(1) Phys 2426 2015-09-08 Lec 4

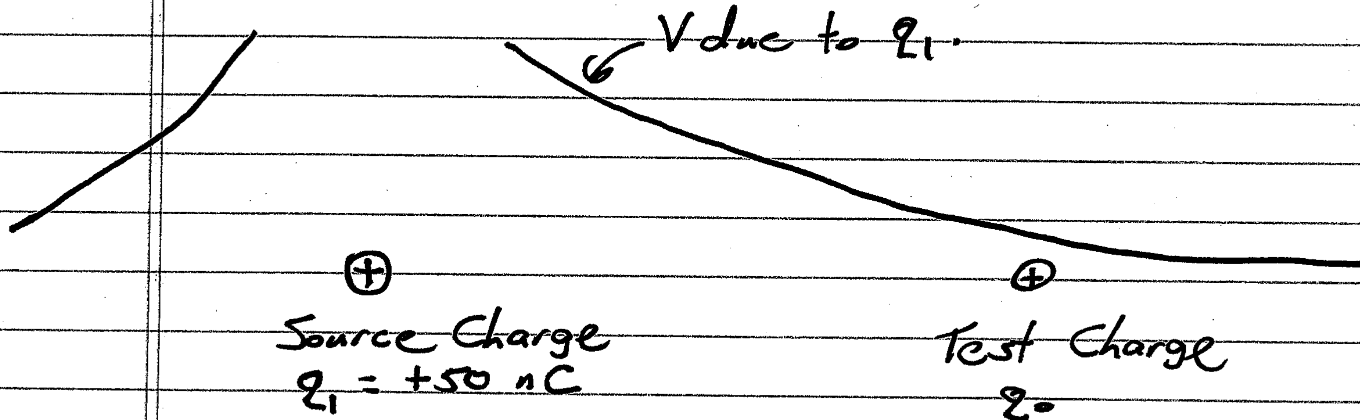
Roles of Electric Field (so far)

- Force per unit charge
- Flow of electric flux
- Slope of Electric Potential "landscape"

What is electric potential (V)?

- Formally: Energy per unit charge
- Analogy 1: Height on a "landscape"
- Analogy 2: Pressure that pushes charges

Relationship between E & V:



- q_0 is pushed to right.
- Rightward is "downhill"
- If we push closer to q_1, hill gets steeper.

$$\text{Slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta V}{\Delta x} = \frac{\partial V}{\partial x}$$

$$\text{Elec field} = -\frac{dV}{dx}$$

1-D $E = -\frac{dV}{dx}$ $V = -\int E\,dx$

3-D $\vec{E} = -\nabla V$ $V = -\int \vec{E} \cdot d\vec{r}$

For a point charge in 1-D

$E = \frac{kq_1}{x^2}$ + if $x > 0$, − if $x < 0$

$V = -\int E\,dx = -\int \frac{kq}{x^2}\,dx$

$V = \frac{kq_1}{|x|} = \frac{kq_1}{r}$

Energy of q_0 in this region

$U = q_0 V$

$E = \frac{kq}{r^2} = \frac{kq_1}{(0.1\,m)^2}$

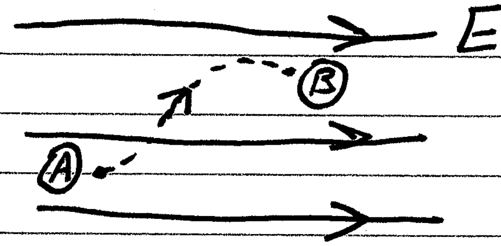
$= 45000$ N/C

Ex w/ values $q_1 = 50$ nC

x (m)	V
0.099	$V = \frac{k(50 \times 10^{-9}\,C)}{(0.099\,m)} = 4545$ V
0.101	$V = 4455$ V
Slope	$\frac{\Delta V}{\Delta x} = \frac{-90\,V}{0.002\,m} = -45000$ V/m

③

If E is Uniform:



$$\Delta V_{A \to B} = V(B) - V(A) = -\int_A^B \vec{E} \cdot d\vec{r}$$

$$= -\int_A^B E\,dx = -E \int_A^B dx = -E\,\Delta X$$

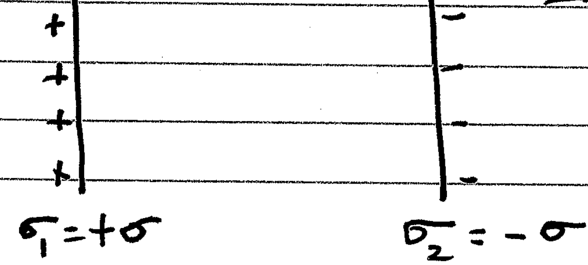
- E points "downhill"
- $V(A)$ is "higher"
- $V(B) - V(A)$ is negative

$$E = \frac{-\Delta V}{\Delta X} \qquad \Delta V = -E\,\Delta X$$

Surface Charge

$$E = 2\pi k \sigma = \frac{\sigma}{2\varepsilon_0}$$ (due to one σ)

Two surface charges



Inside: $E = E_1 + E_2$

$E = 4\pi k \sigma$

$E = \sigma / \varepsilon_0$

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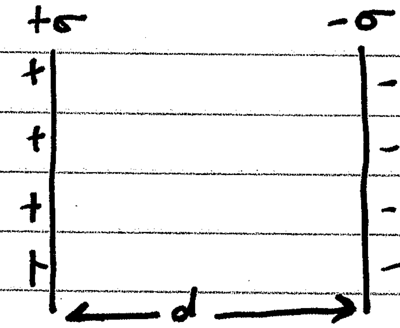

$k = 9\times10^{9}\ \frac{Nm^2}{C^2}$

$\varepsilon_0 = \frac{1}{4\pi k} = 8.85\times10^{-12}\ \frac{C^2}{Nm^2}$

$E = \sigma/\varepsilon_0$ $\qquad \sigma = \frac{Q}{A}$

$\Delta V = -E\cdot\Delta x$

$V = |\Delta V| = Ed = \frac{\sigma d}{\varepsilon_0} = \frac{Qd}{A\varepsilon_0}$

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

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

$\varepsilon = K\varepsilon_0$

↑ Dielectric Const.

Capacitor Notes:
- It is a "tank" for charge.
- Total charge is always zero.
- $Q = Q_1$, but $Q_2 = -Q$

Energy of a single charge $= q_0\Delta V$

Energy of a capacitor $= \frac{1}{2}QV$

When charging, we can stop when:
- Q reaches a limit
- $V_{applied}$ reaches a limit
- V exceeds V_{max} of the capacitor

Air: $E_{max} \approx 10^6$ V/m $\qquad$ Dielectric Strength

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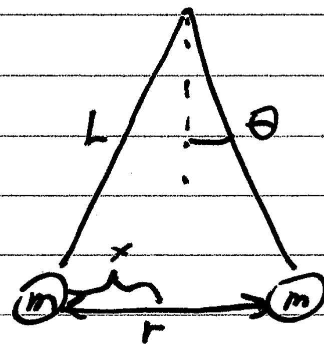

x: $\frac{kq^2}{r^2} - F_T \sin\theta = 0$

y: $F_T \cos\theta - mg = 0$

Force on right mass

$F_E = \frac{k q_0 q_1}{r^2}$ to right

$F_g = mg$ down

$F_T = \sim$ up + left

$F_{Tx} = -F_T \sin\theta$

$F_{Ty} = +F_T \cos\theta$