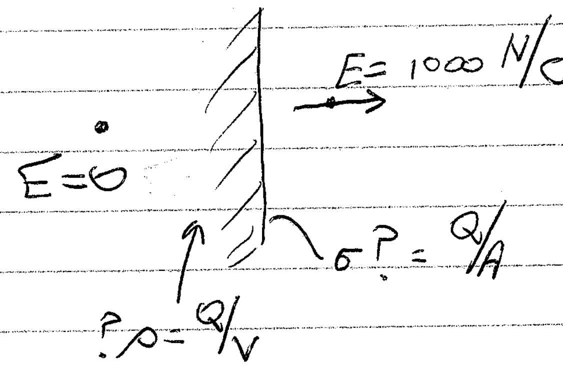
 Phys 2426 2015-09-03 Lec 3

Outside a metal surface $|E| = 1000$ N/C.
What charge exists on the metal?




- $\sigma$ will create uniform $E$.
- $E = 0$ in a conductor.
- $\sigma$ causes $E$ to "step" by $4\pi k \sigma$

$$4\pi k \sigma = 1000 \text{ N/C}$$

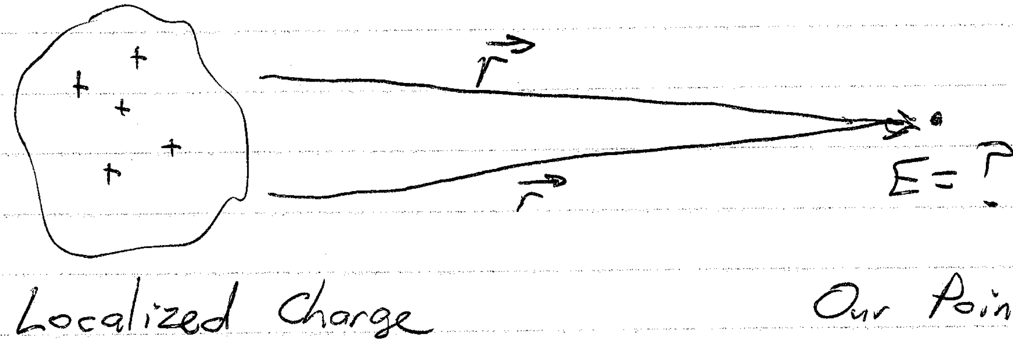
$$\sigma = \left(\frac{1}{4\pi k}\right)\left(1000 \text{ N/C}\right) = 8.85 \times 10^{-9} \text{ C/m}^2$$

- There is $\sim 9$ nC/m² on the surface

E-Fields:

- Point $\vec{E} = \frac{kQ}{r^2}\hat{r}$
- Surface $\vec{E} = 2\pi k \sigma \hat{n}$
- Metal Edge $\vec{E} = 4\pi k \sigma \hat{n}$
- General

$$\vec{E} = \int \frac{k\,dq}{r^2}\hat{r}$$




$$\vec{E} = \int \frac{k\,dq}{r^2}\hat{r} = \frac{k\hat{r}}{r^2}\int dq = \frac{kq}{r^2}\hat{r}$$

$r^2$ is roughly const.
$\hat{r}$ is roughly const.

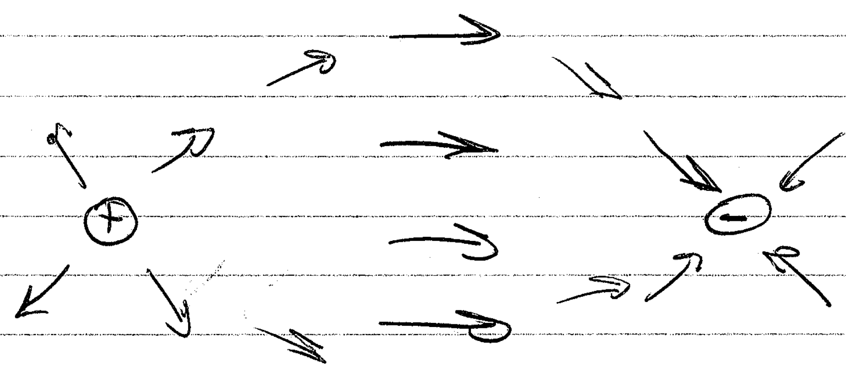
- When far away from a localized charge dist., it "looks like" just $Q_{Tot}$.

technical name: first-order multipole expansion

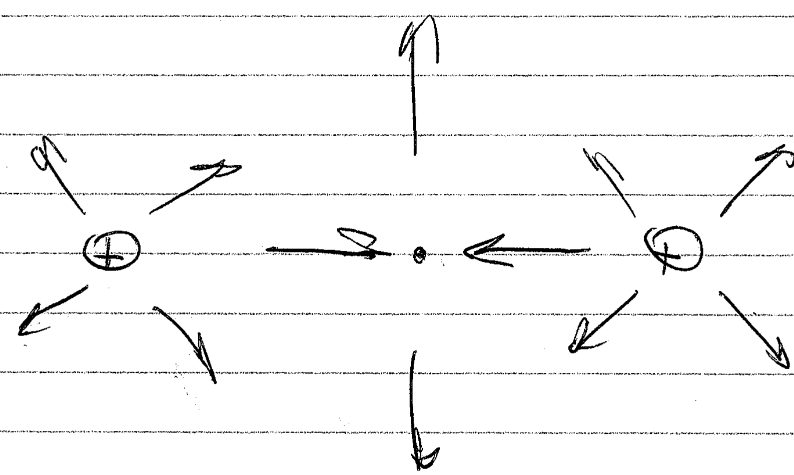
③

$\vec{E}$ always points away from ⊕
toward ⊖

We can think of $\vec{E}$ as the "flow" of something called electric flux.



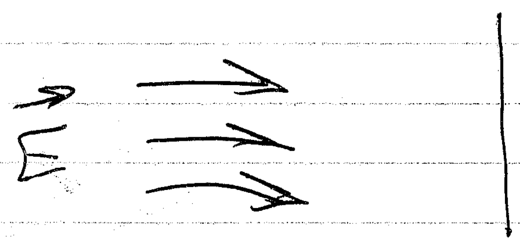
⊕ generates elec flux $\Phi_E$
⊖ acts as a sink of $\Phi_E$



Definition

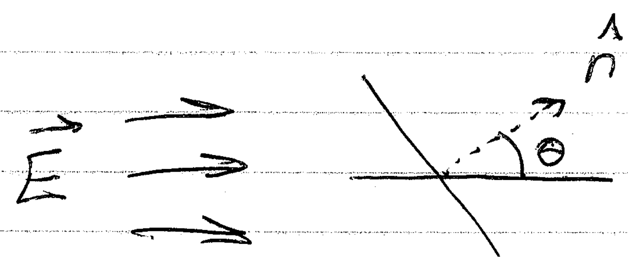
$$\Phi_E = \iint \vec{E} \cdot d\vec{A}$$

- $\iint$ ← Integrate on a surface
- $\vec{E}$ ← must have surface $\perp \vec{E}$ to "catch" flux
- $d\vec{A}$ ← a bit of the surface




$\Phi_E = EA$

Edge view of surface

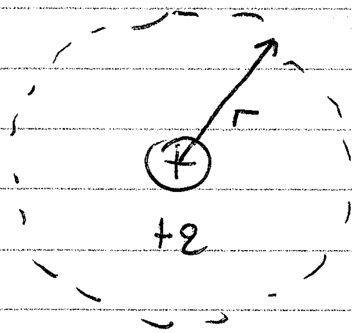



$\Phi_E = EA \cos\theta$

# Gauss's Law

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

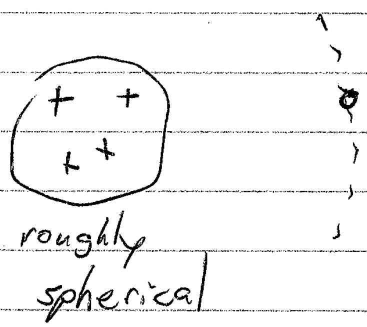
$$\Phi_E = \frac{Q}{\varepsilon_0} = 4\pi k q$$




$$EA = \Phi_E = 4\pi k q$$

$$\cancel{4\pi} r^2 E = \cancel{4\pi} k q$$

$$E = \frac{kq}{r^2}$$



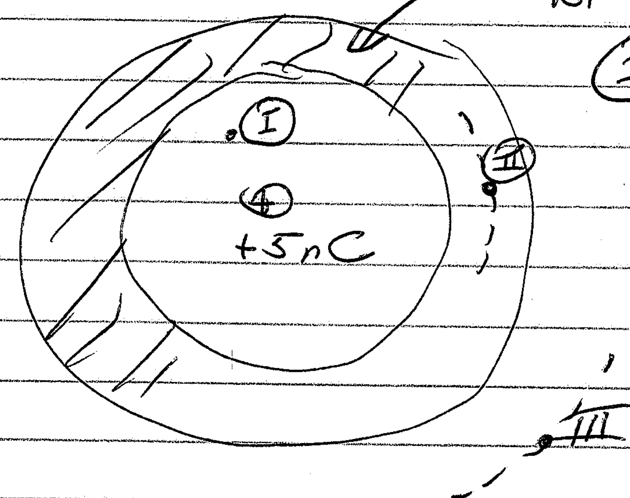

$$E = \frac{kq}{r^2}$$

All enclosed charge

(6)

Charge inside a metal shell

$Q_{Tot} = -15\,nC$ on sphere




II

$E = 0$

$\Phi_E = 0$

$Q_{enc} = 0$

List of charges

- $+5\,nC$
- $q_{inner}$
- $q_{outer}$

$+5\,nC + q_{inner} = 0$

$q_{inner} + q_{outer} = -15\,nC$

$q_{inner} = -5\,nC$, $q_{outer} = -10\,nC$

(I) Inside: $E = \dfrac{k q_{enc}}{r^2} = \dfrac{k\,(+5\,nC)}{r^2}$

(II) In Metal: $E = 0$

(III) Outside: $E = \dfrac{k q_{enc}}{r^2} = \dfrac{k\,(-10\,nC)}{r^2}$

# New Model: Electric Potential

$\vec{E}$ is:

- Force per charge
- "Flow" of $\Phi_E$
- Slope of "landscape" of V

Gravity on Earth

$F = mg$

$W = \vec{F} \cdot \Delta \vec{r}$

$= -mg\,\Delta y$

$\Delta U = mg\,\Delta y$

grav points down

E-Field

$F = q_0 E$

$W = \int \vec{F} \cdot d\vec{r}$

$= q_0 \int \vec{E} \cdot d\vec{r}$

$-\Delta V = \int \vec{E} \cdot d\vec{r}$

$\Delta U = q_0 \Delta V = q_0 \left( -\int \vec{E} \cdot d\vec{r} \right)$

E points "down" to low V.

$\frac{\Delta U}{\Delta y} = mg = -F$

$E = -\frac{\Delta V}{\Delta x}$

$\left( \text{slope} = \frac{\Delta y}{\Delta x} \right)$

(+) creates hills

(−) creates valleys