but $r_{12} = r_{21}$ $r_{13} = r_{31}$ $r_{23} = r_{32}$

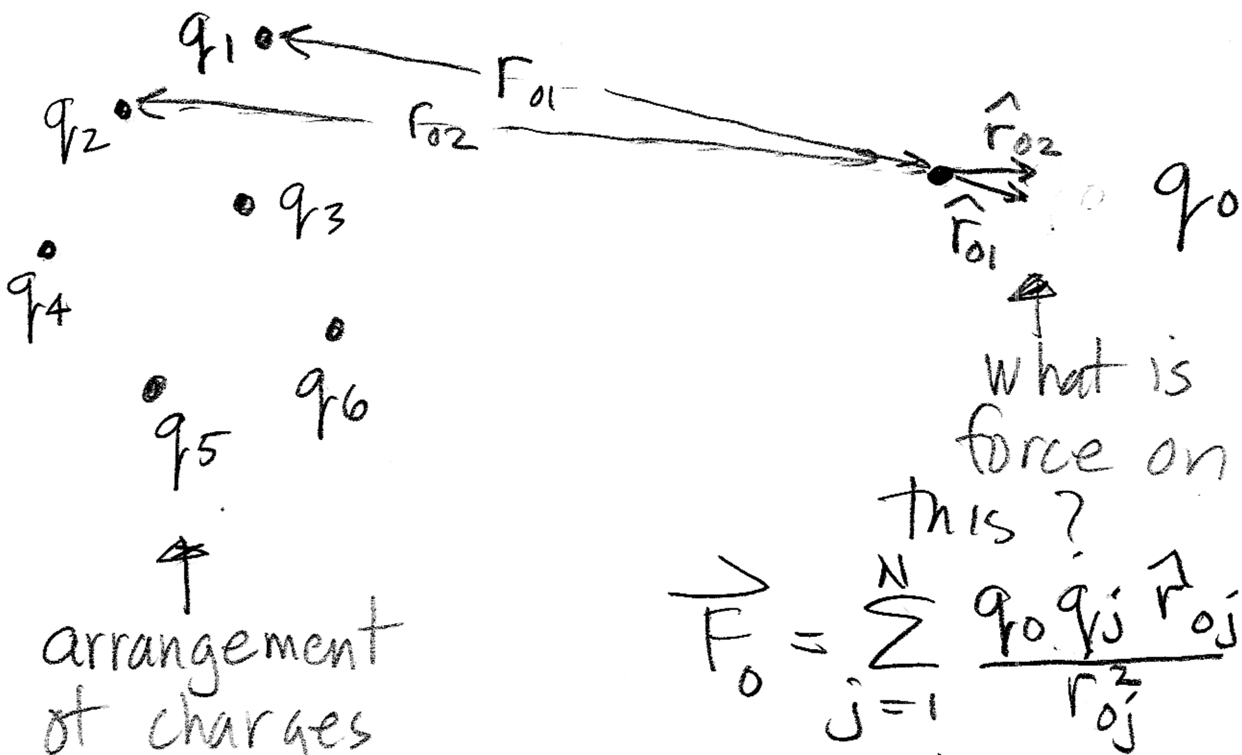
$$U = \frac{q_1 q_2}{r_{21}} + \frac{q_1 q_3}{r_{31}} + \frac{q_2 q_3}{r_{32}}$$

what the $\frac{1}{2}$ does in

$$U = \frac{1}{2} \sum_{j=1}^{N} \sum_{k \neq j} \frac{q_j q_k}{r_{jk}}$$

is eliminate double counting

Electric Field



$$\vec{F}_0 = \sum_{j=1}^{N} \frac{q_0 q_j \hat{r}_{0j}}{r_{0j}^2}$$

$$\vec{F}_0 = q_0 \cdot \sum_{j=1}^{N} \frac{q_j \hat{r}_{0j}}{r_{0j}^2}$$

q_0: property of the charge at position 0

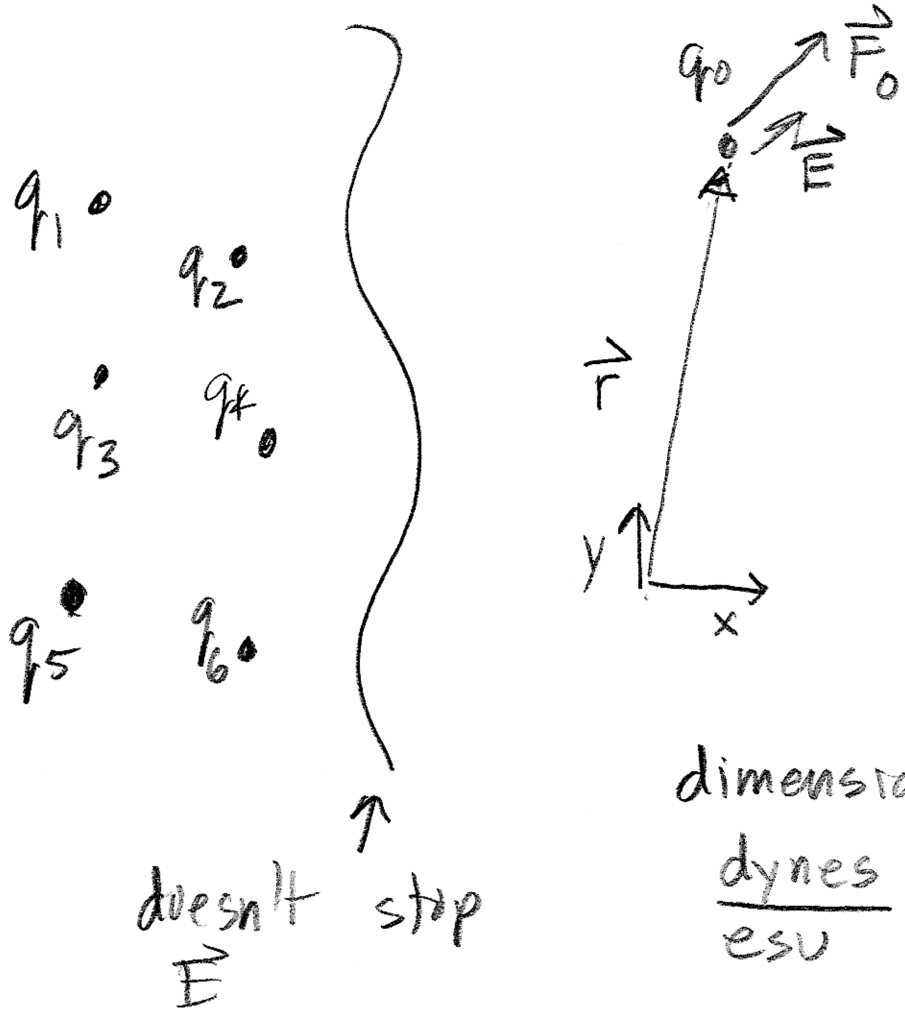
$\sum$: poperty of the other charges + position

$$\vec{F}_0 = q_0 \cdot \vec{E}$$

defined $\vec{E} \equiv \sum_{j=1}^{N} \frac{q_j \hat{r}_{0j}}{r_{0j}^2}$

is the electric field $\vec{E}$.

What is $\vec{E}$, exactly? It is something existing already in space, created by surrounding charges. You may not know the exact distribution of charges that cause the $\vec{E}$ field... imagine a screen...



charge q_0 placed at $\vec{r}$ feels $\vec{F}_0$, meaning $q_1, q_2, \ldots q_N$ caused an $\vec{E}$ field

$$\frac{\vec{F}_0}{q_0} = \vec{E}(\vec{r})$$

dimensions of $\vec{E}$:

$$\frac{\text{dynes}}{\text{esu}} \quad \text{or} \quad \frac{\text{Newtons}}{\text{coulomb}}$$

gCGS: $\vec{E}(\vec{r}) = \sum_{j=1}^{N} \frac{q_j \hat{r}_j}{r_j^2}$ SI $\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0} \sum_{j=1}^{N} \frac{q_j \hat{r}_j}{r_j^2}$

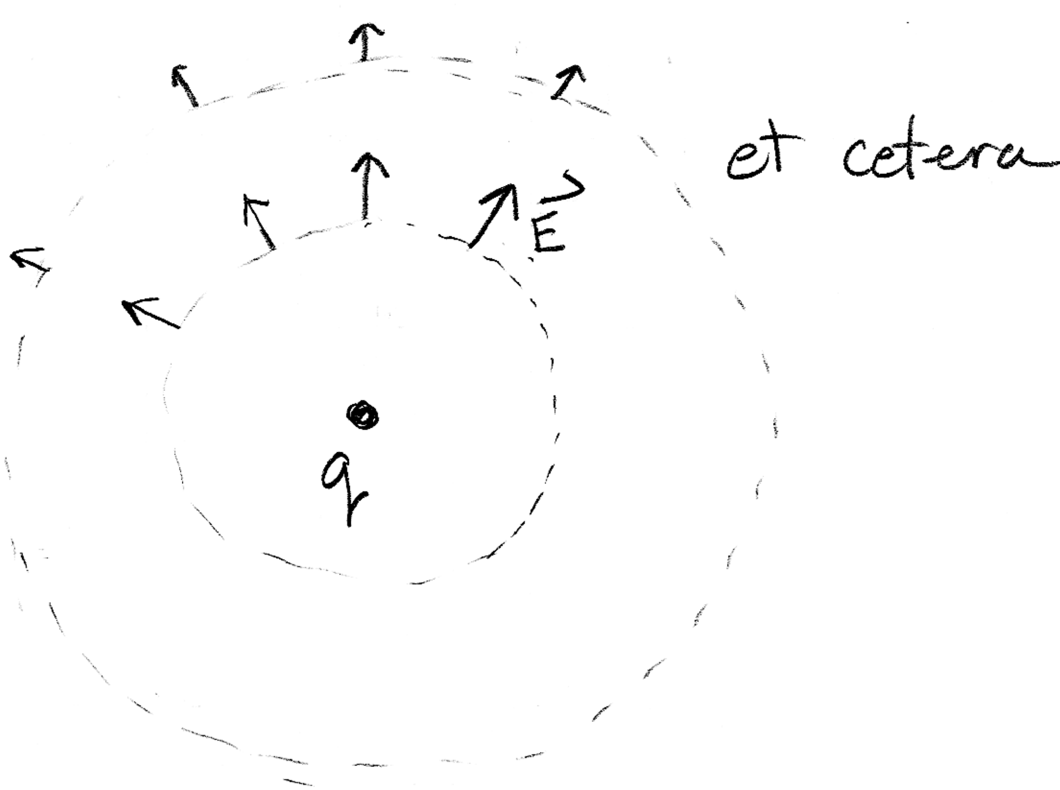
$\frac{1}{4\pi\varepsilon_0} = 9 \cdot 10^9$

$\hat{r}_j$ = unit vector from origin to q_j

r_j = magnitude of vector from origin to q_j

Visualizing $\vec{E}$:
- $\vec{E}$ goes with the source charges.
- Think of $\vec{E}$ everywhere in space at the same time

(1) Vectors hanging in space



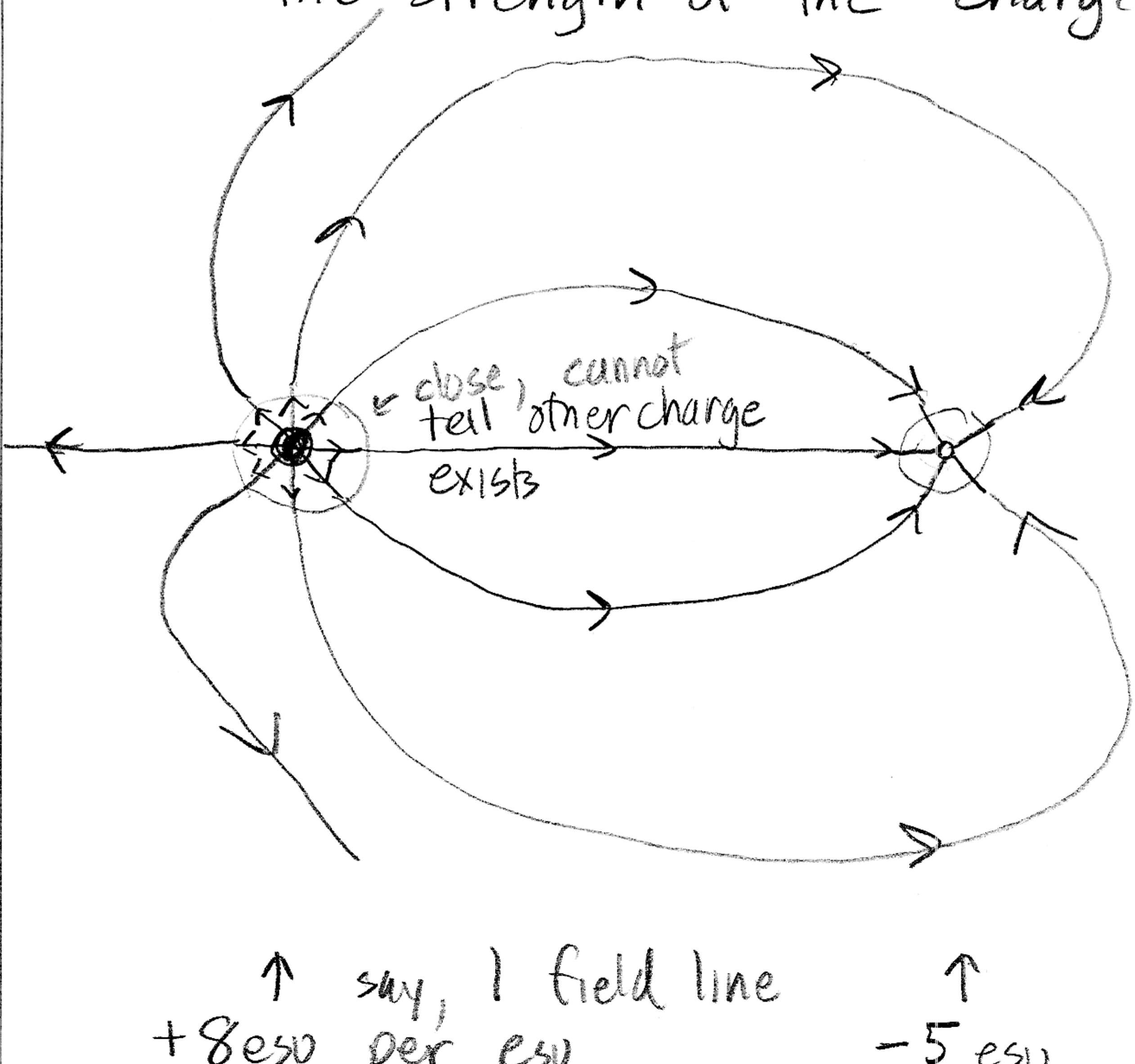
② Field Lines

→ give direction, not magnitude (directly)

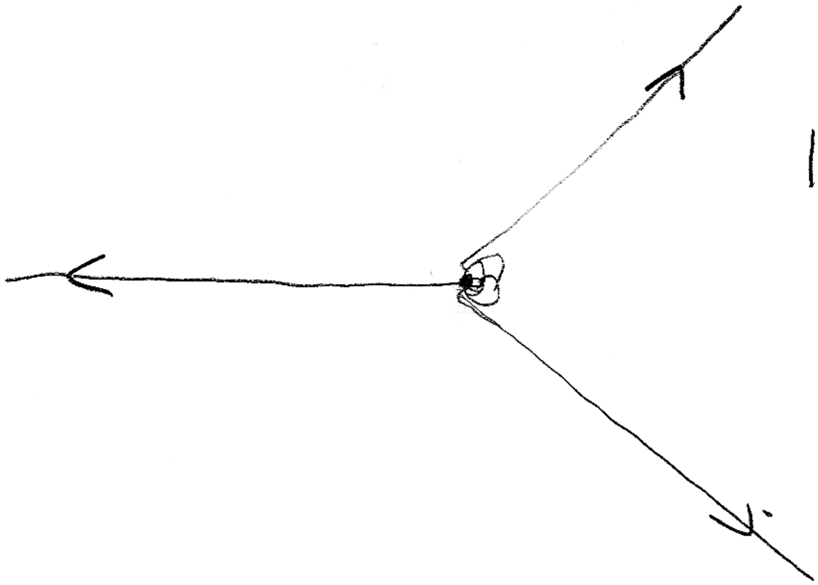
→ field line is <u>tangent</u> to $\vec{E}$ field

→ field lines start on + charge, end on − charge.

→ # of field lines that start/end on a charge is proportional to the strength of the charge.



On a much larger distance scale.



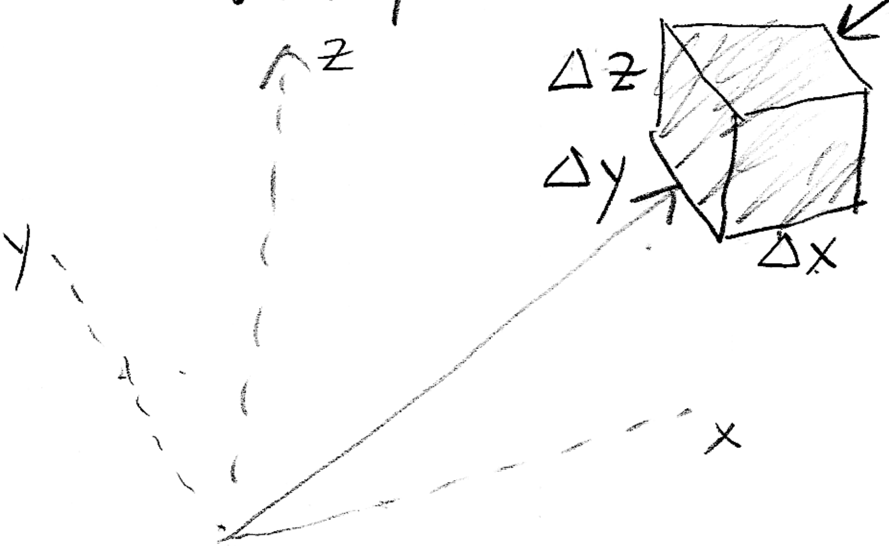
looks, from far away, like charge +3 esu = 8−5 esu = net charge

Continuous Charge Distributions

e is <u>very</u> small... can imagine it being infinitesimal, then

$$\rho(x,y,z) = \lim_{\Delta x,\Delta y,\Delta z \to 0} \frac{\Delta q}{\Delta x \Delta y \Delta z}$$

↑ charge density



Δq is amount of charge in little box located at x, y, z