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 $IL \times B$
      - Uniform $B$, closed loop $\rightarrow \Sigma F = 0$, $\Sigma \tau = \mu \times B$

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

- Magnetic Dipole Moments:
  \[\sum F = 0\]
  \[\vec{\tau} = \vec{\mu} \times \vec{B}\]
  \[U = -\vec{\mu} \cdot \vec{B}\]
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: $R = \rho \frac{l}{A}$

- Ohms Law: $\Delta V = RI$

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

- Ohmic Electric Power: $P = I^2R = \Delta V^2/R$

- $R_1$, $R_2$ 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:
  - $I=I_1+I_2$, $\Delta V_1=\Delta V_2=\Delta V \Rightarrow \frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}$
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 Kirchhoff 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.

1. 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): \( \Sigma \Delta V = 0 \)

3. Solve for unknowns.

4. 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!)

\[ \Delta V = V_b - V_a = -\epsilon \]

\[ \Delta V = V_b - V_a = +\epsilon \]

\[ \Delta V = V_b - V_a = -IR \]

\[ \Delta V = V_b - V_a = +IR \]
Exercise 2: A Circuit with Three emf’s

- In the circuit shown, $R_1=1\Omega$, $R_2=2\Omega$, $\varepsilon_1=3V$, $\varepsilon_2=1V$, $\varepsilon_3=2V$.
- Use Kirchhoff’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

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

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

\( \tau \equiv RC : \text{time constant} \)
Reminder: Time Constant When Discharging

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

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

- Again time constant \( \tau = RC \) ➔ Everything determined by \( t/\tau \)
Exercise 3: Time Constant and RC

- R₁=10 KΩ, R₂=5 KΩ, C=2.0 μF, ε=10V. 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 \( \tau = RC = (R₁+R₂)C = 3.0 \times 10^{-2} \text{s} \)
\( Q = Q_{\text{full}}(1-e^{-t/\tau}) \rightarrow t_{80\%} = -\ln(0.2)\tau = 4.8 \times 10^{-2} \text{s} \)

- What is the charge on C when fully charged?

Solution: when C is fully charged, no current through it. \( \Delta V_C = \varepsilon \)
\( Q_{\text{full}} = C\Delta V_C = C\varepsilon = 2.0 \times 10^{-5} \text{ Coulomb} \)
Reminder:
Forces on Charges and Current

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

- On current segment:
  \[ F = I L \times B \]

- Current inside uniform B field
  \[ F = I L' \times B \]
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 \( \mathbf{B} \mathbf{k} \). \((v_x, v_y > 0)\)
  - 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.

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

\[r = \frac{mv}{eB}, \text{ what } v \text{ to use?} \]
\[v = \sqrt{v_x^2 + v_y^2} \]
Exercise 5: Mass/Velocity Selector

The schematic of a mass selector is shown below. For given $E$ and $B_1$, $B_2$,

1. What is the speed of a particle of charge $q$ that can enter field $B_2$?
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 $E$:
\[ F = qE + qV \times B_1 = 0 \rightarrow v = \frac{E}{B_1} \]

Once into $B_2$:
\[ m = \frac{(qB_2r)}{v} = \frac{qB_1B_2r}{E} \]

$q > 0$
Reminder: All Those Right-Hand Rules

\[ F = q v \times B \]
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)
  \[
  \oint \vec{B} \cdot ds = \mu_0 I
  \]
   **any closed path**
Exercise 7: Biot-Savart Law

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

Solutions: (See board)

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

Answer:

segment 1 contribution:

\[ \mathbf{B} = 0 \]

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

segment 2: \( \mathbf{B} = \frac{\mu_0 I}{4\pi} \int \frac{ds \times \hat{r}}{R^2} = \frac{\mu_0 I}{8R} \)

(into page)
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:

\[
\oint \vec{B} \cdot ds = 2\pi r B = \mu_0 I_{\text{enclosed}}
\]

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

Answers:

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