Physics 202 Exam 2 Review

About Exam 2

- **When and where**
  - Tuesday October 30th 5:30-7:00 pm
  - Same room allocation as in Midterm 1

- **Format**
  - Closed book
  - One 8x11 formula sheet allowed, must be self prepared, no photo copying/download-printing of solutions, lecture slides, etc.
  - Read my emails on formula sheet and exam room policy
  - 20 multiple choice questions
  - Bring a calculator (but no computer). Refer to my earlier email about policy on electronic devices.
  - Bring a B2 pencil for Scantron.

- **Special requests:**
  - Should have been settled by now
  - All specially arranged tests (e.g. those at alternative time) are held in our 202 labs. (for approved requests only)

Chapters Covered

- Chapter 27: Current and Resistance
- Chapter 28: DC Circuit
- Chapter 29: Magnetic Field
- Chapter 30: Source of Magnetic Field

- I will not endorse past/sample exams.
- Review Session: Today. Slides will be posted after lecture.
- There is again a “Super Friday” (Tomorrow) for additional consultation

Exam Topics (1)

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

- **Basic Quantities:**
  - Electrical Current (I), Voltage (ΔV)
  - Power Consumed by R
  - emf
  - Time Constant, RC
  - Magnetic Force
  - Magnetic Field, Magnetic Field Lines, Magnetic Flux
  - Magnetic Dipole Moment.
  - Permeability/susceptibility for ferro/para/dia magnetic materials.
Exam Topics (2)

- 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 \( \xi \)’s

- Time constant and RC circuit (Yes, this will be covered!)

Exam Topics (3)

- Magnetic Force
  - Magnetic force has a form of \( qv \times B \).
    - always perpendicular to \( v \) and \( B \).
    - never does work
  - charged particle moves in circular/helix path in uniform \( B \) field \( (\omega = qB/m, r = mv/qB) \)
    - On current segment, it has the form \( I_{\perp} \times B \)

- Magnetic Field:
  - Field lines, “north” and “south”.
  - \( B \) field never does work.

- Magnetic Dipole Moments:
  \[ \sum F = 0 \]
  \[ \vec{I} = \mu \times B \]
  \[ U = -\mu \cdot \vec{B} \]

Reminder: Basic Current, Resistance, Power

- Current \( I = \frac{\Delta Q}{\Delta t} \) through a cross-section.
- Resistance: \( R = \rho \frac{r}{A} \)
- Ohm’s Law: \( \Delta V = IR \)
- General Electric Power: \( P = I \Delta V \)
- Ohmic Electric Power: \( P = I R = \Delta V R \)

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

- \( R_1, R_2 \) in parallel:
  - \( I = I_1 = I_2 \), \( \Delta V_1 = \Delta V_2 = \Delta V \rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \)
Exercise 1: Two Light Bulbs
- Light bulb A is rated at 12W when operated at 12V, light bulb B is rated at 3W when under 12V. Both bulbs are of resistive type (incandescent).
- What are their resistance $R_A$ and $R_B$?
  Answer: $R_A = 12\Omega$, $R_B = 48\Omega$

Assume the brightness of a bulb is proportional to its power consumption.
- When they are connected to a power source in parallel, which one is brighter?
  Answer: A brighter
- When they are connected to a power source in series, which is brighter?
  Answer: B brighter

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): $\Sigma I_{in} = \Sigma I_{out}$
3. Set up loop rules (as many as necessary): $\Sigma \Delta V = 0$
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.

Exercise 2: A Circuit with Three emf’s
- In the circuit shown, $R_1 = 1\Omega$, $R_2 = 2\Omega$, $\epsilon_1 = 3V$, $\epsilon_2 = 1V$, $\epsilon_3 = 2V$.
- Use Kirchoff’s rules to find the currents (magnitude and direction) passing resistor $R_1$ and $R_2$.

Solution (see board).
Answers: $I_1 = 1A$ to the left, $I_2 = 0.5A$ to the right

- What is the total power consumed in circuit?
  Trivial once you have current, do it after class yourself (hint, only resistors consume power.)
Reminder: Charging A Capacitor in RC Circuit

\[ q(t) = EC(1 - e^{-t/\tau}) \]

\[ I(t) = \frac{E}{R} e^{-t/\tau} \]

\( \tau = RC \) : time constant

Reminder: Time Constant When Discharging

\[ q(t) = Qe^{-t/\tau} \]

\[ I(t) = -\frac{Q}{RC} e^{-t/\tau} \]

\( \tau = RC \) : time constant

Exercise 3: Time Constant and RC

- \( R_1 = 10 \) KΩ, \( R_2 = 5 \) KΩ, \( C = 2.0 \) µF, \( \varepsilon = 10 \) V. Initially S is closed (and C is not charged.)
  - At \( t=0 \), S is open, when is C charged to 80% of full charge?

Solution:

after S is open \( \tau = RC = (R_1 + R_2)C = 3.0 \times 10^{-2} \) s

\[ Q = Q_{\text{full}}(1 - e^{-t/\tau}) \]

\[ t_{80\%} = \ln(0.2) \tau = 4.8 \times 10^{-2} \text{ s} \]

- What is the charge on C when fully charged?

Solution: when C is fully charged, no current through it.

\[ \Delta V_c = \varepsilon \]

\[ Q_{\text{full}} = C\Delta V_c = C\varepsilon = 2.0 \times 10^{-6} \text{ Coulomb} \]

Reminder: Forces on Charges and Current

- On charged particle:
  \[ F = qE + q \mathbf{v} \times \mathbf{B} \]

- On current segment:
  \[ F = IL \times \mathbf{B} \]

  ➢ Current inside uniform B field

\[ F = IL \times B \]

\[ \mathbf{B} \]

\[ \mathbf{B} \]

\[ \mathbf{B} \]

\[ \mathbf{B} \]

\[ \mathbf{B} \]
Exercise 4: Motion of Charged Particle In Uniform B Field

At t=0, an electron of velocity \( v = v_x \mathbf{i} + v_y \mathbf{j} \) enters a uniform B field \( \mathbf{B} \mathbf{k} \cdot (v_x, v_y > 0) \)

- What is the magnetic force on the electron at t=0?
- Convince yourself that the electron will go in a circular path once enters B.
- What is the radius \( r \)?
- On x-y plane, draw the path of the electron and indicate its direction in the circle.

Solution: See board.

\[
\mathbf{F} = -e \mathbf{v} \times \mathbf{B} = -e (v_x \mathbf{i} + v_y \mathbf{j}) \times \mathbf{B} \mathbf{k} = -eB (-v_x \mathbf{j} \times \mathbf{k} + v_y \mathbf{i} \times \mathbf{k}) = -eB (-v_x \mathbf{j} + v_y \mathbf{i})
\]

\[ r = \frac{mv}{eB}, \text{ what } v \text{ to use?} \]

\[ v = \sqrt{v_x^2 + v_y^2} \]

Exercise 5: Mass/Velocity Selector

The schematic of a mass selector is shown below.

For given \( E \) and \( B_1, B_2 \),

- What is the speed of a particle of charge \( q \) that can enter field \( B_2 \)? (in your HW 6)
- Once inside field \( B_2 \), the above particle moves in a semicircle of radius \( r \) as shown, what is the mass of the particle? and what is the sign of its charge?

Solution: While inside \( B_1 \) and \( E \):

\[ \mathbf{F} = q \mathbf{E} + q \mathbf{v} \times \mathbf{B} = 0 \rightarrow \mathbf{v} = E/B_1 \]

Once into \( B_2 \):

\[ m = \frac{qB_2 r}{v} = qB_1 B_2 r/E \]

\( q>0 \)

Exercise 6: Magnetic Force on Seven Sides of an Current Carrying Octagon

A wire carrying current \( I \) is placed in a uniform magnetic field \( \mathbf{B} \) as shown. The part of the wire inside the magnetic field occupies 7 sides of an octagon of side length “a”. Find the total magnetic force on the current carrying wire in the figure.

Solution (see board)

\[ \mathbf{F} = Ia \mathbf{B} \]

direction: up.

Reminder: All Those Right-Hand Rules
Trivial Exercise: Solenoid and Bar Magnet

- A current carrying solenoid is placed near a bar magnet as shown, are they attractive or repulsive to each other?

- Answer: Attractive
- Ask your TA for more imaginative exercises

Reminder:
Two Ways to Calculate Magnetic Field

- Biot-Savart Law (first principle):

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

- Ampere's Law:
(Practical only for settings that are highly symmetric)

\[
\oint \vec{B} \cdot ds = \mu_0 I
\]

Exercise 7: Biot-Savart Law

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

  Solutions: (See board)

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

Answer:
segment 1 contribution: B=0
segment 3 contribution: B=0
segment 2: \[\vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{ds \times \hat{r}}{R^2} = \frac{\mu_0 I}{8R}\]

Exercise 8: Ampere's Law

- An infinite straight thin wire is at the center of two concentric conducting cylinders of radius R and 2R.

The currents are I (into the page), 2I (out), and I (in), respectively for the center wire and the two cylinders. (as color coded).

Find B as function of r.

Solution:

\[\vec{B} = \frac{\mu_0 I_{enclosed}}{2\pi r} \]

Answers:
- r<R, \[B = \frac{\mu_0 I}{2\pi r}\] (Clockwise)
- R<r<2R, \[B = \frac{\mu_0 I}{2\pi r}\] (counter-clockwise)
- r>2R, B=0