Electricity and Magnetism

- Electric field continued

Electric Field

- New concept – Electric Field $\vec{E}$
- Charge Q gives rise to a Vector Field

$$\vec{E}(\vec{x}) = \vec{F}(\vec{x})/q$$

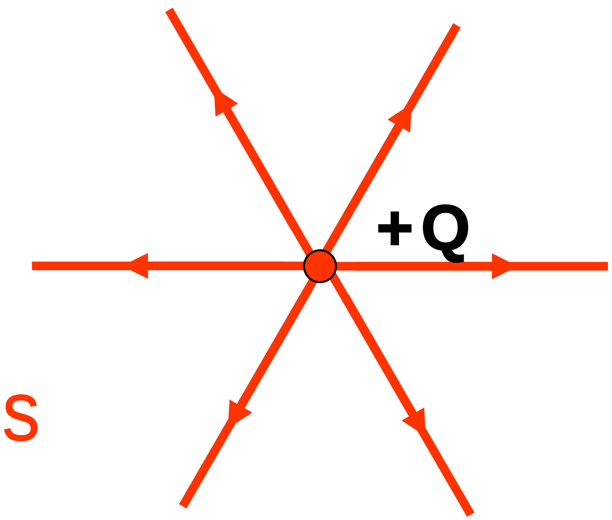
- $\vec{E}$ is defined by strength and direction of force on small test charge q

Electric Field

- For a single charge

$$E = k\frac{Q}{r^2}$$

- Visualize using Field Lines
  - Cartoon!
  - Strength -> Density of Lines
  - Direction -> Direction of Lines
    - away from positive charges



Electric Field

- Field can be used to accelerate charged particles

$$F = Q E$$

-> Particle Accelerators

The Electric Field

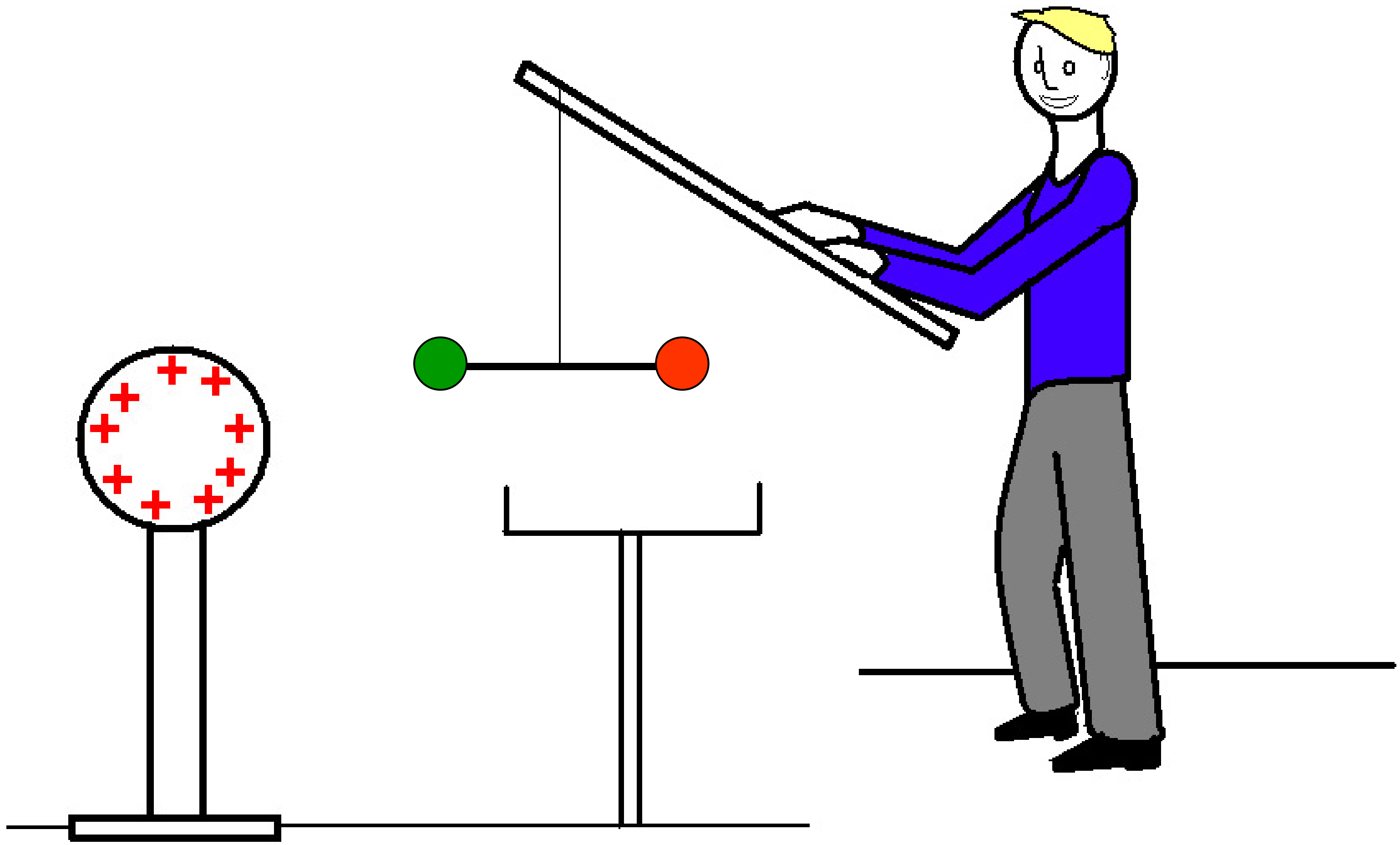
- Electric Field also exists is test charge q is not present
- We can say:

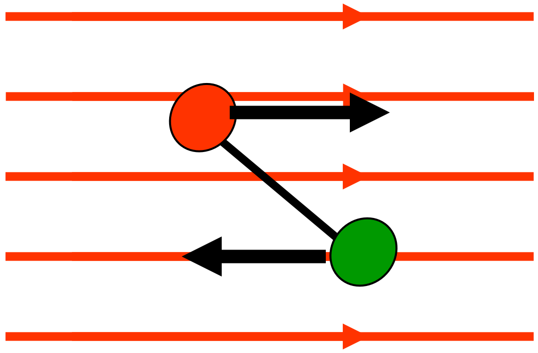
The charge Q gives rise to a property of space itself – the Electric Field

-> In-Class Demo...

Electric Field Demo

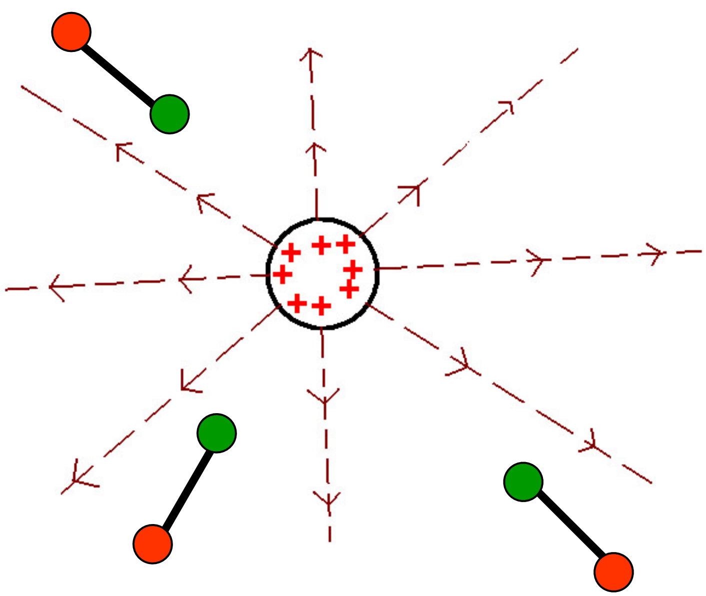
- Use a Van-der-Graaf Generator
- Much more powerful than rubbing glass rods
- Not really dangerous (I've been told) – but potentially painful
- Creates large electric fields
- Really big ones were used in Particle Accelerators (still in use in some labs)





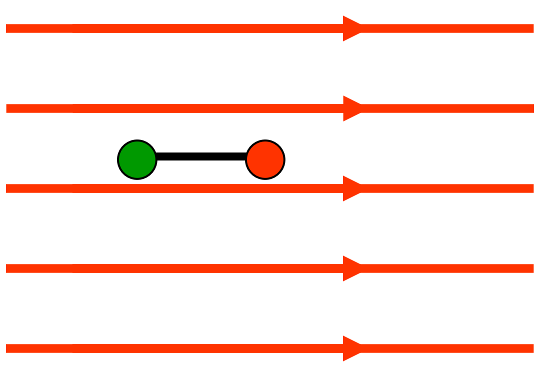
Torque $\vec{\tau} = \vec{p} \times \vec{E}$

$\vec{p} = Q \, \vec{l}$ Dipolemoment

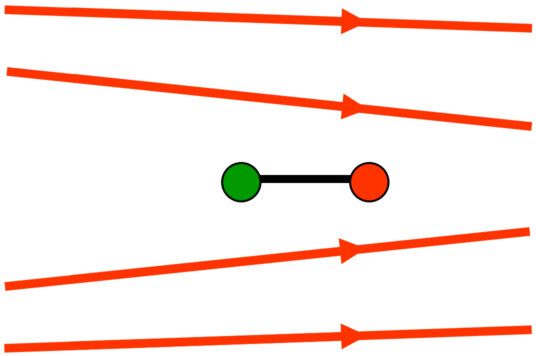


Does Dipole feel a net Force?

No

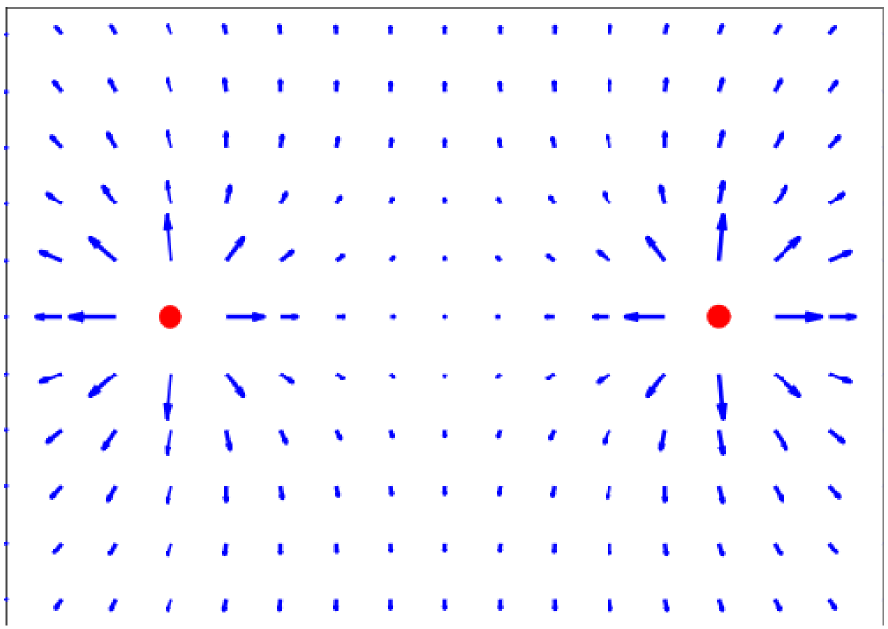


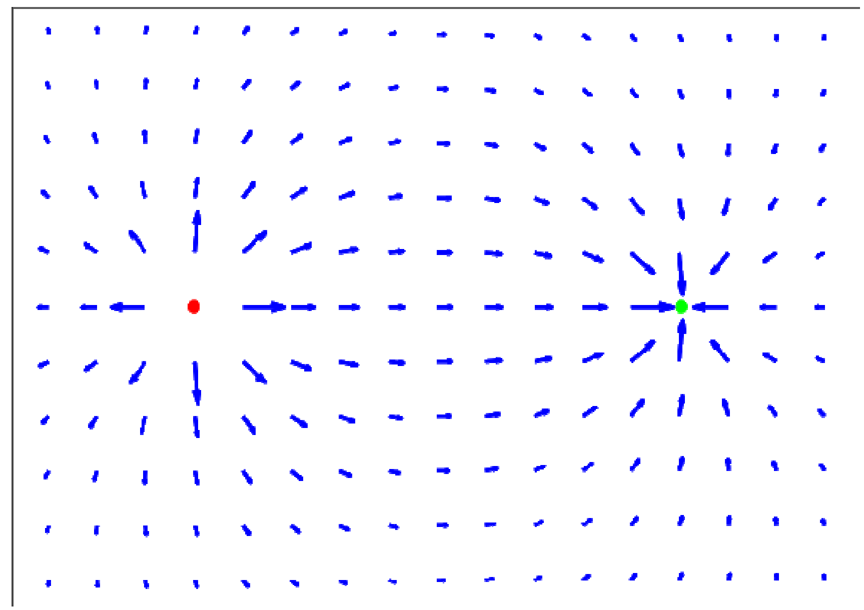
Yes



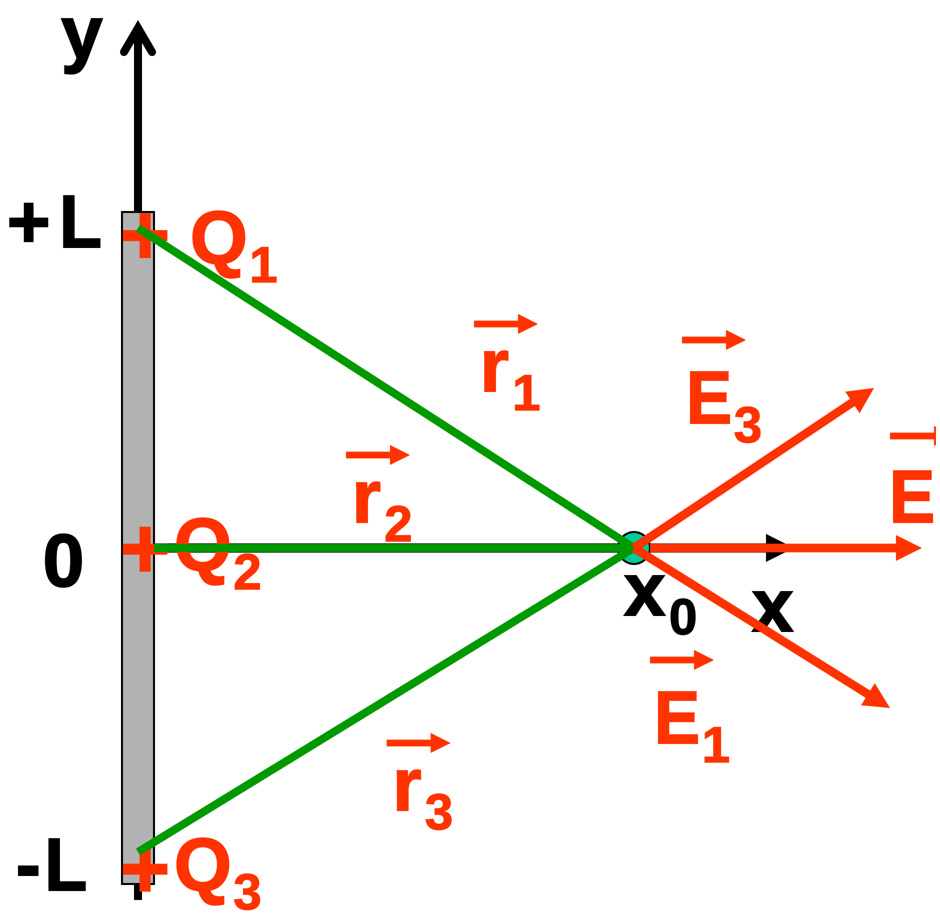
Superposition Principle

- Field of many charges is Vector Sum of individual fields





Example: Superposition principle for 3 charges



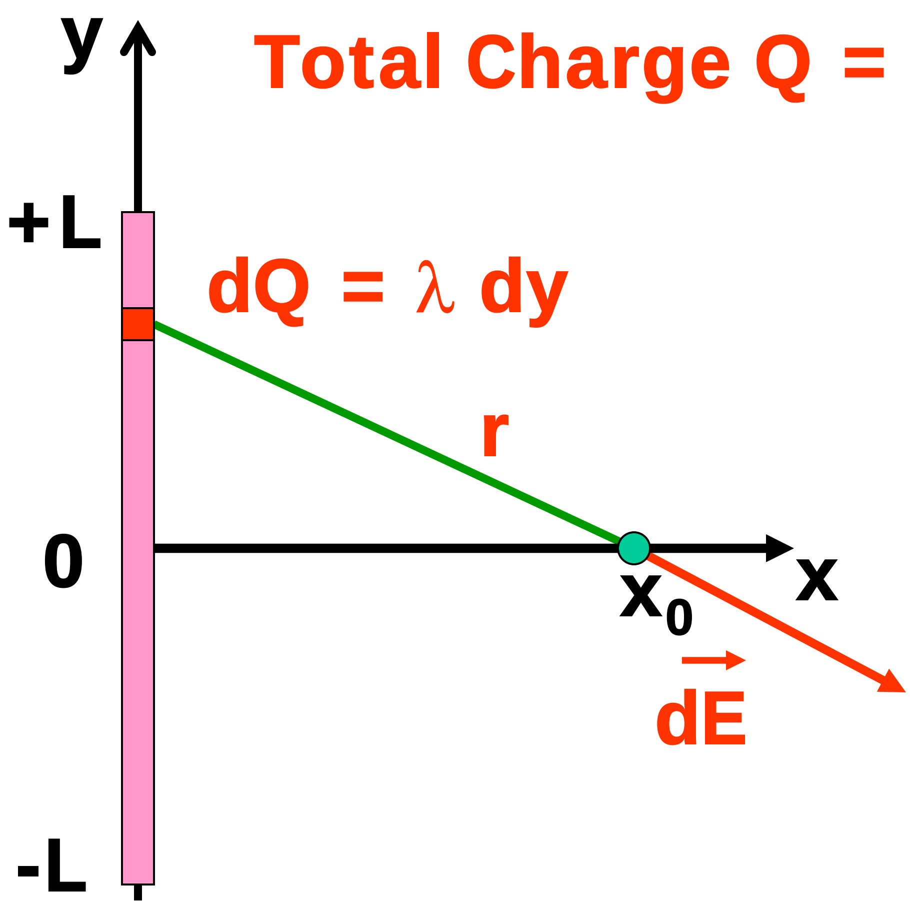
$$\vec{E}_i = k\frac{Q_i}{r_i^2}\hat{r}_i$$

$$E_{y,total} = 0$$

$$E_{i,x} = E_i \cos(\Theta) = E_i \frac{x_0}{x_0^2 + y_i^2}$$

$$\begin{aligned} E_x &= \sum E_{i,x} \\ &= kQ \cdot \left(\frac{1}{x_0^2} + \frac{2x_0}{(x_0^2 + L^2)^{3/2}}\right) \end{aligned}$$

Example: Superposition principle for continous charge distribution



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

$$\begin{aligned} dE_x &= k\frac{dQ}{x_0^2+y^2}\cos(\Theta) \\ &= k\frac{dQ}{x_0^2+y^2}\frac{x_0}{\sqrt{x_0^2+y^2}} \\ &= k\lambda dy\frac{x_0}{(x_0^2+y^2)^{3/2}} \end{aligned}$$

Example: Superposition principle for continous charge distribution

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

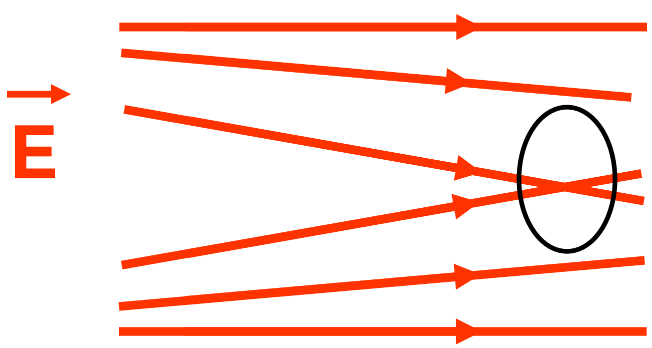
$$\begin{aligned}\vec{E} &= E_x\hat{x} \\ &= \int_{allcharge} dE_x \\ &= k\lambda x_0 \int_{-L}^{+L} \frac{dy}{(x_0^2 + y^2)^{3/2}}\end{aligned}$$

$$\begin{aligned}dE_x &= k\frac{dQ}{x_0^2 + y^2}\cos(\Theta) \\ &= k\frac{dQ}{x_0^2 + y^2}\frac{x_0}{\sqrt{x_0^2 + y^2}} \\ &= k\lambda dy\frac{x_0}{(x_0^2 + y^2)^{3/2}}\end{aligned}$$

$$E_x = 2k\lambda\frac{L}{x_0\sqrt{x_0^2 + L^2}}$$

More on Fields and Field Lines

- What's wrong with this picture?
- Magnitude and direction of field have to be unique at each point!
- Field lines can't cross!



More on Fields and Field Lines

- Very close to surface of charged object
- Field lines perpendicular to surface (if we go close enough)!
- Symmetry left and right (like an infinite plane)