Study Guide
Physics C1402(001) – Midterm 2
Prof. H. Evans

Wednesday, Apr. 11 – 1:10-2:25
Room 301, Pupin

(ver.1) http://www.nevis.columbia.edu/~evans/c1402/pdf/m2_guide.pdf

MATERIAL COVERED

- Concepts in Halliday, Resnick and Walker, **Chapters 28** (RC circuits),**29-31,33**
  - There will be 3 questions on the exam
- Questions will be based on material covered in:
  - Lectures
  - Problems in the Homework
  - Sections of the Text not touched on in Lectures or Homework **will not be included** in the exam.
- Question Format:
  - Questions will be very similar to the homework

WHAT TO BRING

- The exam will be closed book, but
- You will be allowed to use one 8½ x 11 note sheet
  - You may use **one side** of the note sheet
  - The notes must be in your handwriting – No photocopies
  - You may include anything you want on the note sheet (formulas, example problems, graphs, inspirational poetry…)
  - You will be asked to hand in your note sheet with your exam, so **put your name on it**
    - The note sheet will not be graded, but
    - Failure to hand in your note sheet will cost you points
- Remember to bring a **calculator**
- I will provide all necessary:
  - constants
  - unit conversions

GENERAL ADVICE

- **Studying for the Exam**
  - Do **all** the homework problems and understand the solutions.
  - Review your lecture notes.
  - Have a look at the "Questions" at the end of each chapter. If you find that you have problems with groups of them you should concentrate on understanding those areas.
- **Exam-Taking Strategies**
  - Before beginning the exam read over all the problems.
  - Before doing a problem read it carefully so you don't miss anything.
  - Start with the easiest problem.
  - If you get stuck – don't waste time. Go on to another problem.
  - Write legibly. If the grader can't read your solution he/she can't grade it.
  - Show your work. No work = no partial credit.
  - Draw detailed pictures - this can indicate to the grader that you understand the concept of the problem even if you don't do the math correctly.
  - Solve problems algebraically before plugging in numbers.
  - Check your answers for correct units and reasonable values.
  - **Don't worry if you can't do everything**. Grading will be on a curve.
- **Time Budgeting**
  - Do not allow yourself to miss out on points by wasting all your time on one problem.
  - Make a time budget at the beginning of the exam and stick carefully to it!
  - For a 1-hour 15-minute exam with 3 questions a sample budget could be:
    - 10 min Read over all problems and decide the order to do them.
    - 20 min Spend this amount of time on each problem. When a problem's time is up, stop, and go to the next one.
    - 5 min Check over your work and revisit any parts you couldn't do.
- **Partial Credit**. How to make sure you get it.
  - **Show your work.** You will not get credit if you simply write down the correct answer.
  - **Draw a diagram** of the problem with forces and a coordinate system.
    - A well drawn diagram will be worth points.
    - No diagram will make it difficult for the grader to give partial credit.
  - **Show clearly the steps** you have taken in attempting to solve the problem.
    - If the grader can't follow your reasoning you won't get much credit.
  - **Include units** in your answers.
    - Points will be taken off for answers without units.
  - **Use appropriate significant digits**
    - Points will be taken off for answers that have many (3-4) more significant digits than the information given.

Key Concepts

UNITS

- Always include units in answers!
- Know common units (V = J/C, A = C/s, T = V·s/m^2 etc…)
- Be able to convert back and forth between different units

VECTORS

- Don't forget about these!
- Difference between Vectors and Scalars
    - Vector = magnitude and direction (at least two numbers)
    - Scalar = number with sign
- Vector Representation
    - Cartesian: $\mathbf{v} = v_x\mathbf{i} + v_y\mathbf{j} + v_z\mathbf{k}$
        - Unit vectors
    - Polar: **v** = magnitude(v) and angle(θ)
    - Calculating components of vectors along coordinate axes
- Adding and Subtracting Vectors
- Multiplying Vectors
    - Dot Product: $c = \mathbf{a}\cdot\mathbf{b} = ab\cos\theta$
    - Cross Product: $\mathbf{c} = \mathbf{a}\times\mathbf{b}$
        - $c = ab\sin\theta$
        - Direction of **c** from Right-Hand-Rule

MAGNETIC FIELDS AND FORCES

- Magnetic Force:
    - Charges: $\mathbf{F} = q\mathbf{v}\times\mathbf{B}$ (point particle)
    - Currents: $\mathbf{F} = I\mathbf{L}\times\mathbf{B}$ (straight wire)
    - Use right-hand rule to find direction
    - Force between current carrying wires:
        - Two straight wires
        - Straight wire and Loop
    - Circular Path of Charged Particle in a Uniform Magnetic Field:
        - For **v** perpendicular to **B**
            - $mv = qBr$
- Crossed Magnetic and Electric Fields
    - Understand examples of systems using both Electric and Magnetic Fields
        - Mass Spectrometer
        - Electron Discovery (cathode ray tube)
    - Generally:
        - E-Field used to accelerate particle
            - $\Delta K = q\,\Delta V$

- B-Field used to make particle move in a circle
  - > $mv = qBr$
- Undeviated motion through region of crossed E and B
  - > $F_E = F_B$

- Magnetic Dipoles: Torque & Energy
  - $\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B}$
  - $U = -\boldsymbol{\mu} \cdot \mathbf{B}$
  - μ = Magnetic Dipole Moment
    - $\mu = N\,I\,A$ (for current loop of N turns)
- Magnetic Fields
  - Biot Savart Law:
    - $d\vec{B} = \frac{\mu_o}{4\pi} i \frac{d\vec{s} \times \hat{r}}{r^2}$ currents
    - $\vec{B} = \frac{\mu_o}{4\pi} q \frac{\vec{v} \times \hat{r}}{r^2}$ charges
    - Simple Applications – no complicated integrals
    - Use with symmetry of problem to get direction of **B**
  - Ampere's Law:
    - $\oint_{loop} \vec{B} \cdot d\vec{s} = \mu_o i_{enc}$
    - Steps for using Ampere's Law (similar to Gauss' Law)
      - > Determine direction of Magnetic Field using symmetry of problem
      - > Choose Amperean Loop either parallel or perpendicular to Field
      - > Do the integral
      - > Calculate how much current is enclosed by loop
        - · sign of current from (yet another) right-hand rule
    - Understand derivation of fields for:
      - > Straight Wires
      - > Planes of Current
      - > Solenoids
      - > Toroids
  - Superposition of Magnetic Fields
    - Add fields from several known configurations like vectors
  - Right-Hand Rules for Direction of Fields from Wires:
    - Straight Wires
    - Circular Loops
    - Solenoids

TIME VARYING MAGNETIC FIELDS

- Magnetic Flux: $\Phi = \int \mathbf{B} \cdot d\mathbf{A}$
  - Understand calculation for:
    - **B** = constant (in space)
    - **B** varies with position

> only very simple calculations here

- Faraday's Law / Lenz's Law
  - EMF Induced Around Loop = $-d\Phi_B / dt$
    - induced EMF opposes change in flux
  - Induced Current from Induced EMF
    - Direction of induced current
      > sets up induced B-field to oppose change in flux from external B-field
    - Magnitude of induced current from:
      > $I_{ind} = V_{ind} / R$
  - Understand Ways to get $d\Phi_B / dt$
    - Time Varying B
    - Area of Loop Changes
    - Loop Rotates in Constant Field
    - Loop moves through region of non-uniform field
  - Simple Calculations of induced EMFs and Currents

INDUCTANCE

- Mutual Inductance:
  - Know what this is and how it arises
- Self Inductance
  - Definition: $L = N \Phi / I$
    - Calculate for simple configurations (especially solenoids)
  - Voltage Drop across an inductor:
    - $V_L = -L\, di/dt$
  - Adding Inductances
    - Series: $L_{eq} = \Sigma L_i$
    - Parallel: $(1/ L_{eq}) = \Sigma (1/L_i)$
  - Energy in Inductor:
    - $U = ½ L i^2$
  - Energy Density in Magnetic Field
    - $u_B = B^2 / 2\mu_o$

RC & RL CIRCUITS

- Know general forms of current and voltage in series RC and RL circuits when connecting or disconnecting from a battery of voltage V.

		Connect	Disconnect	
RC	$Q(t)$	$Q_f [1 - \exp(-t/\tau_C)]$	$Q_o \exp(-t/\tau_C)$	$\tau_C = RC$
	$I(t)$	$I_o \exp(-t/\tau_C)$	$I_o \exp(-t/\tau_C)$	$I_o = V / R$
	$V_C(t)$	$V [1 - \exp(-t/\tau_C)]$	$V \exp(-t/\tau_C)$	
RL	$I(t)$	$I_f [1 - \exp(-t/\tau_L)]$	$I_o \exp(-t/\tau_L)$	$\tau_L = L/R$
	$V_L(t)$	$V \exp(-t/\tau_L)$	$V \exp(-t/\tau_L)$	$I_o = I_f = V / R$

- Understand t=0 and t=∞ values of current through parts of a circuit containing capacitors or inductors after connecting a voltage source
  - $t = 0$ Capacitor acts like a wire
    Inductor acts like a block
  - $t = \infty$ Capacitor acts like a block
    Inductor acts like a wire

ALTERNATING CURRENT CIRCUITS

- Form for Voltage Supplied and Current:
  - $v(t) = V_m \sin(\omega t)$
  - $i(t) = I_m \sin(\omega t - \phi)$
- Single Element Circuits
  - Phase Difference between v and i
  - Reactances: X_R, X_C, X_L
- RMS quantities
  - Definition: $A_{rms} = (\langle A^2 \rangle)^{1/2}$
  - $A = A_m \sin\omega t \rightarrow A_{rms} = A_m/\sqrt{2}$
- Series RLC Circuits
  - Total Impedance
    - $Z = [R^2 + (X_L - X_C)^2]^{1/2}$
  - Phase Angle & Current Amplitude
    - $\tan \phi = (X_L - X_C) / R$
    - $I_m = V_m / Z$
  - Resonance Condition: Driving Frequency = Natural Frequency
    - $\omega_o = 1 / \sqrt{(LC)}$
  - RMS and Average Current and Voltages across elements
  - Energy Stored in Capacitor and Inductor and how it changes
  - Average Power and where it is dissipated
    - $\langle P \rangle = I_{rms}^2 R = I_{rms} V_{rms} \cos\phi$
    - understand how to calculate power usage in circuit
    - only resistors dissipate power
- Transformers
  - Relationships between V and I in Primary and Secondary Circuits
    - $V_s = V_p (N_s/N_p)$
    - $I_s = I_p (N_p/N_s)$
  - Equivalent Resistance
    - $R_{eq} = R (N_p/N_s)^2$
    - understand what is meant by impedance matching