Physics 202, Lecture 29

Today’s Topics

- Review for Final Exam (I)
Chapters Covered (I)

- Chapter 23: Electric Fields
- Chapter 24: Gauss’s Law
- Chapter 25: Electric Potential
- Chapter 26: Capacitance
- Chapter 27: Electric Currents
- Chapter 28: DC Circuit
- Chapter 29: Magnetism
- Chapter 30: Source of Magnetic Field

Disclaimer
- This review is a supplement to your own preparation.
- Hints and exercises presented in this review are not meant to be complete.
Exam Topics (I)

- Key concepts
  (“key”: those in summary box at the end of each chapter)

- Basic Quantities:
  - Electric Charge
  - Electric Force
  - Electric Field, Field Lines
  - Electric Flux
  - Electric Potential
  - Electric Potential Energy
  - Capacitance
  - Energy carried by electric field
Exam Topics (I) (cont)

- Electric charge
  - Two types
  - Total charge is conserved.

- Electric force
  - Can be attractive/repulsive
  - Coulomb’s Law

- Electric field
  - Electric field is a form of matter, it carries energy.
  - Electric field is independent of test charge.
  - Electric field is a vector quantity.
  - Three ways to calculate electric field
    - direct vector sum, Gauss’s Law, derivative of $V$
  - $F = qE$ (note: $E$ does not include the one created by $q$)
Exam Topics (I) (cont)

- Electric potential energy.
  - Electric force is a conservative force
  - Electric potential energy depends on both the source and test charge.
  - Like all potential energies, the electric potential energy is relative to a certain reference state. (Usually, an “infinity” state is taken as $U=0$.)
  - Energy conservation, work-kinetic energy theorem, etc. are applicable to electric potential energy too.

- Electric potential
  - Electric potential depends only on the source.
  - Electric Potential and Electric Field are closely related. ($\mathbf{E} \leftrightarrow V$)
  - Electric potential ($V$) and electric potential energy ($U$) are different quantities.
    - higher $V$ does not necessarily mean higher $U$.
  - Electric potential and Electric potential energy are related: $U=qV$
Exam Topics (I) (cont)

- Conductors and Electrostatic Equilibrium
  - Regardless of shape:
    - The electric field is zero inside the conductor.
    - All net charges reside on the surface of the conductor.
    - E field on the surface of the conductor is always normal to the surface, and has a magnitude of $\sigma/\varepsilon_0$.
    - The electric field is also zero inside an empty cavity within the conductor.
    - Potential is the same throughout the whole conductor (Equipotential).

- Capacitance
  - $C = Q/\Delta V$
  - Connection in parallel and in series.
  - Energy stored in capacitor.
  - Dielectrics enhance the capacitance by a factor of $\kappa$. 
Exam Topics (I) (cont)

- **Key concepts**
  ("key": those in summary box at the end of each chapter)

- **Basic Quantities:**
  - Electrical Current (I), Voltage (ΔV)
  - Resistance (R), resistivity (ρ)
  - Power Consumed by R
  - emf
  - Time Constant, RC
  - Magnetic Force
  - Magnetic Field, Magnetic Field Lines, Magnetic Flux
  - Magnetic Dipole Moment.
    - (Definition, force, torque, potential energy)
  - Permeability/susceptibility for ferro/para/dia magnetic materials.
Exam Topics (I) (cont)

- **Current and resistance.**
  - \( I = \frac{\Delta Q}{\Delta t} \)
  - Ohm’s Law \( \Delta V = IR \) for Ohmic materials
  - Resistors in series and parallel
  - Power consumption on R

- **DC circuit**
  - Kirchhoff’s Rules
    - Junction rule
    - Loop rule
  - Simple 1-loop, 2-loop circuit of R’s and ε’s

- **Time constant and RC circuit**
Exam Topics (I) (cont)

- Magnetic Force
  - Magnetic force has a form of $q\mathbf{v} \times \mathbf{B}$.
    - always perpendicular to $\mathbf{v}$ and $\mathbf{B}$.
    - never does work
    - charged particle moves in circular/helix path in uniform \( B \) field \( (\omega=qB/m, \quad r=mv/qB) \)
    - On current segment, it has the form $ILxB$
      - Uniform B, closed loop $\rightarrow \Sigma F=0, \Sigma T=\mu x B$

- Magnetic Field:
  - Field lines, “north” and “south”.
  - B field never does work.
Exam Topics (I) (cont)

- Magnetic Fields can be produced by:
  - moving charge (Biot-Savart law)
  - change of \(E\) field
    (displacement current, not in this exam.)

- Ampere’s Law
  - Ampere’s law simplifies the calculation of B field in some symmetric cases.
    - (infinite) straight line, (infinite) current sheet, Solenoid, Toroid

- Gauss’s Law in Magnetism → no magnetic charge.

- Forces between two currents
  - Can be attractive/repulsive
  - No force if perpendicular
Reminder: Three Ways to Calculate Electrostatic Field

- Superposition with Coulomb's Law (first principle):
  \[ \vec{E} = k_e \sum \frac{q_i}{r_i^2} \hat{r}_i = k_e \int \frac{dq}{r^2} \hat{r} \]

- Apply Gauss’s Law:
  (Practical only for cases with high symmetry)
  \[ \Phi_E = \oint \vec{E} \cdot d\vec{A} = \sum \frac{q_{in}}{\varepsilon_0} \]

- From a known potential:
  \[ E_x = -\frac{\partial V}{\partial x}, \quad E_y = -\frac{\partial V}{\partial y}, \quad E_z = -\frac{\partial V}{\partial z} \]
Quick Exercise : Charge Distribution On Conductors

The total charge on this conductor shell is +5q. A point charge of +q is placed at the center (r=0). How is the charge distributed? (shell radius: \( r_{\text{inner}} = \text{R} \), \( r_{\text{outer}} = 2\text{R} \))

- \( Q_{\text{Inner_surface}} = -q \), \( Q_{\text{Outer_surface}} = 6q \), \( Q_{\text{body}} = 0 \)
- \( Q_{\text{Inner_surface}} = q \), \( Q_{\text{Outer_surface}} = 4q \), \( Q_{\text{body}} = 0 \)
- \( Q_{\text{Inner_surface}} = 0 \), \( Q_{\text{Outer_surface}} = 5q \), \( Q_{\text{body}} = 0 \)

Challenge to you
Are you able to calculate \( E \) and \( V \) at \( r=0.5\text{R}, 1.5\text{R}, 2.5\text{R} \)?
(discuss with your TAs if in puzzle)
Current $I = \frac{\Delta Q}{\Delta t}$ through a cross-section.

Resistance: $R = \rho \frac{\ell}{A}$

Ohms Law: $\Delta V = RI$

General Electric Power: $P = I \Delta V$

Ohmic Electric Power: $P = I^2R = \frac{\Delta V^2}{R}$

$R_1, R_2$ in series:
- $I_1 = I_2$, $\Delta V_1 + \Delta V_2 = \Delta V \rightarrow R = R_1 + R_2$

$R_1, R_2$ in parallel:
- $I = I_1 + I_2$, $\Delta V_1 = \Delta V_2 = \Delta V \rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$
Reminder: Capacitors

- Capacitance: \( C = \frac{Q}{V} \)  \((Q=CV)\)
- Two capacitors in series:
  \( Q = Q_1 = Q_2, \ V = V_1 + V_2 \rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \)

- Two capacitors in parallel:
  \( V = V_1 = V_2, \ Q = Q_1 + Q_2 \rightarrow C = C_1 + C_2 \)

- Energy storage: \( U = \frac{1}{2} CV^2 \)

- Dielectrics: \( C = \kappa C_0 \)
Reminder: Procedure to Use Kirchoff Rules

1. Assign a directional current for each branch (segment) of a circuit. The assigned direction for each current can be arbitrarily chosen but, once assigned, need to be observed.

2. Set up junction rules (for as many junctions as necessary):
   \[ \sum I_{\text{in}} = \sum I_{\text{out}} \]

3. Set up loop rules (as many as necessary): \[ \sum \Delta V = 0 \]

4. Solve for unknowns.

5. If a current is found to be negative, it means its actual direction is opposite to the originally chosen one. The magnitude is always correct.
Determine Potential Difference
Put this on your formula sheet (no photo copy!)
Reminder: All Those Right-Hand Rules

\[ \mathbf{F}_B = q \mathbf{v} \times \mathbf{B} \]
Reminder:
Two Ways to Calculate Magnetic Field

- **Biot-Savart Law (first principle):**
  \[
  \vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{\hat{r} \times ds}{r^2}
  \]

- **Ampere’s Law:**
  (Practical only for settings that are highly symmetric)
  
  \[
  \oint \vec{B} \cdot ds = \mu_0 I
  \]
  (any closed path)
Reminder: 
Forces on Charges and Current

- On charged particle: \( F = qE + qv \times B \)

- On current segment: \( F = IL \times B \)

- Current inside uniform B field \( F = IL' \times B \)
Exercise: Biot-Savart Law

Use Biot-Savart to find the magnetic field at the point P.

Solutions: (See board)

Answer:

segment 1 contribution:

\[ \vec{B} = 0 \]

segment 3 contribution: \( \vec{B} = 0 \)

segment 2: \[ \vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{ds \times \hat{r}}{r^2} = \frac{\mu_0 I}{8R} \]