Lecture 6

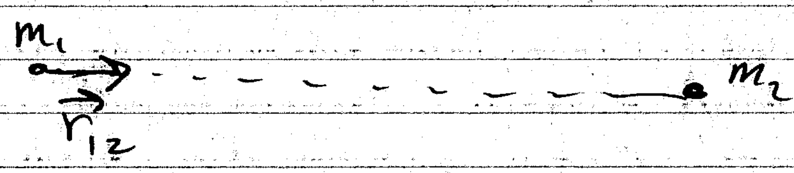
8 SEP 2014

Notion of electric field
(Chapter 22)

We already talked about the notion of a gravitational field. Think of every mass as exerting a force field on masses around it.

Newton law is

$$\vec{F}_{12} = \frac{G \cdot m_1 \cdot m_2}{r^2} \vec{r}_{12}$$



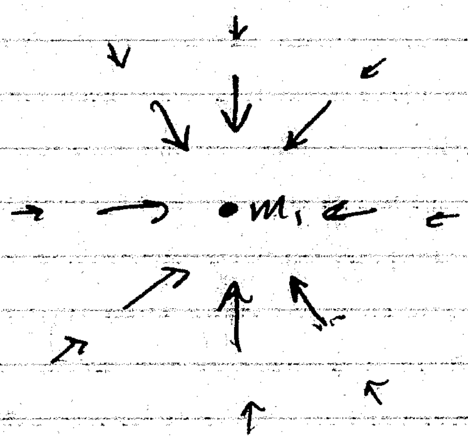
gravitational field arises. Think of putting test mass at a position $\vec{r}$ from m_1

then gravitational field due to m_1 is

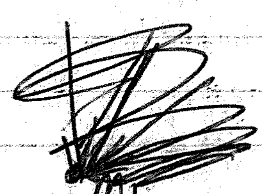
$$\vec{g}(\vec{r}) = -\frac{G m_1}{r^2}\,\vec{r}_u$$

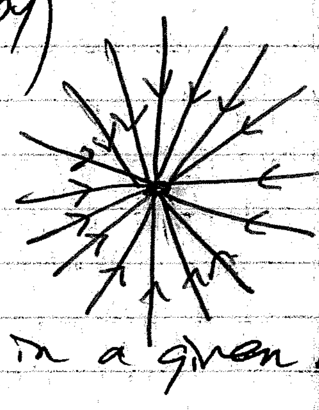
where $\vec{r}_u$ is a unit vector in direction of m_1 to position $\vec{r}$

We can draw the field as



can also draw gravitational field lines (introduced by Faraday)





convention is that

1) the more lines there are in a given area, the stronger the force.

2) the direction of the field is given by tangent to a field line (or for straight lines, direction is same as straight line)

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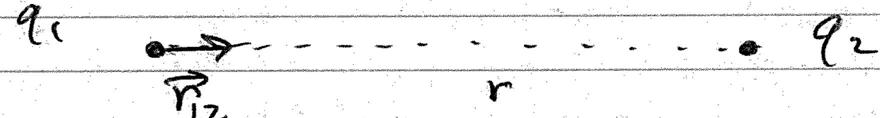
electric field lines are useful for visualizing the electric field.

Recall the Coulomb law:

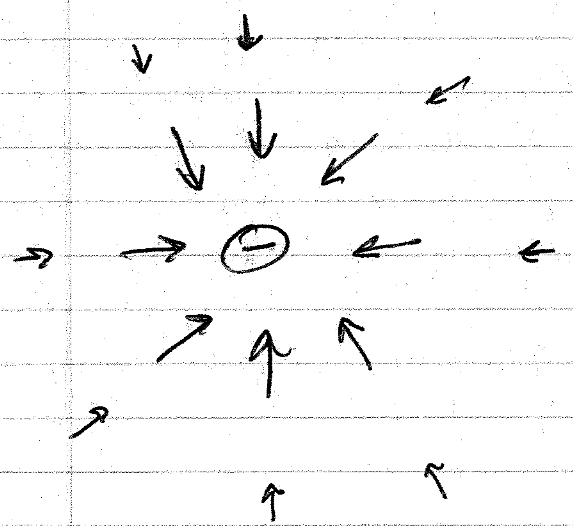
$$\vec{F}_{12} = \frac{-k \cdot q_1 q_2}{r^2} \vec{r}_{12}$$



we can think of a charge exerting a force on the space around it. capture this w/ notion of electric field

Suppose that a negatively charged particle is placed at the origin:

Then we imagine if we were to place a positively charged test particle at some distance from the particle. At any point, the test particle would be attracted to ⊖.

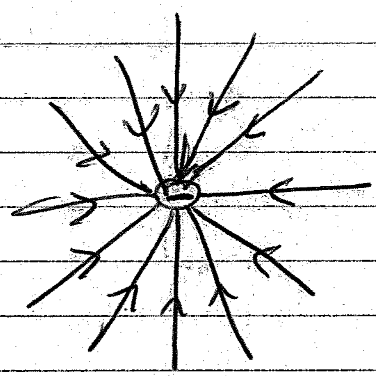


electric field defined as

$$\vec{E}(\vec{r}) = \frac{k \cdot q}{r^2}\vec{r}_u$$

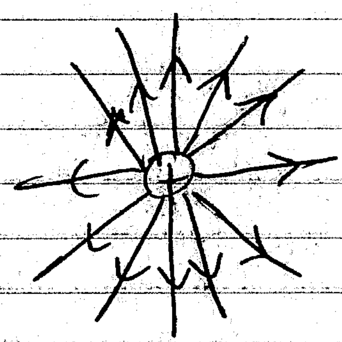
N/C (units)

If q is negative, lines go inward. If q is positive, lines outward can draw electric field lines as



- arrows indicate direction
- density of lines indicates strength

for a positive charge



exerts a repulsive force on positive test charges in space around it.

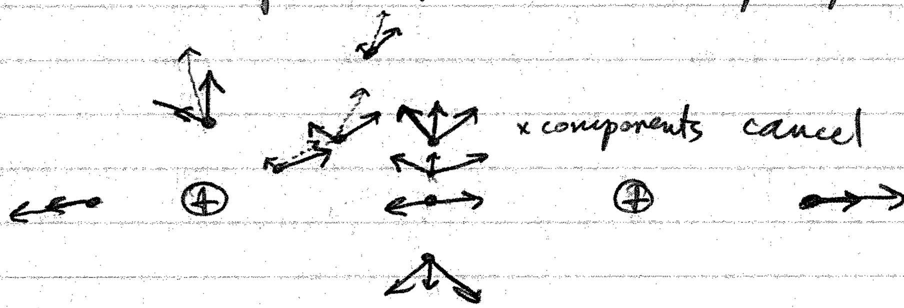
So convention

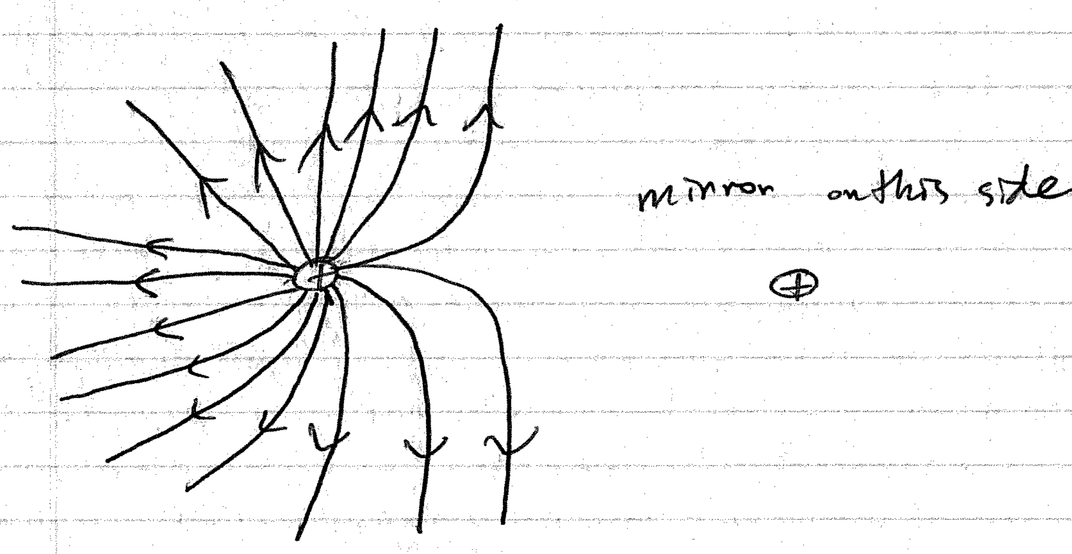
$$\vec{E}(\vec{r}) = \frac{kq}{r^2}\,\vec{r}_u$$ is consistent

field lines always start at positive charges (sources) and end at negative charges (sinks)

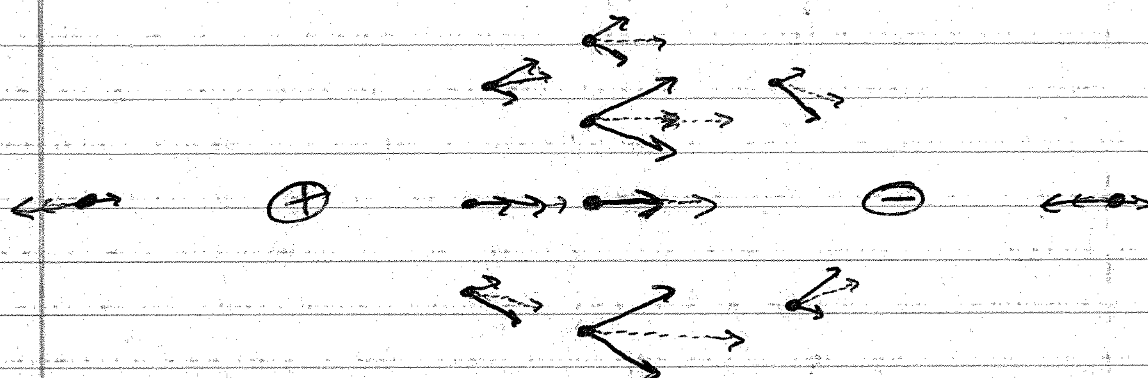
Question: How to figure out electric field lines for two positive charges near each other?

use principle of superposition

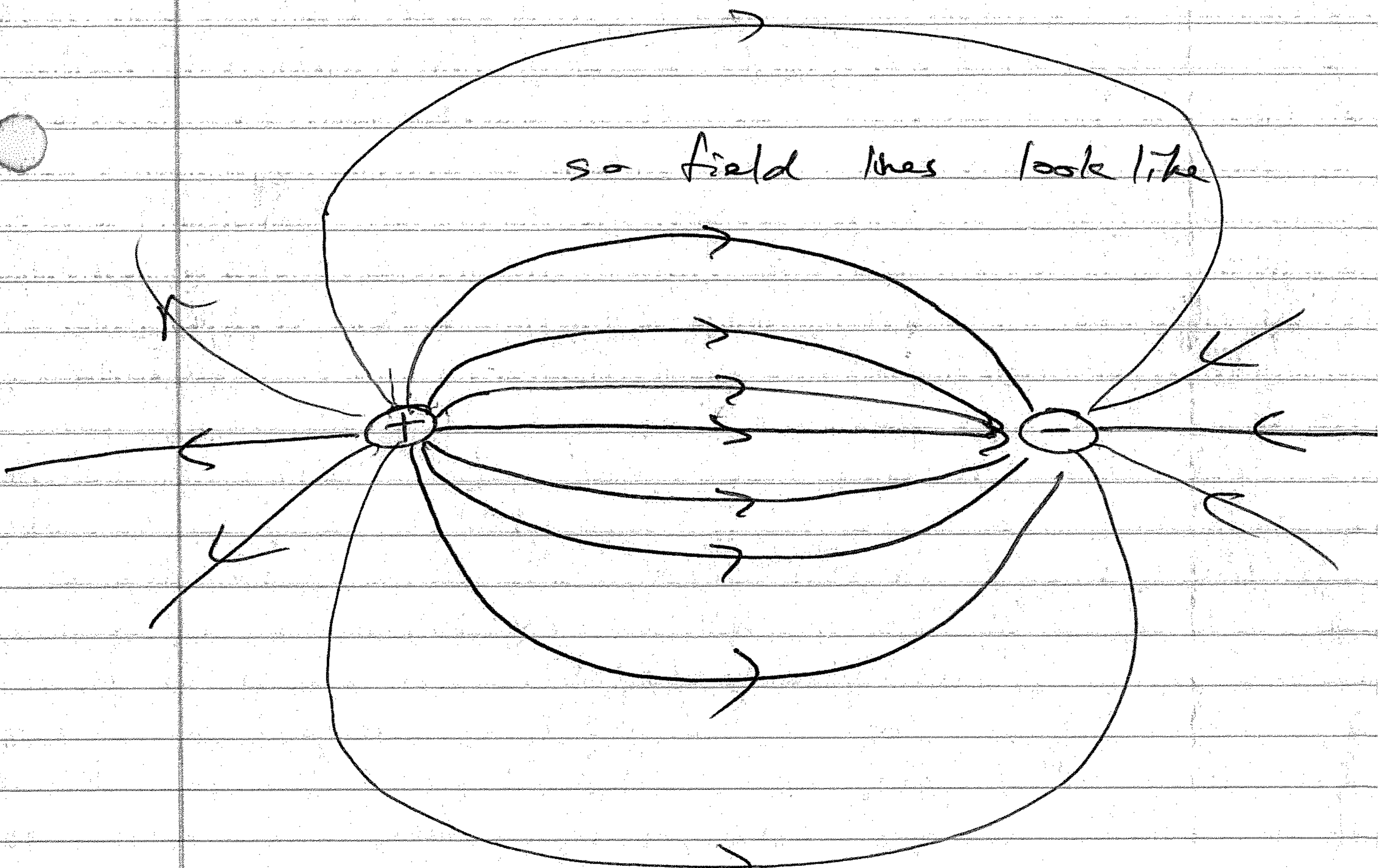




what about positive + negative charges ?



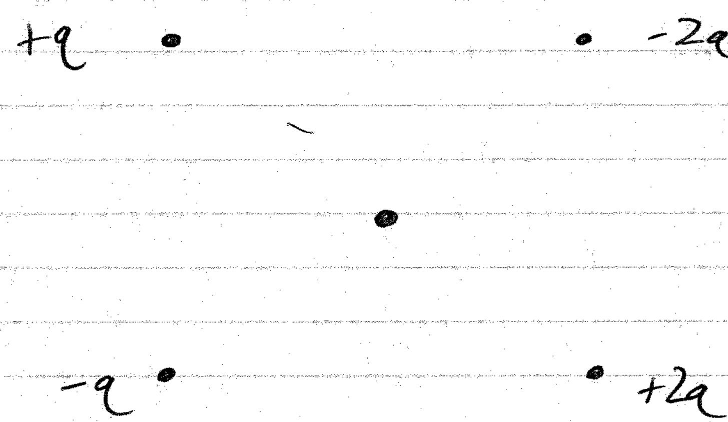
so field lines look like



configuration is called electric dipole

QUESTION:

Suppose we have a square w/ charges on corners

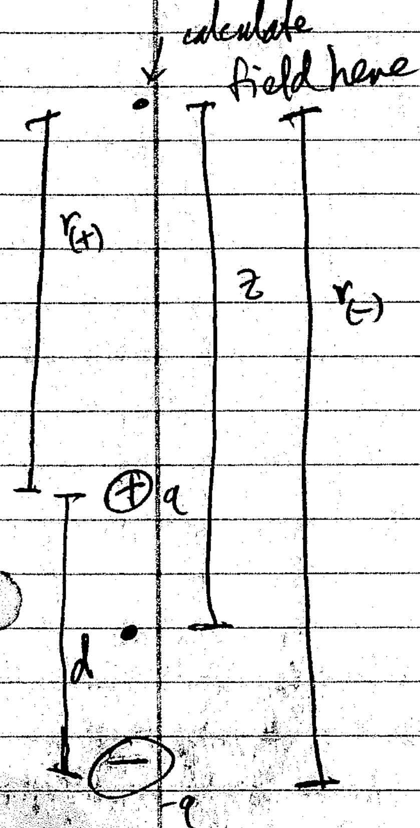


What is net direction of the field at the center of square?

up (use superposition principle)

Question: Does field cancel along axis of the dipole?

Electric Field due to an electric dipole



use principle of superposition

$$E = E_{(+)} - E_{(-)}$$

$$= \frac{kq}{r_{(+)}^2} - \frac{kq}{r_{(-)}^2}$$

$$= kq\left[\frac{1}{r_{(+)}^2} - \frac{1}{r_{(-)}^2}\right]$$

$$= kq\left[\frac{1}{\left(z-\frac{d}{2}\right)^2} - \frac{1}{\left(z+\frac{d}{2}\right)^2}\right]$$

$$= \frac{kq}{z^2}\left[\frac{1}{\left(1-\frac{d}{2z}\right)^2} - \frac{1}{\left(1+\frac{d}{2z}\right)^2}\right]$$

w/ some algebra, can show

$$= \frac{kq}{z^3}\left[\frac{d}{\left[1-\left(\frac{d}{2z}\right)^2\right]^2}\right]$$

When $z \gg d$, this becomes

$$\approx \frac{kqd}{z^3}$$

So electric field goes as $\frac{1}{r^3}$ for distant points away from a dipole

so the field does not cancel due to opposite charges but it is significantly weaker than $\frac{1}{r^2}$