Physics 202, Lecture 2

Today’s Topics

- **Electric Fields** (Ch 21.6-21.11)
  - Determining the Electric Field of given charge distribution (discrete and continuous)
  - Electric Field Lines
  - Motion of Charged Particles in External Electric Fields

- Announcements:
  - No honors lecture tomorrow

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**Coulomb’s Law: Vector Form**

2 charges: force on $q_2$ by $q_1$

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

Multiple charges: force on charge $i$

$$\vec{F}_i = \sum_j \vec{F}_{ij} = \sum_i k \frac{q_i q_j}{r_{ij}^2} \hat{r}_{ij}$$

principle of linear superposition

Examples (board): 21.18, 21.20
The Electric Field

Original (Coulomb’s) view:
q applies electric force on \( q_0 \) (action at a distance)
\[
\vec{F} = k \frac{q q_0}{r^2} \hat{r}
\]
Force on charge always proportional to strength of that charge!

“Modern” view:
q is source of electric field \( \mathbf{E} \), which fills all of space.
Interaction with the field leads to a force on \( q_0 \)
\[
\vec{F} = q_0 k \frac{q}{r^2} \hat{r} = q_0 \mathbf{E}
\]
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,...)
These isolated temperatures sample the scalar field (you only learn the temperature at the point you choose, but $T$ is defined everywhere $(x, y)$)

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:

\[ d\vec{E} = k \frac{dq}{r} \hat{r} \quad \vec{E} = \int d\vec{E} \]

Examples: 21.41, 21.40 (ring), line charge, disk

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

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

\( +q \)

\( -q \)

Examples: Two Charged Particles

\( +q \) and \( +q \)

\( +q \) and \( -q \) (dipole)
Two Charged Particles

Fundamental Formulas:

- \( \mathbf{F} = q \mathbf{E} \)
- \( \mathbf{a} = \mathbf{E}/m = q \mathbf{E}/m \)
- \( \mathbf{v} = \mathbf{v}_i + \mathbf{a} t \)

If initially at rest (\( \mathbf{v}_i = 0 \)) then

\[ \mathbf{v} = \mathbf{a} t = \left( \frac{q \mathbf{E}}{m} \right) t \]

Motion of +q:
Same dir. as \( \mathbf{E} \)

Motion of -q:
Opposite dir. as \( \mathbf{E} \)

Examples: 21.56, 2d example (next slide)
Exercise: An Electron in a Uniform E. Field

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

Answer: $y = -\frac{1}{2} \frac{(e/m)}{(l/v_i)^2} E$