Physics 208, Lecture 6

Today’s Topics

- Capacitance (Ch. 26.1-3)
- Capacitors and Capacitance
- Calculating Capacitance for parallel-plate, cylindrical, spherical capacitors.
- Combinations of capacitors
- Hope you have previewed!

About Exam 1

- When and where
  - Tuesday Oct. 2nd 5:30-7:00 pm
  - (room to be announced)
- Format
  - Closed book
  - One 8x11 formula sheet allowed, must be self prepared, no photo copying/download-printing of solutions, lecture slides, etc.
  - 20 multiple choice questions
  - Bring a calculator (but no computer). Only basic calculation functionality can be used.
  - Bring a B2 pencil for Scantron.
- Special requests:
  - Have to be approved. Deadline is 12pm tomorrow (Sep 21st).
  - All specially arranged tests (e.g. those at alternative time) are held in our 202 labs. (for approved requests only)

Chapters Covered

- Chapter 23: Electric Fields
- Chapter 24: Gauss’ Law
- Chapter 25: Electric Potential
- Chapter 26: Capacitance

I will not endorse past/sample exams as they are usually not representative. Often those can be misleading.

I will use next Thursday’s lecture to review for the test. (and will show a few sample test questions to help you get familiar with the test style)

Review: Electric Potential Difference

- Electric Potential Energy: q In a Generic E. Field
  \[ \Delta U = U_B - U_A = -q \int_A^B \vec{E} \cdot d\vec{s} = q \Delta V \]

- Electric Potential Difference
  \[ \Delta V = \frac{\Delta U}{q} = -\int_A^B \vec{E} \cdot d\vec{s} = V_B - V_A \]
Exercise: Parallel Plates

- Find the potential difference between the two large conductor plates of area $A$ and separation $d$.

  - Answer
  $\Delta V = \frac{Qd}{\varepsilon_0 A}$

  - Note: $\Delta V$ is proportional to $Q$

  - Realistic case

Understand a Battery (I)

- What is a 1.5V battery?

  - Chemical process maintains a charge distribution, such that $V_+ - V_- = 1.5V$, regardless of shape.
  - Electric energy is stored in the E field.

Understand a Battery (II)

- In-use

  - Electron flow from negative side to positive side.
  - In the process, the 1.5V potential Diff. is maintained.
  - Kinetic energy acquired by each electron 1.5 eV.
  - This energy is converted into heat, light etc.
  - Chemical energy $\rightarrow$ electric potential energy $\rightarrow$ load

Capacitors

- A generic capacitor:
  - $\Delta V \propto Q$

  - Unlike battery, capacitors are passive devices.
  - Capacitor are very useful devices:
    - Timing control, noise filters, energy buffer, frequency generator/selector/filter, sensors, memories...
Demo: Charging A Pair of Parallel Conductors

Uncharged

Charging

\[ \Delta V = V_1 - V_2 \]

Capacitance

- \( \Delta V = Q \Rightarrow Q = C \Delta V \Rightarrow C \) is called capacitance
- \( C = Q / \Delta V \): amount of charge per unit of potential difference
- Unit: Farad (F) = 1 Coulomb/Volt
- Parallel-plate: \( C = \varepsilon_0 \frac{A}{d} \)
- Cylindrical and Spherical: see examples in text
  - Cylindrical:
    \[ C = \frac{\varepsilon_0 l}{\ln(b/a)} \]
  - Spherical:
    \[ C = \frac{\varepsilon_0 a b}{k} \]

Combinations of Capacitors In Series

Charge conservation: \( Q_1 = Q_2 = Q \)

Effective Capacitance

\[ C = \frac{Q}{\Delta V} \Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \]

\[ \frac{1}{C_{\text{series}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots \]
Note: \( C_{\text{series}} \) always < \( C_i \)

Combinations of Capacitors In Parallel

\[ \Delta V_1 = \Delta V_2 = \Delta V \]

Effective Capacitance

\[ C = \frac{Q}{\Delta V} \Rightarrow C = \frac{C_1 + C_2}{2} \]

\[ C_{\text{parallel}} = C_1 + C_2 + C_3 + \ldots \]
Note: \( C_{\text{parallel}} \) always > \( C_i \)
Quick Quiz/exercise: Combination of Capacitors

- What is the effective capacitance for this combination? 
  \((C_1=1\mu F, C_2=2\mu F, C_3=3\mu F)\)
  1. \(C=6\mu F\)
  2. \(C=3\mu F\)
  3. \(C=1.5\mu F\)
  4. None of above

Charging A Capacitor

Two things happen while charging:
- Positive work done to system
- \(\Delta V\) increasing

After charging the capacitor stores potential energy: 
\(U=\frac{1}{2}Q^2/C\)

Discharging A Capacitor

Two things happen while discharging:
- Electric field does positive work
- \(\Delta V\) decreasing

The originally charged capacitor has potential energy: 
\(U=\frac{1}{2}Q^2/C\)