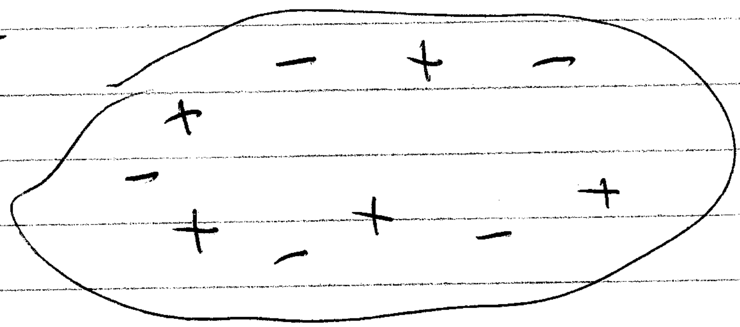
1 Phys 2426 2016-08-30 Lec 2

Charge (q, Q) measured in coulombs (C).

Fundamental charge $e = 1.6 \times 10^{-19}$ C

Typical matter is neutral.
Same N_p as N_e



Types of materials:
- Conductors ⊕ "stuck" ⊖ mobile
- Insulators ⊕ "stuck" ⊖ stuck

Ways to make charges move:
- Friction / abrasion - triboelectric effect
  PhET Balloons simulation
- Induced charge - induced dipole

Electric Field - model of electric effects.

- Source Charges cause elec field.
- Elec Field is a vector field.
- E-Field causes the effects.

E is defined by how much force it causes.

$$\vec{E} = \frac{\vec{F}}{q_0}$$

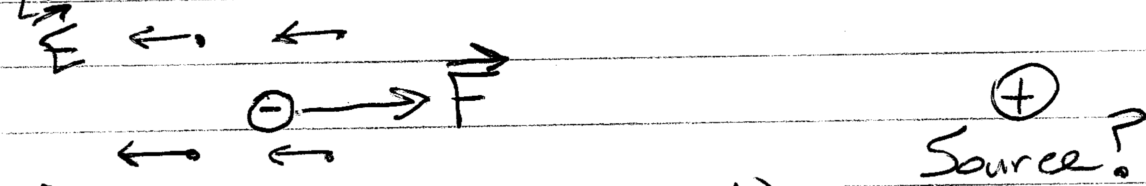
$\vec{E}$ = field at a point

$\vec{F}$ = force on our test charge

q_0 = our test charge

We assume q_0 can't feel its own $\vec{E}$.
Source is something else.

Ex: q_0 = electron $\qquad \vec{F} = F\hat{x}$



$$\vec{E} = \frac{(F\hat{x})}{-e} = \left(\frac{F}{e}\right)(-\hat{x})$$

E points in $-\hat{x}$ direction.

What could be the source?

- Positive off to right.
- Generates $\vec{E}$ pointing "away".

Electric Field Formulas

Point Source $\qquad \vec{E} = \dfrac{k q_1}{r^2} \hat{r}$

$k = 9 \times 10^9 \ Nm^2/C^2$

q_1 = source charge

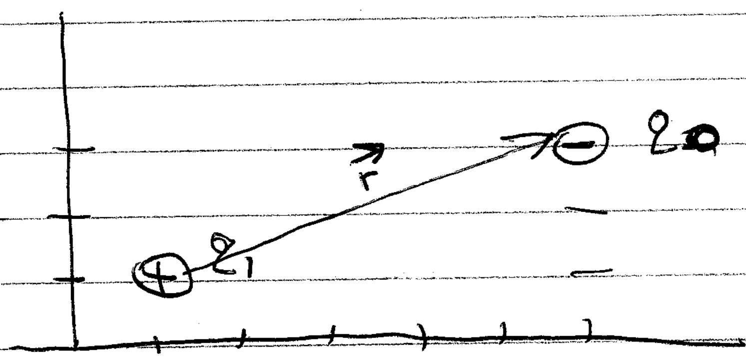
r^2 = distance squared to our point

$\hat{r}$ = unit vector from source toward point

$$\hat{r} = \frac{\vec{r}}{r}$$

$\vec{r}$ = vector from source to our point.

Ex:



$q_1 = 5\,nC$ @ (1 cm, 1 cm)

$q_0 = -3\,nC$ @ (6 cm, 3 cm)

$\vec{r} = 5\,cm\,\hat{i} + 2\,cm\,\hat{j}$

$r^2 = (5^2 + 2^2)\,cm^2 = 29\,cm^2$

$|r| = \sqrt{29}\ cm = 5.39\ cm$

$\hat{r} = \dfrac{5}{5.39}\hat{i} + \dfrac{2}{5.39}\hat{j}$ (units cancel)

(4)

$$E = \frac{k q_1}{r^2} \cancel{\hat{r}} = \frac{\left(9\times10^{9}\,\frac{Nm^2}{C^2}\right)\left(5\times10^{-9}\,C\right)}{\left(0.0029\ m^2\right)}$$

$$= 15500\ N/C$$

$$\vec{E} = E\hat{E} = \left(15500\ N/C\right)\left(\frac{5}{5.39}\hat{i} + \frac{2}{5.39}\hat{j}\right)$$

$$= 14400\,\hat{i} + \overset{57}{\cancel{59}}00\,\hat{j}\quad N/C$$

Force on q_6:

$$\vec{F} = q_6\vec{E} = \left(-3\times10^{-9}\,C\right)\left(14400\,\hat{i} + 5700\,\hat{j}\right)N/C$$

$$= -43\,\mu N\,\hat{i} - 17\,\mu N\,\hat{j}$$

Charge Distributions

Method: Break charge into bits, and think of each bit as a point charge.

Line Charge $\lambda = Q/L$

$$dq = \begin{cases} \lambda\, dx \\ \lambda\, dy \\ \lambda\, dl \end{cases}$$

Each dq contributes $d\vec{E} = \frac{k\,dq}{r^2}\hat{r}$

Since $\hat{r}$ varies, the integral is a pain.

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

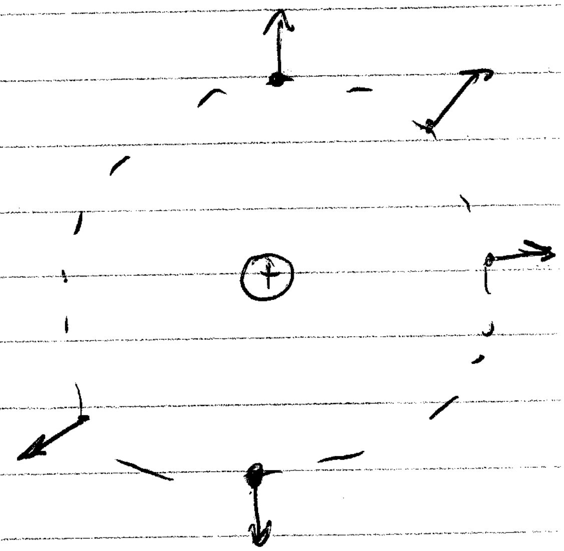
Infinite Line Charge

$$\vec{E} = \frac{2k\lambda}{r}\hat{r}$$

Are these results part of the same physics?

~~(See p④ of 1402~~

Gauss's Law



Start w/ a ⊕ charge
Look at points "around" the charge. This dashed line represents a sphere.

$\vec{E}$ is always "away". Which is "outward".

No matter how big the sphere is, the "total" of all of the $\vec{E}$ vectors is the same.

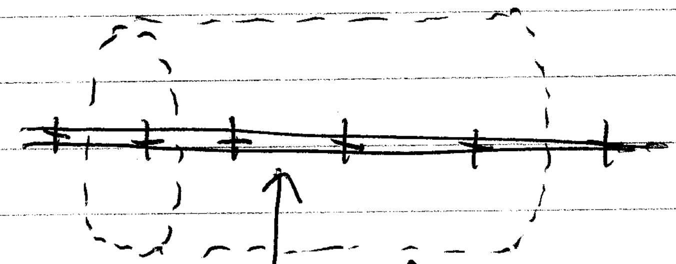
$$\vec{E}\cdot \text{Area} = \frac{kq_1}{\cancel{r^2}}\, 4\pi \cancel{r^2} = 4\pi k q_1$$

We could "walk around" any sphere, measure $\vec{E}$, and deduce how much charge is inside.

$$\text{Electric Flux} = \vec{E}\cdot\vec{\text{Area}} = 4\pi k q_{enc}$$

7

Gauss's Law For Line Charge



Area $= 2\pi r L$

$q_{enc} = \lambda L$

$$E \cdot A \stackrel{?}{=} 4\pi k \, q_{enc}$$

$$\left(\frac{2k\lambda}{r}\right)(2\pi r L) = 4\pi k(\lambda L)$$

$$4\pi k \lambda L = 4\pi k \lambda L \quad \checkmark$$