Physics 202 Exam 2 Review

About Exam 2

- When and where
  - Wednesday March 21st 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.
  - 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 post past/sample exams as none that I can find are representative. Often those can be misleading.
- Review Session: Today. Slides will be posted after lecture.
- There is again a "Super Friday" (March 16th) 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)
  - 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(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 \( \varepsilon \)'s
- Time constant and RC circuit

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 \( I \mathbf{L} \times B \)
      - Uniform \( B \), closed loop \( \rightarrow \sum \mathbf{F} = 0, \sum \tau = \mu \times B \)
- Magnetic Field:
  - Field lines, “north” and “south”.
  - \( B \) field never does work.
- Magnetic Dipole Moments:
  \[ \sum \mathbf{F} = 0 \]
  \[ \tau = \mu \times B \]

Exam Topics(4)
- 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 \( \Rightarrow \) no magnetic charge.
- Forces between two currents:
  - Can be attractive/repulsive
  - No force if perpendicular

Reminder:
- Basic Current, Resistance, Power
- Current \( I = \frac{\Delta Q}{\Delta t} \) through a cross-section.
- Resistance: \( R = \rho \frac{\ell}{A} \)
- Ohm’s Law: \( \Delta V = IR \)
- General Electric Power: \( P = I \Delta V \)
- Ohmic Electric Power: \( P = I \Delta V = P \frac{\Delta V}{R} \)
- \( R_1, R_2 \) in series:
  - \( I = I_2 = \frac{\Delta V}{R_2} \Rightarrow R = R_1 + R_2 \)
- \( R_1, R_2 \) in parallel:
  - \( I = I_1 = \frac{\Delta V}{R_1} \Rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \)
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): $\sum I_{\text{in}} = \sum I_{\text{out}}$

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

4. Solve for unknowns.

Exercise 2: A Circuit with Three emf’s

- In the circuit shown, $R_1=1\,\Omega$, $R_2=2\,\Omega$, $\varepsilon_1=3\,V$, $\varepsilon_2=1\,V$, $\varepsilon_3=2\,V$.
  - Use Kirchoff’s rules to find the currents (magnitude and direction) passing resistor $R_1$ and $R_2$.

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

- \( q(t) = EC(1 - e^{-t/RC}) \)
- \( I(t) = \frac{E}{R} e^{-t/RC} \)

\( \tau = RC \): time constant

**Reminder:**

**Time Constant When Discharging**

- \( q(t) = Q e^{-t/RC} \)
- \( I(t) = -\frac{Q}{RC} e^{-t/RC} \)

- Again time constant \( \tau = RC \) \( \Rightarrow \) Everything determined by \( t/\tau \)

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**Exercise 3: Time Constant and RC**

- \( R_1 = 10 \text{ K } \Omega \), \( R_2 = 5 \text{ K } \Omega \), \( C = 2.0 \mu \text{F} \), \( \varepsilon = 10 \text{V} \). 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 \( \tau = RC = (R_1 + R_2)C = 3.0 \times 10^{-2} \text{s} \)
  
  \( Q = Q_{\text{full}}(1 - e^{-t/\tau}) \)
  
  \( t_{80\%} = \ln(0.2)/\tau = 4.8 \times 10^{-2} \text{s} \)

- What is the charge on \( C \) when fully charged?

  **Solution:** when \( C \) is fully charged, no current through it. \( \Delta V_c = \varepsilon \)
  
  \( Q_{\text{full}} = C \Delta V_c = C \varepsilon = 2.0 \times 10^{-6} \text{Coulomb} \)

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**Reminder:**

**Forces on Charges and Current**

- **On charged particle:**
  
  \( F = qE + q \times v \times B \)

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

- **Current inside uniform B field**
  
  \( F = IL' \times B \)
Exercise 4: Motion of Charged Particle In Uniform B Field

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

\[ F = eV \times B \]
\[ = -e (v_x i + v_y j) \times B \hat{k} \]
\[ = -eB (v_x i \times \hat{k} + v_y j \times \hat{k}) \]
\[ = -eB (-v_x j + v_y i) \]
\[ r = \frac{mv}{eB}, \text{ what } v \text{ to use?} \]
\[ v = \sqrt{v_x^2 + v_y^2} \]

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 \( B_2 \)?
- 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 \( E \):
\[ F = qE + qV \times B_1 = 0 \Rightarrow v = E/B_1 \]
Once into \( B_2 \):
\[ m = \frac{qB_2 r}{v} = qB_1 B_2 r/E \]
\( q > 0 \)

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?

Solution:
\[ F = qiB \]
\[ \text{Answer: Attractive} \]
\[ \text{Ask your TA for more imaginative exercises} \]
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)
  \[ \oint B \cdot ds = \mu_0 I \]
  \[ \text{closed path} \]

Exercise 7: Biot-Savart Law

- Use Biot-Savart to find the magnetic field at the point P.
  \[ \vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{ds \times \hat{r}}{r^2} \]
  \[ \text{Solutions: (See board)} \]

  - 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:
    \[ \oint B \cdot ds = 2\pi r B = \mu_0 I_{\text{enclosed}} \]
    \[ \Rightarrow B = \frac{\mu_0 I_{\text{enclosed}}}{2\pi r} \]

  - Answers:
    - \( r < R \), \( B = \mu_0 I/2\pi r \) (Clockwise)
    - \( R < r < 2R \), \( B = \mu_0 I/2\pi r \) (counter-clockwise)
    - \( r > 2R \), \( B = 0 \)