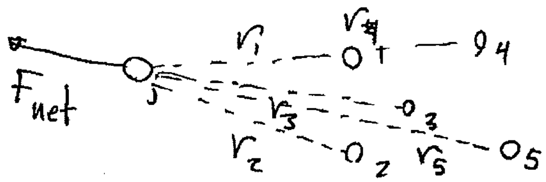
Setlist L4 (90 minutes)

Introduction to electrostatics.
Prep: Charges and Fields PhET. Electric field worksheet

1. The electric field - the field is a physical thing that can appear independent of charge. It's not just a trick.
2. Definition of the electric field. Charges and Fields PhET.
3. Superposition of Electric Fields.
4. Worksheet - an important aspect of this is the derivation of the electric field of the dipole
5. The dipole is an example of electric field Configuration. Talk about continuous field configurations.
6. Clicker Question: Direction of a field from infinite plane - C
7. Clicker Question: Strength of a field from an infinite plane - C
8. Discussion of how if the system doesn't change, the physics can't change (symmetry arguments)
9. Show them the standard field configurations. Point out that the plane depend on nothing, the line depends on $1/r$, and the sphere depends on $1/r^2$. This is not a coincidence.
10. Clicker Question: Unevenly charged plates. Starts with activity - C
11. Electric Field of a capacitor.

The Electric Field

Last class: Superposition of forces



$$\vec{F}_{net\,on\,j} = \sum_i \vec{F}_{i\,on\,j}$$

$$= \sum_i \frac{k q_j q_i}{r_i^2} \hat{r}_i$$

The force on the charge depends more on the configuration rather than the charge itself.

$$\vec{F}_{net\,on\,j} = q_j \sum_i \frac{k q_i}{r_i^2} \hat{r}_i$$

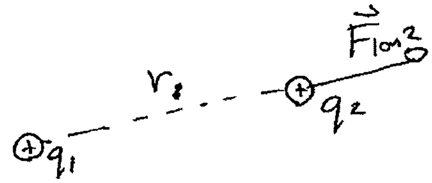
$$= q_j \vec{E}(at\ j)$$

We have the electric field,

$$\vec{E}(at\ j) = \frac{\vec{F}_{net\,on\,j}}{q_j}$$

It's a quality of the configuration of charges, rather than and interaction between two charges.

Example: $\vec{E}$ of a point charge.



$$|\vec{E}(at\ q_2)| = \frac{|\vec{F}_{1\,on\,2}|}{q_2} = \frac{k q_1 q_2}{r^2}\frac{1}{q_2} = \frac{k q_1}{r^2}$$ ← depends just on q_1!

The direction of the electric field is the same as the force if q_2 is positive. q_2 is called a test charge.

The dipole: The configuration of a positive charge next to a negative charge makes a dipole. This is one of the most important electric field configuration.

The electric field at point p is

$$E = kq\left[\frac{1}{(x-s/2)^2} - \frac{1}{(x+\frac{s}{2})^2}\right]$$

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

$$= kq \frac{(x^2 + sx + \frac{s^2}{4}) - (x^2 - sx + \frac{s^2}{4})}{(x-\frac{s}{2})^2(x+\frac{s}{2})^2}$$

$$= kq \frac{2sx}{(x-\frac{s}{2})^2(x+\frac{s}{2})^2} \qquad (x-\tfrac{s}{2})^2 \sim x^2 \quad (x+\tfrac{s}{2})^2 \sim x^2$$

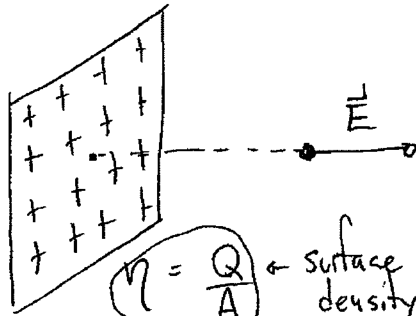
$$= kq \frac{2sx}{x^4}$$

$$= kq \frac{s}{x^3}$$ ← cubed dependance appears!

The field points in the positive x direction, which is what we want because the ⊕ is closer to p.

Forces and ~~Potential Energy~~

Clicker question: direction of a field from an infinite plane:

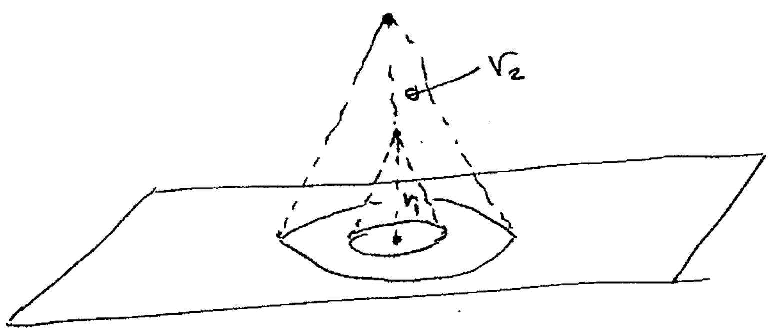


$\eta = \frac{Q}{A}$ ← surface charge density

All the vector's ~~horizontal~~ parallel components cancel out, so we're left with the perpendicular component.

How does $\vec{E}$ change with distance?

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



The strength falls off as $\frac{1}{r^2}$ but the amount of charge increases by r^2.

The electric field as a function of r is

$$E(r) = \frac{\text{const}\cdot r^2}{r^2} = \text{const}.$$

What we've created is a uniform electric field.
The value of the field is

$$E = \frac{\eta}{2\epsilon_0} \quad , \quad \epsilon_0 = \frac{1}{4\pi k}$$

There are no infinite planes in reality, but they're well approximated in many situations.
A capacitor does a good job. [Show capacitor slide. explain what a capacitor is.]