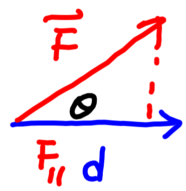
Electric potential:

Review: Work done by a force in moving a mass from initial position to a final position



" component of the force in the direction of displacement

$$W_{i\to f} = F_{\parallel} d$$

$$= F\cos\theta \, d$$

$\Delta K = K_f - K_i$ //

change in kinetic energy

for conservative force

$$= -(U_f - U_i)$$

↑ negative change in potential energy

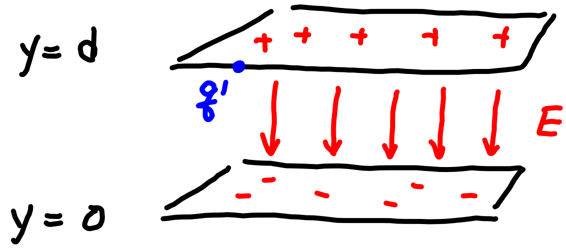
$$K_f - K_i = -(U_f - U_i)$$

$$= -U_f + U_i$$

$$K_f + U_f = K_i + U_i$$

conservation of total mechanical energy

1) Electric potential of a const electric field



uniformly charged plates

$\vec{E}$ constant

what is the work done by the electrical force on a charge q' in moving for $y = d$ to $y = 0$?

$q' > 0$

$$W_{y=d \to y=0} = q'Ed = -(U_f - U_i)$$

pot. energy

$$= -U(0) + U(d)$$

$$\Rightarrow \quad U(y) = q'Ey \qquad = U(d) - U(0)$$

exactly like $U(y) = mgy$

just like $\vec{F} = q'\vec{E}$

$$U(y) = q'V(y)$$

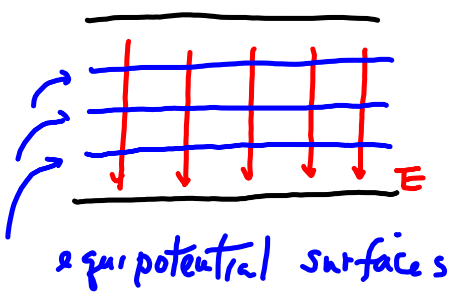
pot. energy (U); electric potential (V)

$$\not{q}Ed = \not{q}\,(V(d) - V(0))$$

← electric potential difference

← voltage difference

The electric potential decreases in the direction of the electric field

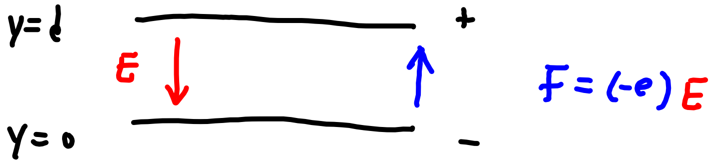


The lines of constant potential are Ey at any y value

Equipotential surface ⊥ to $\vec{E}$

Ex

d = 4.5 nm



An electron is released at rest from the negative plate
what is its velocity when reaching the upper plate?

$K_f - K_i = U_i - U_f$ $\qquad U = q' E y$

$\frac{1}{2} m_e v^2 \quad K_i = 0$

$= (-e)[V_i - V_f]$

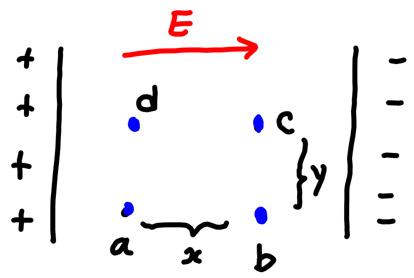
$= (-e)(-9V)$

$\frac{1}{2} m_e v^2 = e\, 9V$

$v = \sqrt{\frac{2e\,9V}{m_e}} = 1.78 \times 10^{16}$ m/s

the pot diff is 9 V $= V_f - V_i$

Constant E field



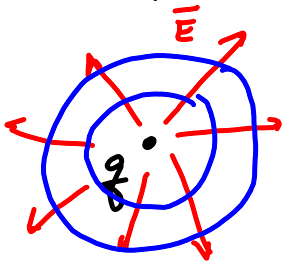
what is the work done by the electric force when q moves from a to b

A	B	C	D
qEy	0	qEx	$qE\sqrt{x^2+y^2}$

which of the following is true

A	B	C	D
$V_b > V_c$	$V_a > V_d$	$V_a > V_c$	$V_b > V_d$

Electric potential of a point charge



← equipotential surface $\perp$ to $\vec{E}$

$\bullet\, q'$

$$\boxed{V(r) = \frac{kq}{r}} \qquad k = \frac{1}{4\pi\epsilon_0}$$

The potential energy of charge q' in the presence of q's is

$$U(r) = q' V(r)$$

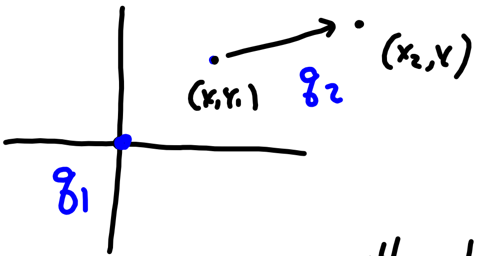
$$\vec{F} = q' \vec{E}$$

$\vec{F}$ " due to q — $\vec{E}$ ↑ due q

Ex Given q_1 at the origin

and q_2 moves from (x_1, y_1) to (x_2, y_2)

1) what is the change of the electric potential experience by q_2



$$V_1 = \frac{k q_1}{r_1} \qquad r_1 = \sqrt{x_1^2 + y_1^2}$$

$$V_2 = \frac{k q_1}{r_2} \qquad r_2 = \sqrt{x_2^2 + y_2^2}$$

the change in electric pot is

$$\Delta V = V_2 - V_1 = k q_1 \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$$

2) what is the change in the pot energy of q_2

$$\Delta U = q_2 \Delta V$$

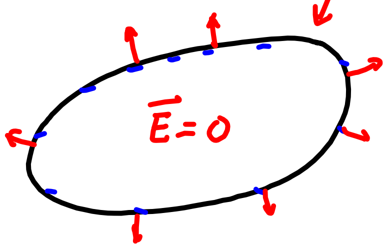
Conductors & Insulators:

Conductors → are materials in which charge particles (electrons) are free to move

metals

Insulators → no free moving charge particles

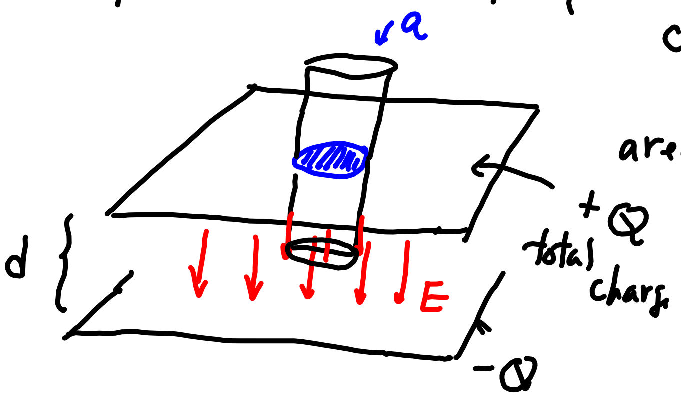
surface is an equipotential surface



metal objects are shiny.

Capacitors : the capacity to hold charge.

use Gauss' theorem



$\sigma =$ surface charge density $= \frac{Q}{A}$

at the bottom

$\cancel{a} E = 4\pi k\, q_{enclosed}$

$= 4\pi k\, a\, \sigma$

$= 4\pi k\, \cancel{a}\, \frac{Q}{A}$

$E = 4\pi k \frac{Q}{A}$

$= \cancel{4\pi} \frac{1}{\cancel{4\pi}\epsilon_0} \frac{Q}{A}$

$$\boxed{E = \frac{Q}{\epsilon_0 A}}$$

The potential difference $= V_{Top} - V_{bot} = V = Ed$

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

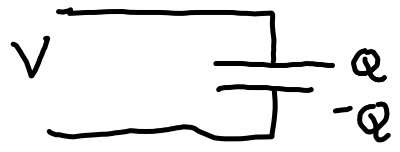
$\Rightarrow$ $\boxed{Q = \frac{\epsilon_0 A}{d} V}$ $= C\,V$

↑ capacitance

✓ given a pot. diff $V \rightarrow$ induce separation of Q.

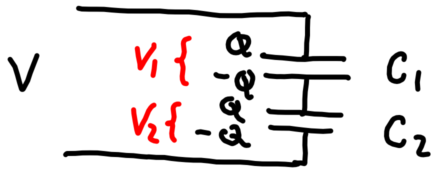
$C = \frac{\epsilon_0 A}{d}$

Capacitor → capacity to hold charges



$$Q = CV$$

Capacitors in series ↔ having the same charge

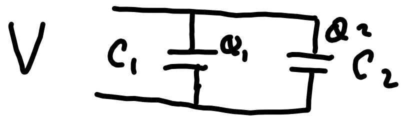


$$V = V_1 + V_2$$

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

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

Capacitors in parallel → same voltage difference.



$$Q = Q_1 + Q_2$$

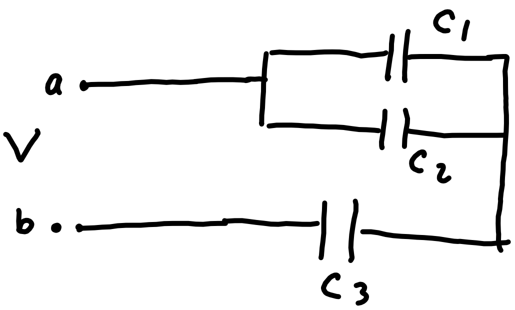
$$= C_1 V + C_2 V$$

$$CV = (C_1 + C_2)V$$

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

Ex

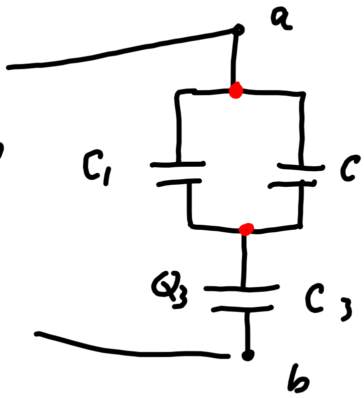
$V_a > V_b$

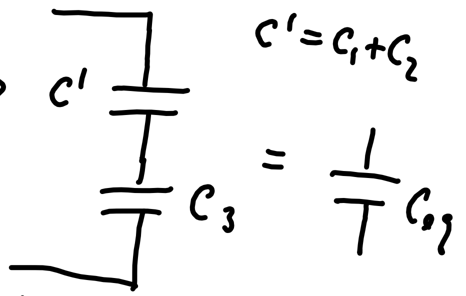


Given V,
C_1, C_2, C_3

find: V_1, V_2, V_3,
Q_1, Q_2, Q_3 !

Easier:





$C' = C_1 + C_2$

$\frac{1}{C_{eq}} = \frac{1}{C'} + \frac{1}{C_3}$

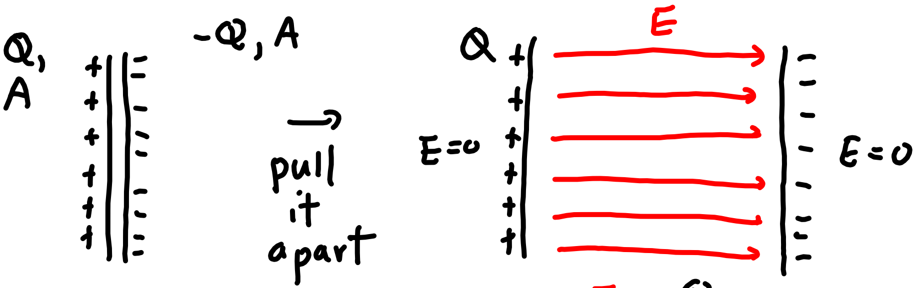
1) $Q = C_{eq} V$
$= Q_3$

2) $V_3 = \frac{Q_3}{C_3}$

3) $V_1 = V_2 = V - V_3$

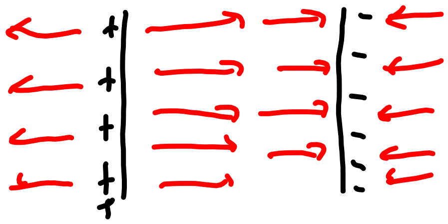
4) $Q_1 = C_1 V_1$; $Q_2 = C_2 V_2$

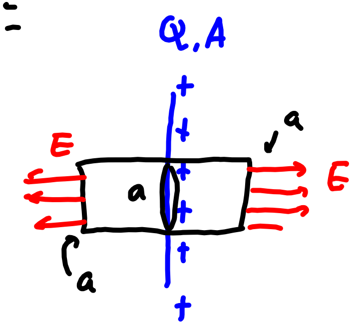
Electric field energy (in a capacitor)



$\rightarrow \rho = \frac{Q}{A}$

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





The force on the negative plate

$F = \left(\frac{1}{2}\frac{Q}{\epsilon_0 A}\right) Q$

(E field of the + plate) (charge on the negative plate)

$2EA = 4\pi k\, q_{enclosed}$

$= 4\pi k\, A \frac{Q}{A}$

$E = 4\pi k \frac{Q}{2A}$

$= \frac{Q}{\epsilon_0 2A}$

$k = \frac{1}{4\pi\epsilon_0}$

$W = F d = U$

work done; gain pot energy

$= \frac{1}{2}\frac{1}{\epsilon_0 A}\frac{Q}{A} d A$

$= Ad\,\frac{1}{2}\frac{1}{\epsilon_0}\left(\frac{Q}{A}\right)^2$

$U = Ad\,\frac{1}{2}\frac{1}{\epsilon_0}\epsilon_0^2 E^2 = (Ad)\,\frac{1}{2}\epsilon_0 E^2$

$$\boxed{U = (Ad)\,\frac{1}{2}\epsilon_0 E^2}$$

(energy) (volume) (energy density)

$\frac{1}{2}\epsilon_0 E^2$: energy density in the electric field

More over:

$U = Ad\,\frac{1}{2}\epsilon_0 E \frac{Q}{\epsilon_0 A}$

$= \frac{1}{2} Q\, Ed = \frac{1}{2} Q V$

$V = Ed$

but

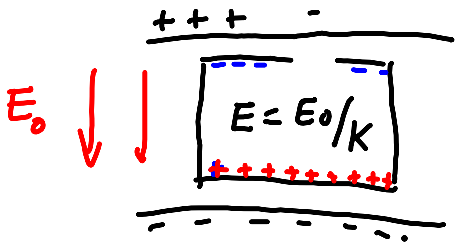
$Q = CV$

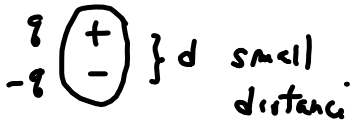
$$\boxed{U = \frac{1}{2} C V^2}$$

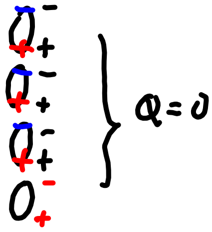
Dielectric materials

- non-conductor no free, mobile charge

→ have orientable dipoles







The electric field inside of an dielectric

$$E = E_0/K \leftarrow \text{dielectric const.}$$

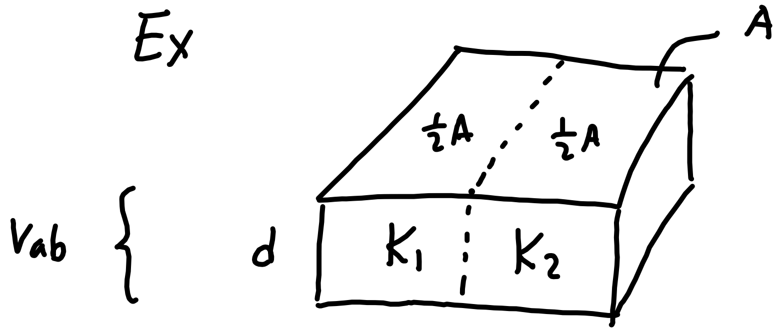
(E_0: vacuum)

Since $V = Ed$

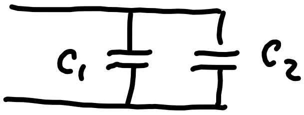
$$V = E_0 d/K = V_0/K$$ reduced in a dielectric

$$C = Q_0/V = \frac{Q_0}{V_0} K = C_0 K$$

Ex



for a given V_{ab} find Q



$$C_{10} = C_{20} = \epsilon_0 \frac{\frac{1}{2}A}{d}$$

$$C_1 = K_1 C_{10}$$

$$C_2 = K_2 C_{20}$$

$$C = C_1 + C_2 = (k_1 + k_2)\frac{\epsilon_0 A}{2d}$$

$$Q = CV$$

Ex 2: