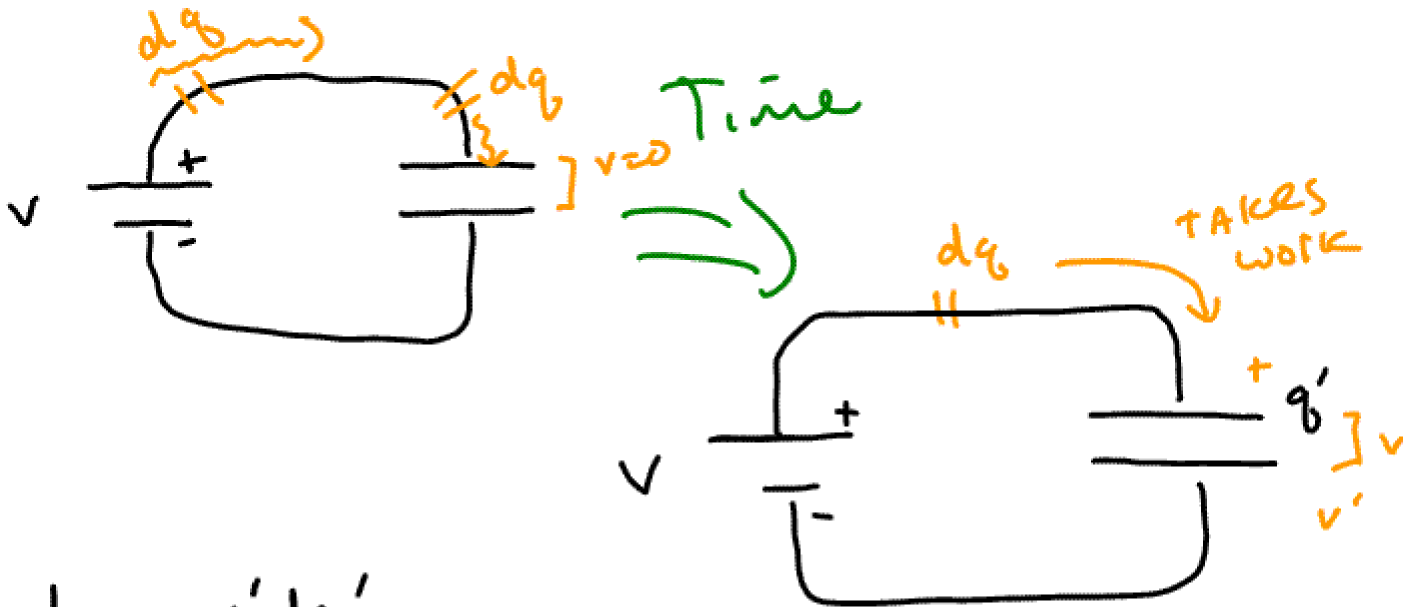
Energy

Initially uncharged capacitor

hook to Battery



How much work to charge C to full value?



$$dw = v'\,dq'$$

work required to transfer dq'
when pot. across plates is v'

$$dw = \frac{q'}{C}\,dq'$$

$$W = \int dw = \int_0^Q \frac{q'}{c}\,dq' = \frac{q^2}{2c}\Big|_0^Q = \frac{1}{2}\frac{Q^2}{C}$$

$$\boxed{\underset{|||}{U} = W = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2}$$

Important

Energy to charge the capacitor

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

Capacitor Stores energy in form of $\vec{E}$

$$\text{Energy density of } \vec{E} = u = \frac{U}{\text{vol. bet. plates}}$$

Ad

Area

dist bet plates

$\parallel$ plate system $\quad C = \dfrac{\epsilon_0 A}{d}$

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

$$u = \tfrac{1}{2} C V^2 / Ad = \frac{1}{2} \frac{\epsilon_0 A}{d} V^2 / Ad = \frac{\epsilon_0}{2} \frac{V^2}{d^2}$$

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

$$\boxed{u = \frac{\epsilon_0}{2} E^2}$$

Energy density of electric field

Important

and Cool