Physics 202, Lecture 2

Today's Topics

- Electric Fields
  - Determining the Electric Field of given charge distribution (discrete and continuous)
  - Electric Field Lines
  - Motion of Charged Particles in External Electric Fields

Coulomb's Law: Vector Form

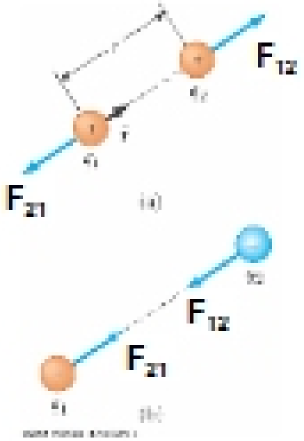
2 charges: force on q_2 by q_1

$$\vec{F}_{12} = k\frac{q_1 q_2}{r^2}\hat{r}_{12} = -\vec{F}_{21}$$

>2 charges: force on charge i

$$\vec{F}_i = \vec{F}_{1i} + \vec{F}_{2i} + \vec{F}_{3i} + \ldots$$

principle of linear superposition



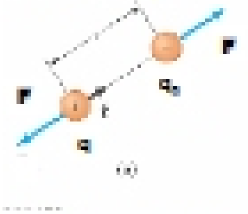
The Electric Field

Original (Coulomb's) view:

q applies electric force on q_0 (action at a distance)

$$\vec{F} = k\frac{q_0 q}{r^2}\hat{r}$$

Force on charge always proportional to strength of that charge!



"Modern" view:

q is source of electric field E, (units: N/C) which fills all of space. Interaction with E leads to a force on q_0

$$\vec{F} = q_0 \boxed{k\frac{q}{r^2}\hat{r}} = q_0\vec{E}$$

q: source charge
E independent of q_0!

(q_0 often called the "test charge": take the limit as $q_0 \to 0$)

Aside: Vector and Scalar Fields

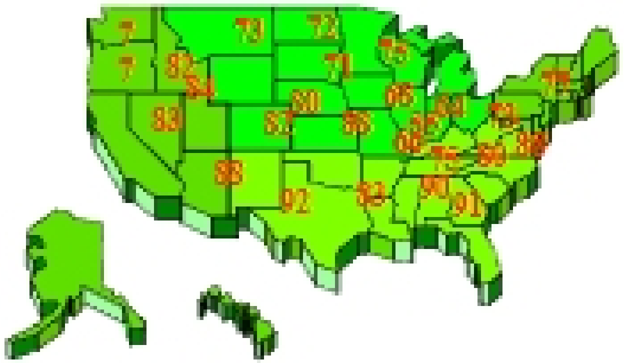
Concept of the electric field (and the magnetic field) is the most useful way to describe the physics of electromagnetism.

What is a field?

A physical quantity which has a value at each point in space (for example: temperature, wind speed,...)

Here we will consider only scalar fields (e.g., temperature, electric potential,...) and vector fields (e.g., windspeed, electric fields,...)

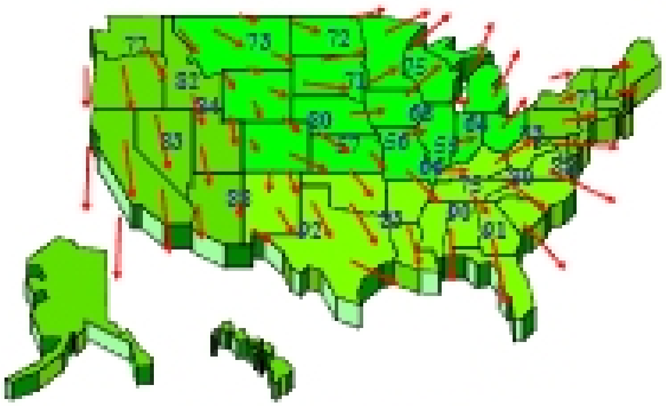
A Scalar Field



These isolated temperatures sample the scalar field
(you only learn the temperature at the point you choose,
but **T** is defined everywhere (x, y)

A Vector Field

Example: the way the wind is blowing...



This is a vector field
(specify both wind speed and direction)

Calculating the Electric Field for a Given Charge Distribution

E field of point charge q:

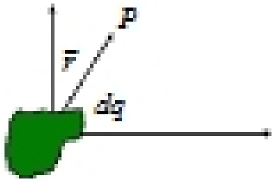
$$\vec{E} = k\frac{q}{r^2}\hat{r}$$

Multiple point charge sources

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

Continuous distributions:

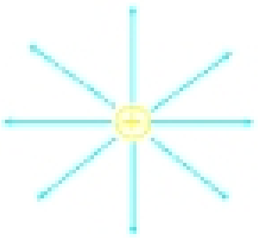
$$d\vec{E} = k\frac{dq}{r^2}\hat{r} \qquad \vec{E} = \int d\vec{E}$$



Visualizing the Electric Field: Field Lines

Visualize the electric field of a positive point charge:

Field lines



Rules for Field Lines:

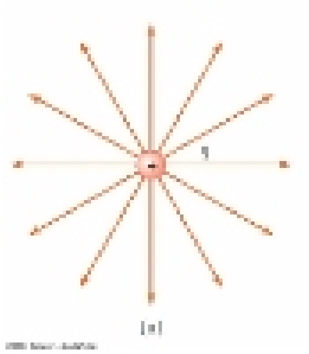
Field lines start or end only on charges (never empty space). They start on positive and end on negative charges.

Field lines of point charges extend to infinity (true for any localized distribution with nonzero net charge).

Field lines can never cross.

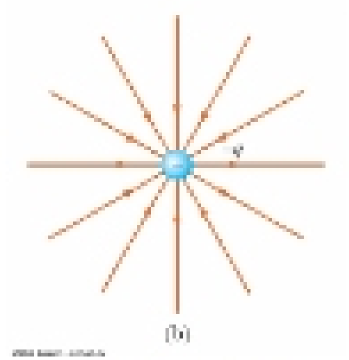
Magnitude: local density of lines
Direction: direction of arrows

Example: Point-Like Charges



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

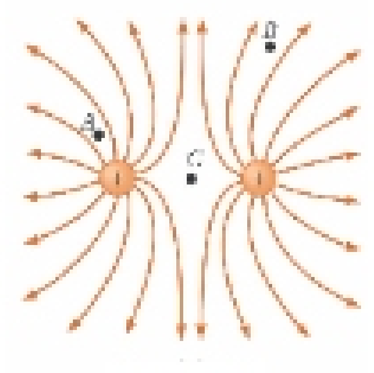
+q



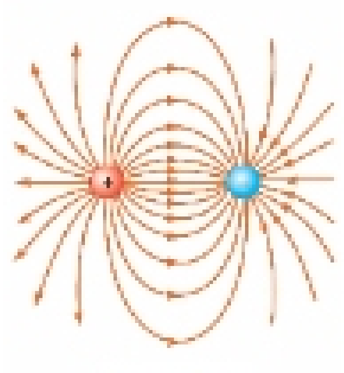
$$\vec{E}(\vec{r}) = k\frac{q}{r^2}\hat{r}$$

-q

Examples: Two Charged Particles



+q and +q



+q and -q
(dipole)

Motion Of Charged Particle In Uniform Electric Field

Fundamental Formulas:

- **F**=q**E**, a=**F**/m = q**E**/m
  (always true)
- v= v_i +at
  (true only for uniform E field)

If a particle is in
a uniform E field,
and is initially at rest (v_i =0)
then v= at = (q**E**/m) t

Motion of +q:
Same dir. as **E**

Motion of - q:
Opposite dir. as **E**

Exercise: An Electron in a Uniform E. Field

Find out vertical displacement after the electron passes through a downward uniform electric field **E**

Answer: y= - ½ (e/m)E $(l/v_i)^2$