① Phys 2426   2017-07-03   Lec 1

MTWR 2pm - 4pm

Why Study E&M?

- Everyday Life
  - Energy
  - Info & Comm
- Basis for Light & Optics
- Basis for Matter & Chemistry
- Practice for Math & Learning

Electrostatics

Charge (q) is a property of matter.
Many charges together act like the total.
Most matter has $q=0$.
Even single atoms have $q=0$.
Atoms made of
- protons ⊕
- neutrons ○
- electrons ⊖

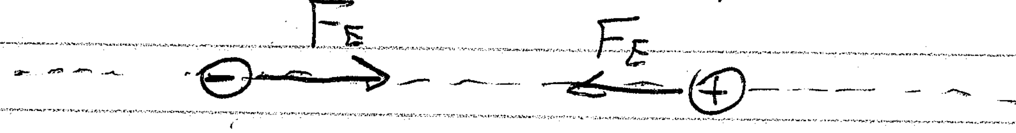
Charge is measured in coulombs (C).
~ 1 C is a lot!
$\sim$ n C is static electric
$e = 1.6 \times 10^{-19}$ C is a proton or electron

"e notation" is different 1.6e-19 = e

(2)

Interactions of Charges - Electric Force

Direction: Opposites Attract
Like Charges Repel



$q_1 = {}^{-}5\,nC$ $\qquad$ $q_2 = +8\,nC$

If $r = 0.25\,m$, we can calculate the strength:

$$F_E = \frac{k\,q\,Q}{r^2}$$

(All magnitudes)

$q =$ charge "feeling" force
$Q =$ "source" charge
$r =$ center-to-center dist
$k = 9\times10^9\ Nm^2/C^2$

$$F_E = \frac{(9\times10^9\ \sim)(5\times10^{-9}\,C)(8\times10^{-9}\,C)}{(0.25\,m)^2}$$

$= 5.76\times10^{-6}\ N$

How big would a styrofoam ($\rho = 0.05\ g/cm^3$) be to have this value as its weight? $(0.14\,cm = r)$

Hint: $V = \frac{4}{3}\pi r^3$

$F_g = mg$ $\qquad$ $m = F_g/g = 5.76\times10^{-6}/9.8 = 5.88\times10^{-7}\,kg$

$m = \rho V$ $\qquad$ $V = m/\rho = (5.88\times10^{-4}\,g)/(0.05\ g/cm^3) = 0.0118\,cm^3$

$V = \frac{4}{3}\pi r^3$ $\qquad$ $r = \left(\frac{3V}{4\pi}\right)^{1/3} = 0.14\ cm$

Electric Fields - Vector Fields -
Every Location has a vector value.

Relate to Coulomb's Law

$$\vec{F_E} = \frac{kqQ}{r^2}\,\hat{r} \quad \text{direction}$$

$$= (q)\left(\frac{kQ}{r^2}\,\hat{r}\right)$$

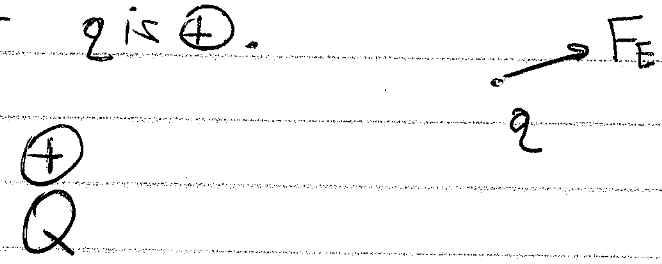
$$\vec{F_E} = q\,\vec{E}$$

Why is this better?
- We don't care about the source of $\vec{E}$.
- Can incorporate many sources.
- Can interchange q's.

Calculating $\vec{E}$ of a source distribution.

Point charge: $E = \frac{kQ}{r^2}$ ($\oplus$ = away, $\ominus$ = toward)

From $\vec{F_E} = q\vec{E}$, dir is that of $\vec{F_E}$ if q is $\oplus$.



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Lots of Q's:

$$\vec{F_e} = \frac{kqQ_1}{r_1^2}\hat{r}_1 + \frac{kqQ_2}{r_2^2}\hat{r}_2 + \cdots$$

$$\vec{F_e} = q\left(\frac{kQ_1}{r_1^2}\hat{r}_1 + \frac{kQ_2}{r_2^2}\hat{r}_2 + \cdots\right)$$

$$= q\left(\vec{E_1} + \vec{E_2} + \cdots\right)$$

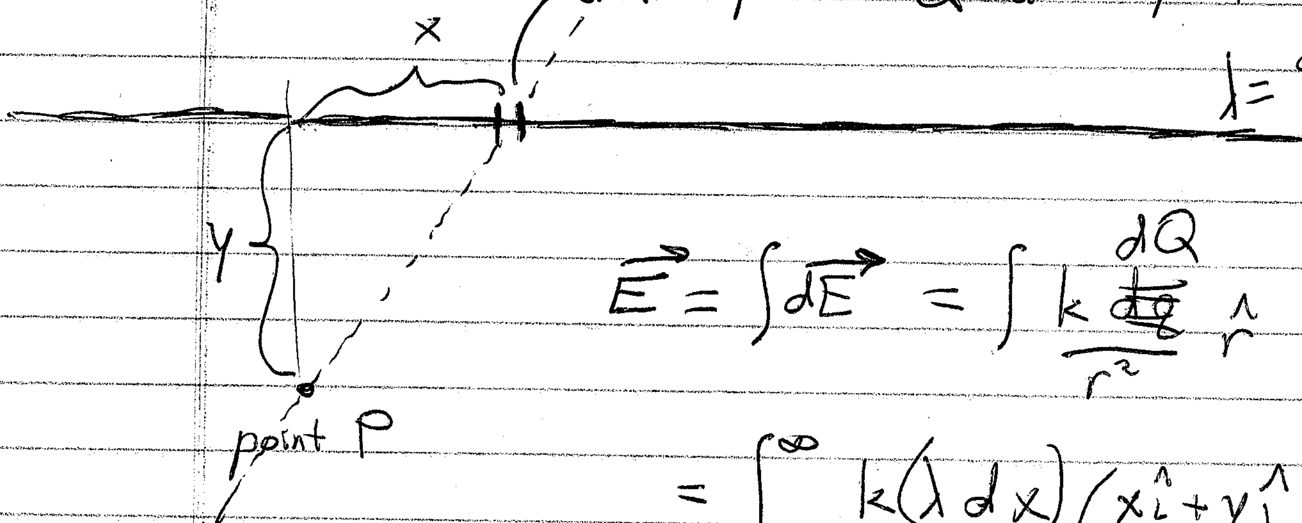
$$= q\,\vec{E}$$

$$\vec{E} = \vec{E_1} + \vec{E_2} + \cdots$$

For a line charge: λ = Linear Charge Density

dQ is part of Q "at this point"

λ = charge per length



$$\vec{E} = \int d\vec{E} = \int k\frac{dQ}{r^2}\hat{r}$$

$$= \int_{-\infty}^{\infty} \frac{k(\lambda\,dx)}{(x^2+y^2)}\left(\frac{x\hat{i}+y\hat{j}}{(x^2+y^2)^{1/2}}\right)$$

Result: $\vec{E} = \frac{2k\lambda}{y}$ (away if $\lambda = \oplus$)

More Fun: $\vec{E} = \int \frac{k\,\sigma\, dA}{r^2}\,\hat{r}$

For flat, infinite plane: $\vec{E} = 2\pi k \sigma$

charge per area

This is the contribution to $\vec{E}$ caused by that surface charge.