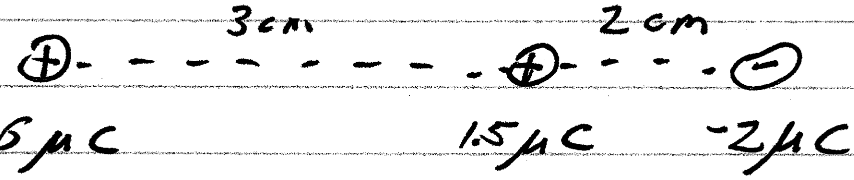
Phys 1402 2014-09-09 Lecture 4



Force on +6 μC Charge

- Repelled From +1.5 μC

$$F = k\frac{q_0 q_1}{r^2} = \frac{k(6\times10^{-6}\,C)(1.5\times10^{-6}\,C)}{(0.03\,m)^2}$$

= ______ to the left.

- Attracted toward −2 μC

$$F = k\frac{q_0 q_1}{r^2} = \frac{k(6\times10^{-6}\,C)(2\times10^{-6}\,C)}{(0.05\,m)^2}$$

= 43.2 N to the right

- Total = + ______ to the ______

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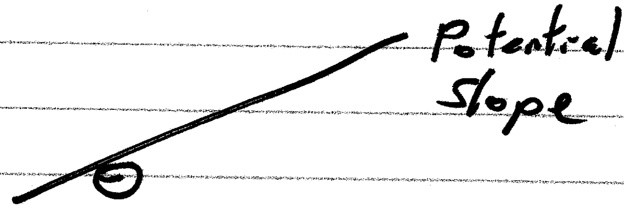
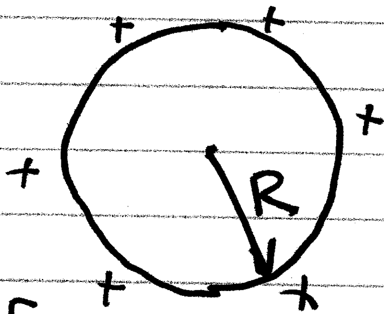


E-Field of a charged metal ball

- Charge is all on surface.
- From far away:

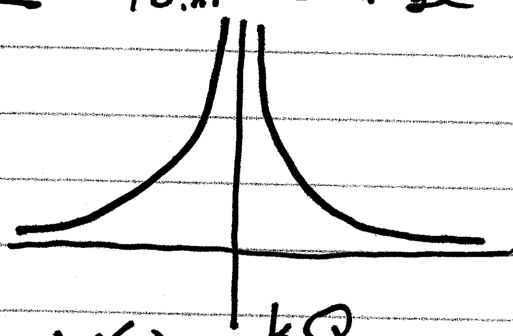


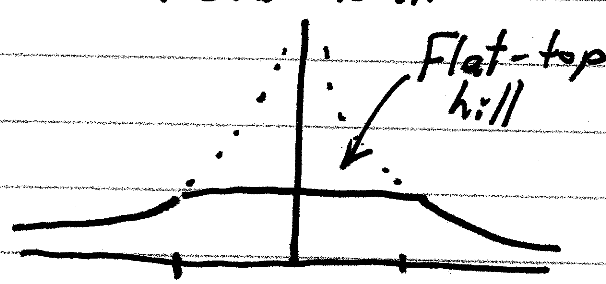
$$E = \frac{kQ}{r^2}$$ r = our dist from center

This is true for all r outside the ball.

Inside, $E = 0$.

V(r) — Point Charge / Metal Ball





$$V(r) = \frac{kQ}{r}$$

$$V(r) = \begin{cases} \frac{kQ}{r} & (r > R) \\ \text{const} & (r < R) \end{cases}$$

Potential of a charged metal ball

$$V = \frac{kQ}{R}$$

Amount of charge

$$Q = \frac{R}{k} V$$

With 100 V of voltage and a 10 cm ball:

$$Q = \frac{R}{k} V = \frac{(0.1\ m)}{\left(9 \times 10^{9} \frac{N m^2}{C^2}\right)} (100\ V)$$

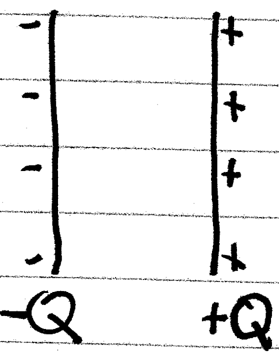
$$= 1.1 \times 10^{-9}\ C = 1.1\ nC$$

Is there a way of storing more charge?

A capacitor makes use of both ⊕ and ⊖ charges. It has two charge-storing areas called plates. One is ⊕, the other is equal & opposite.

In between: $E = \frac{\sigma}{\varepsilon_0}$ ($\sigma \sim Q/A$, $\varepsilon_0 \sim \frac{1}{4\pi k}$)

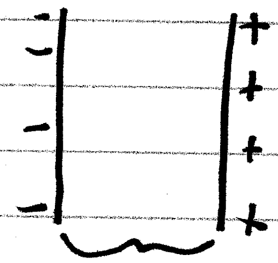
$$E = \frac{Q}{\varepsilon_0 A}$$



Notice that the charges add to zero.

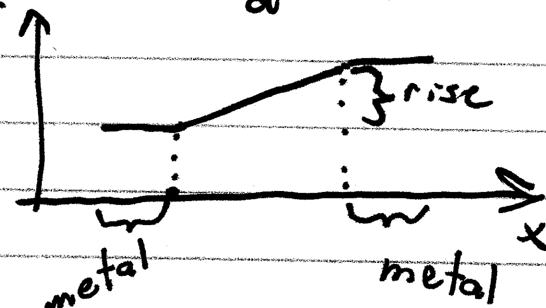
④

$$E = \frac{Q}{\varepsilon_0 A}$$



This is a constant slope

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$



$$\frac{Q}{\varepsilon_0 A} = \frac{\Delta V}{d}$$

$$Q = \frac{\varepsilon_0 A}{d} \Delta V$$

Ex: Al-foil Area $= 0.3\ m^2$

Wax paper $d = 0.1\ mm = 0.0001\ m$

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$

$\Delta V = 100\ V$

$$Q = 2.7 \times 10^{-6}\ C = 2.7\ \mu C$$

Typical Big manufactured capacitors

$100{,}000\ \mu F$

$$Q = C\ V$$

↖ measured in Farads (F)

@ 100 V: $Q = (100000 \times 10^{-6} F)(100\ V)$

$= 10\ C$

C = capacitance as a variable

C = coulombs as a unit

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Capacitor Formulas

$$Q = CV$$ charge vs. voltage

$$E = \frac{Q}{\varepsilon_0 A}$$ E inside air-filled cap.

$$E = \frac{Q}{K\varepsilon_0 A}$$ E in a dielectric cap.

↳ Kappa = dielectric constant
Ex: $K = 10$

$$C = \frac{\varepsilon_0 A}{d}$$ Capacitance of air-filled

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

Energy of a capacitor

$$\text{Voltage} = \frac{\text{Energy}}{\text{Charge}} \rightarrow \text{Energy} = \text{Voltage} \cdot \text{Charge}$$

When "Filling" a capacitor, the first charges go in easily.

Q	V	Energy
First Tenth	$0.1\ V_{final}$	$(Q/10)\ 0.1\ V_{final}$
Middle Tenth	$0.5\ V_{final}$	$(Q/10)\ 0.5\ V_{final}$
Last Tenth	$0.9\ V_{final}$	$(Q/10)\ 0.9\ V_{final}$

$$\text{Energy} = \frac{1}{2} QV$$

$\text{Average} = 0.5\ V_{final}$

Capacitor vs. Battery

Capacitor	Battery
Store Charge	Store Charge
Store Energy	Store Energy
$V = Q/C$	$V = \text{const}$
$\text{Energy} = \frac{1}{2}QV$	$\text{Energy} = QV$
Q limited by maximum V	Q limited by chemical reactants.
	Very large Q is possible