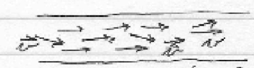
L3 p1

Electric Field

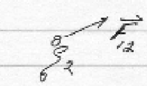
a field: "any physical quantity which can be specified simultaneosly for all points within a given region of interest."

Example: flowing water in a pipe



- each point has a velocity, $\vec{v}$

- Consider a pair of charges



- q_1 sets up a force that acts on q_2.

→ what is this force?

- imagine q_2 is a small test charge $= q_0$

why? So we can measure undisturbed.)

$$\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0}$$

is "electric field" (← force per charge of q_2)

L3 p2

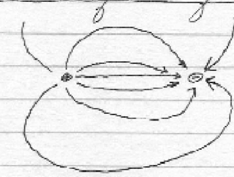
This elaborates the idea of "action-at-a-distance":

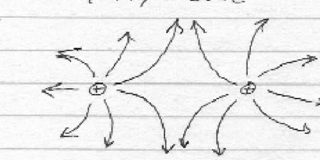
- "E field" is what contains information about forces

- with moving charges
  - a delay expected because $\vec{E}$ carries, or propagates, this information at the speed of light
  - → this is what we observe

Lines of E-field / direction & number is important

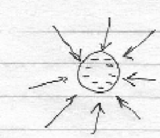
2 equal & opposite charges

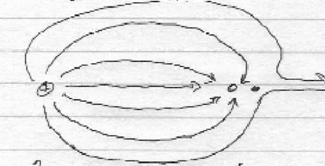




2 equal charges

- charge sphere





2q -1q

$\vec{E}$ field for Point Charges

Consider 2 charge example

$$\vec{F}_{12} = k \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12}$$

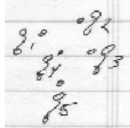
$\vec{E}$ also has a direction, & it's expressed

$$\boxed{\vec{E}_1 = k \frac{q_1}{r^2} \hat{r}}$$

where $\vec{r}$ is the vector to whatever point we place our test charge.

$\ast \{ \rightarrow \vec{E}$ does not depend on the presence of a test charge.

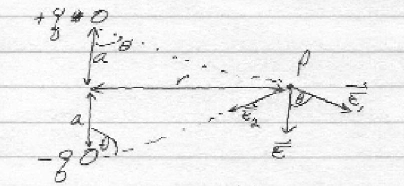
For multiple charges, invoke superposition



$$\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 \cdots = \sum \vec{E}_i$$

Example: Electric dipole

What is $\vec{E}$
@ P along ⊥
bisector, r



$r \gg a$

$$\vec{E} = \vec{E}_1 + \vec{E}_2 \quad ; \quad |\vec{E}_1| (= E_2) = k \frac{q}{a^2 + r^2}$$

$\vec{E}$ points down w/ magnitude:

$$E = 2 E_1 \cos\theta$$
$$= 2k \frac{q}{a^2 + r^2} \underbrace{\left(\frac{a}{\sqrt{a^2 + r^2}} \right)}_{\text{"}\cos\theta\text{"}}$$
$$= \frac{2kaq}{(a^2 + r^2)^{3/2}}$$

Since $a \ll r$, $\boxed{E = 2kaq / r^3}$

$2aq$ is "electric dipole moment" & reflects that separation & charge can't be measured seperately

→ for a dipole $E(r) \propto 1/r^3$ not $1/r^2$ because 2 charges' $\vec{E}$ fields cancel more & more with distance