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**
  - Monday Feb. 14th 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.
  - 20-25 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 (Feb 4th.)
  - 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’s Law
- Chapter 25: Electric Potential
- Chapter 26: Capacitance

I will not post past/sample exams as none that I can find are 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)
Exercise: Parallel Plates

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

See board

Answer

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

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

- A generic capacitor:
  - Two conductors oppositely charged:
    - $\Delta V \propto Q$

- Capacitors are very useful devices:
  - Timing control, noise filters, energy buffer, frequency generator/selector/filter, sensors, memories...
Capacitance

- $\Delta V \propto Q \rightarrow Q = C \Delta V \rightarrow C$ is called capacitance
- $C = Q/\Delta V$: amount of charge per unit of potential diff.
  - Unit: Farad (F) = 1 Coulomb/Volt
  - Parallel-plate: $C = \varepsilon_0 A/d$
  - Cylindrical and Spherical: see examples in text

- **Cylindrical:**
  \[
  C = \frac{\ell}{2 k_e \ln \left( \frac{b}{a} \right)}
  \]

- **Spherical:**
  \[
  C = \frac{ab}{k_e (b - a)}
  \]
Demo: Charging A Pair of Parallel Conductors

Uncharged

Charging

$\Delta V = V_+ - V_-$
Charging A Capacitor

Uncharged

Charging

Charged

\[ \Delta V = \frac{q}{C} \]

\[ -dq \]

\[ \Delta V = \frac{Q}{C} \]

Electric potential energy gained:

\[ U = \int du = \int (-\Delta V)(-dq) = \int_0^Q \frac{q}{C} dq = \frac{1}{2} \frac{Q^2}{C} \]

After charging the capacitor stores potential energy:

\[ U = \frac{1}{2} \frac{Q^2}{C} \]
Discharging A Capacitor

\[ \Delta V = \frac{Q}{C} \]

\[ \Delta V = \frac{q}{C} \]

\[ du = \Delta V dq \]

Potential energy released:

\[ U = \int dU = \int \Delta V (-dq) = \int_{Q}^{0} -\frac{q}{C} dq = \frac{1}{2} \frac{Q^2}{C} \]

the originally charged capacitor has potential energy:

\[ U = \frac{1}{2} \frac{Q^2}{C} \]
Combinations of Capacitors In Series

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

\[ C_1 \Delta V_1 = Q \]
\[ C_2 \Delta V_2 = Q \]

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

\( 1/C_{\text{series}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots \)

Note: \( C_{\text{series}} \) always < \( C_i \)
Combinations of Capacitors In Parallel

\[ C_1 \Delta V_1 = Q_1 \]
\[ C_2 \Delta V_2 = Q_2 \]

\[ \Delta V_1 = \Delta V_2 = \Delta V \]  (why?)

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

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

What is the effective capacitance for this combination? (C₁=1µF, C₂=2µF, C₃=3µF)

1. C=6µF
2. C=3µF
3. C=1.5µF
4. None of above