① Phys 2426 2015-09.01 Lec 2

A 0.5 g styrofoam bead has a charge of 50 nC. What is the charge of just the electrons?
50% of mass of organics is protons.

$$\Sigma m_p = 0.25\ g$$

$$N_p = \frac{\Sigma m_p}{m_p} = \frac{(0.25 \times 10^{-3}\ kg)}{(1.67 \times 10^{-27}\ kg)}$$

$$= 1.5 \times 10^{23}\ \text{protons}$$

$$\Sigma q_p = N_p\, e = (1.5 \times 10^{23})(1.6 \times 10^{-19}\ C)$$

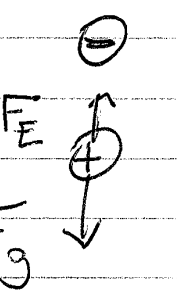
$$= +24000\ C$$

$$Q = \Sigma q_i = \Sigma q_p + \Sigma q_e = 50\ nC$$

$+24000\ C$ $\quad -24000\ C$

$|\Sigma q_p| \approx |\Sigma q_e|$ Diff by $0.00000005\ C$

# Model 1: Coulomb's Law




$$F_E = k\frac{q_0 q_s}{r^2}$$

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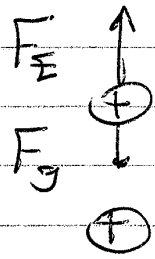


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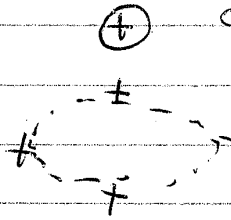



but....

$$\sum \vec{F}_i = \sum_i k\frac{q_0 q_i}{r_i^2}\left(\hat{r}_i\right)$$

$$\hat{r}_i = \vec{r}_i / |r_i|$$

# Model 2: Electric Field

$F_E = q_0 E$ $\quad$ $E$ = effect of sources

Ex: Levitate the 0.5 g, 50 nC bead.

$F_E = q_0 E$

$q_0 = 50\ nC$

$F_g = mg = (0.5\times10^{-3}\ kg)(9.8\ N/kg)$
$= 0.0049\ N$

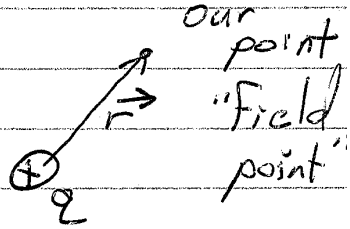
$$E = \frac{F_E}{q_0} = \frac{0.0049\ N}{50\times10^{-9}\ C} = 98000\ N/C$$

Max $E$ in air is $3\times10^{6}\ N/C$
Try to exceed, sparks, lightning

# Sources of E-Field

**Point Charge** Charge = $q$

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

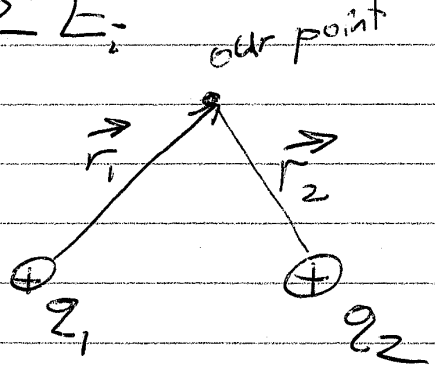



$\hat{r}$ = away from source

$\vec{E}$ = away from ⊕, toward ⊖

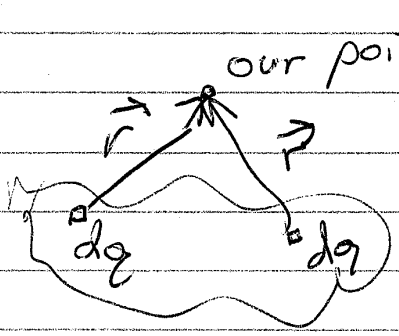
**Many Point Charges** $Q = \Sigma q_i$

$$\vec{E} = \sum \frac{kq_i}{r_i^2}\hat{r}_i = \sum \vec{E}_i$$




**Spread out charge** $Q = \int \rho\, dV = \int dq$

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




$dq = \rho\, dV$

$dq = \sigma\, dA$

$dq = \lambda\, dx$

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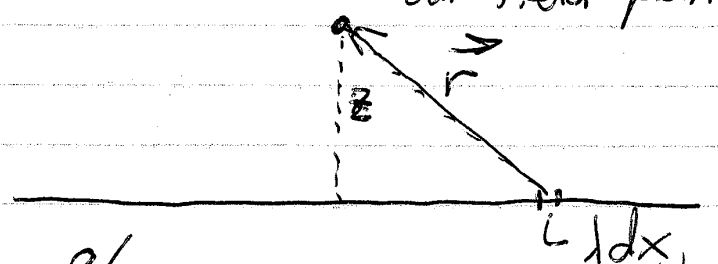
Infinite Line Charge




$\lambda = q/\ell$ = charge per length

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

$$\vec{r} = -x\hat{\imath} + z\hat{k}$$

$$r^2 = x^2 + z^2$$

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

$$E_x = k\lambda\int_{-\infty}^{\infty}\frac{dx}{r^2}\left(\frac{-x}{r}\right) = 0$$

$$E_z = k\lambda\int_{-\infty}^{\infty}\frac{dx}{r^2}\left(\frac{z}{r}\right) = k\lambda z\int_{-\infty}^{\infty}\frac{dx}{(x^2+z^2)^{3/2}}$$

$$= \frac{2k\lambda}{z} \leftarrow \text{result!}$$

Rephrase

Line Charge  Charge $Q = \lambda\ell$

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

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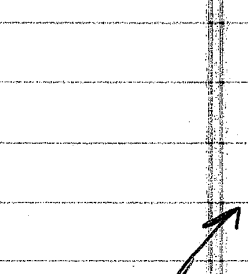
Surface Charge $\sigma = Q/A$

$(dQ = \sigma dA = \sigma dx dy)$
$= \sigma r dr d\theta$

Infinite, flat, uniform surface.

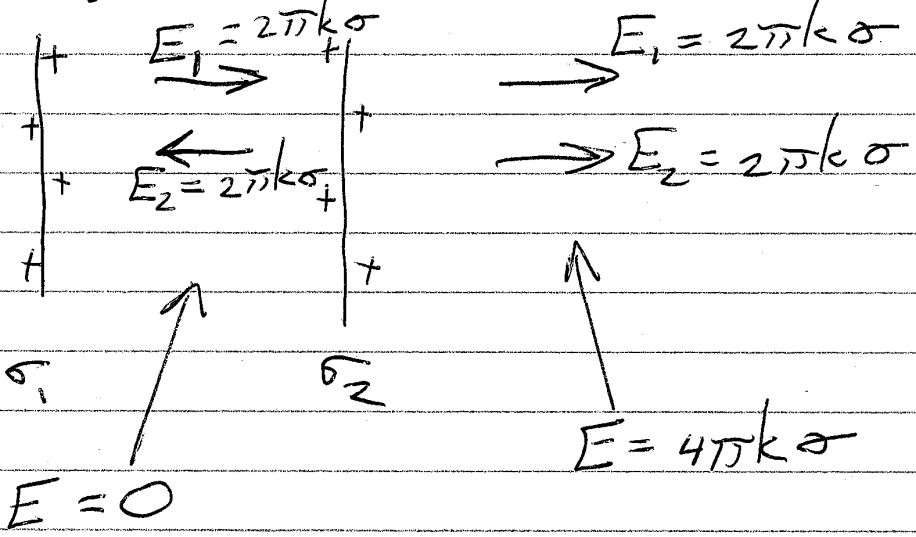


$E = 2\pi k\sigma$

This is the contribution of just that surface.

$E_x = -2\pi k\sigma$ (Edge view)

Two equal surfaces




$E_x$ steps by $4\pi k\sigma$

This is explained by Gauss's Law