Study Guide
Physics C1402(001) – Midterm 1
Prof. H. Evans

Wednesday, Feb. 28 – 1:10-2:25
Room 301, Pupin

(ver.1) http://www.nevis.columbia.edu/~evans/c1402/m1_guide.pdf

MATERIAL COVERED

- Concepts in Halliday, Resnick and Walker, **Chapters 22-28** (except RC circuits)
  - 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, etc.
- Be able to convert back and forth between different units

VECTORS

- 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: $\mathbf{v}$ = 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

ELECTRIC FORCES & FIELDS

- Charge is quantized:
  - $e = 1.60\times10^{-19}$ C
- Electrostatic Force and Coulomb's Law:
  - $\vec{F} = \dfrac{kq_1q_2}{r^2}\hat{r}$
- Electric Fields: $\mathbf{E} = \mathbf{F}/q_o$
  - Be able to calculate Forces from Fields and vice versa
- Draw Field Lines for Simple Configurations of Charge
  - small numbers of discrete charges
  - simple continuous charge distributions: lines, planes, spheres, cylinders
- Simple applications of Coulomb's Law for E-Fields
  - no complicated integrals
- Superposition of E-Fields
  - remember that **E** is a vector
  - apply this to find total fields for systems where you know the fields separately for each of the components
- Electric Dipoles

  - field configuration
  - dipole moment: $\mathbf{p} = q\mathbf{d}$
  - torque in an external field: $\boldsymbol{\tau} = \mathbf{p}\times\mathbf{E}$
  - energy in an external field: $U = \mathbf{p}\cdot\mathbf{E}$
- Electric Flux: $d\Phi = \mathbf{E}\cdot d\mathbf{A}$
  - understand meaning of flux (field lines per area)
  - direction of area element d**A**
- Gauss' Law: $\int_{surf}\mathbf{E}\cdot d\mathbf{A} = q_{enc}/\varepsilon_o$
  - find E for simple shapes:
    - points, spheres
    - lines, cylinders
    - planes
  - use superposition to find field for combinations
  - understand consequences of special cases:
    - $q_{enc} = 0$
    - $E = 0$ on surface
  - General Steps for Solving Gauss' Law Problems
    - 1) Use symmetry to get:
      - a) direction of E-Field vectors
      - b) surfaces where E is constant
    - 2) Choosing your Gaussian surface:
      - a) break up a simple surface so that E-Field is constant (or zero) on all elements of it
        - non-constant E-Fields make the integral very difficult
      - b) it's also helpful if the d**A**'s of your surface are parallel to the field
        - non-constant angles → difficult integration
      - Note: in this class we've only considered three surfaces (spheres, cylinders and boxes). Your surface should be one of these!
    - 3) $\Phi = \Sigma\, E_{surface}\, A_{surface}$
    - 4) Evaluate Enclosed Charge

ELECTRIC POTENTIAL

- Definition of Electric Potential: $\Delta V = \Delta U / q$
  - Potential differences are path independent (Electric Force is conservative)
- Understand concept of "reference potential"
- Use conservation of Energy to describe how particles move in a potential
  - Kinetic vs. Potential energy
- Calculate Potentials for simple situations: $\Delta V = -\int_i^f \mathbf{E}\cdot d\mathbf{s}$
  - point charges
  - simple distributions: spheres, lines, cylinders, planes
- Superposition of Potentials
  - calculate potential of groups of objects
- Potential Energy required to build a charge distribution

PROPERTIES OF CONDUCTORS

- Note: applies only to electrostatics
- Always keep these in mind when confronted with a problem involving conductors!
- 1) All free charge on a conductor resides on the surface
  - Free Charge is:
    - a) charge that you put on the conductor
    - b) accumulations of negative or positive charge from the atoms in the conductor that are induced by external fields
- 2) $E = 0$ at all points inside a conductor
  - Gaussian surfaces which lie completely inside a conductor enclose zero net charge
- 3) At the surface of the conductor: **E** points perpendicular to the surface at each point
- 4) All points on a conductor (or a set of connected conductors) are at the same potential.
- Be able to solve Gauss' Law problems involving conductors

CAPACITANCE

- Definition: $Q = CV$
- Calculate C for simple configurations
  - C from calculation of potential difference (V) between two conductors when charge (Q) is put on them
  - plates, cylinders, spheres
- Energy Stored in Capacitor: $U = ½\, CV^2 = ½\, Q^2/C$
- Energy Density: $u = ½\, \varepsilon_o E^2$
- Equivalent Capacitances:
  - Series: $1/C = \Sigma\, 1/C_i$
  - Parallel: $C = \Sigma\, C_i$
  - Remember how these were derived
- Effect of Introducing a Dielectric: $C = \kappa C_{vacuum}$

CURRENT

- Definition: $I = dq/dt$
  - remember defined as motion of positive charges
- Getting current from drift velocity of electrons
  - $I = nev_dA$

RESISTANCE

- Definition: $R = \rho\,(L/A)$ (for most materials)
  - Resistivity depends on Temperature: $\rho = \rho(T)$
- Ohm's Law: $V = IR$
  - understand concept of potential drop across resistor
  - sign of potential drop

- Equivalent Resistance
  - Series: $R = \Sigma R_i$
  - Parallel: $1/R = \Sigma 1/R_i$
  - Remember how these were derived

CIRCUITS

- **Circuit Solving Techniques**
  1. Draw Equivalent Circuits when possible
     - Conductors in contact are at the same potential
     - Change shape of circuit to suit your taste, but:
       - Conserve number of Junctions
       - Only change *shape* of Loops
         - don't cut them
         - don't add extra loops
     - Replace groups of Resistors and Capacitors with Equivalent R or C using rules for combining in parallel and series
  2. Label the sides of each EMF to indicate high (+) or low (–) potential
  3. Find the Branches (Loops) in the circuit
  4. Choose a direction for the Current in each Element
     - *and draw an arrow indicating that direction*
  5. Apply the Junction Rule (currents) to the Currents going into and out of each Branch Point
     - $\Sigma I_{in} = \Sigma I_{out}$
  6. Apply the Loop Rule (voltages) to all the Loops in the circuit
     - $\Sigma \Delta V = 0$ around loop
     - for EMF's:
       - $\Delta V > 0$ $+ \rightarrow -$
       - $\Delta V < 0$ $- \rightarrow +$
     - for Resistors:
       - $\Delta V > 0$ traversing element opposite to direction of I
       - $\Delta V < 0$ traversing element in same direction as I
     - for Capacitors:
       - $\Delta V > 0$ +plate → –plate
       - $\Delta V < 0$ –plate → +plate
  7. Solve the Simultaneous Equations
- Power
  - Supplied (or absorbed) by EMF: $P = IV$
  - Dissipated in Resistor: $P = I^2R = V^2/R$
  - Understand the how to tell whether power is supplied or absorbed