AP Physics C (Electricity and Magnetism)

Goal: To prepare the student for the AP Physics C (EM) exam in May. The student can earn college credit if his/her performance merits it.

Schedule: The class meets 15 periods every two weeks. Each period is 42 minutes in duration. This allows for a double period of instruction and or lab work every other day.

Approach: This course presents an inquiry-based, problem-solving oriented approach to electricity and magnetism topics in physics. The instructor uses various teaching techniques which are designed to impart both process skills and content knowledge to the student. The pedagogy includes lecture, individual problem solving, group problem solving, group lab work, and concept demonstration (both with actual equipment and with computer simulation). The lecture portion of the presentation utilizes calculus (which is then expected to be used in student problem solving as well). A wide variety of teaching strategies are employed to ensure student understanding of the learning objectives. These include such strategies as computer-based learning, inquiry-based and open-ended lab work, and of particular importance, team based "challenge" problems in which groups of students work together to solve difficult problems and earn points based on both speed and accuracy.

Prerequisites and Math Competencies: Students who take this course meet the following prerequisites:

1) 9th grade-Honors Biology
2) 10th grade-Honors Chemistry
3) 11th grade-Honors Physics or AP Physics B
4) Honors Calculus or AP Calculus (AB or BC) previous or concurrent to AP Physics C

Text: Fundamentals of Physics 4th Ed, (Wiley Pub.) Halliday, Resnick, Walker, ©1993
This text presents a calculus-based, problem-solving oriented approach to the study of physics. It is meant for college students studying a pure science or engineering. Additionally, among others, the following texts are used a primary supplementals:
Physics for Scientists and Engineers, 6th Edition, (Thompson Pub.) Serway and Jewett, ©2004
Physics, 3rd Edition, AP Edition, (Prentice Hall Pub.), Walker, ©2007

HW Policy: Each week, an overview of learning objectives, homework problems, and reading assignments is distributed to the students. Since pop quizzes are administered on a routine basis, the student will not do well on the quizzes w/o doing the homework on a nightly basis.

Lab Work: Students will have a wide-variety of hands-on lab experiences occurring at least once per week. Approximately 20% of the class time is devoted to lab work. Many of the labs involve the use of PASCO GLX data collection devices. A lab report is always required and will be kept in a cumulative lab notebook. The lab report always includes detailed analysis of the lab work including, but not limited to, graphical analysis of data, presentation of equation manipulation, scientifically valid conclusions based on data, and analysis of error. The lab notebook will be periodically evaluated for neatness, completeness and correctness.

Tests: Each unit has an 80 to 100 point test. The test questions are comparable to AP exam questions. The tests are timed and are generally thought to be difficult.

Grading Scale: Total points are used to determine percentage grades in each quarter. The quarterly grades are averaged to determine the semester and final grades.

A=90 to 100% B=80 to 89% C=70 to 79% D=60 to 69% E=59% and below

Unit	Topic	Approximate Date of Completion
1	Electrostatics and Gauss's Law	Mid February
2	Conductors, Capacitors and Dielectrics	End February
3	Current, Resistors and RC Circuits	Mid March
4	Magnetostatics	Early April
5	Electromagnetic Induction	End April
	AP Test Review	Early May

DETAILS FOR EACH UNIT ARE SHOWN ON THE FOLLOWING PAGES.

AP Physics C (EM) Unit 1 Topics: Electrostatics and Gauss's Law

- Basic electrostatics stuff
- Coulomb's law $\mathbf{F}=kqq\hat{\mathbf{r}}/r^2$
- E-field $\mathbf{E}=\mathbf{F}/q$
- Dipole moment (**p**) $p=qd$
- E-field for continuous charge distribution by direct integration
  - Uniform line of charge
  - Uniform ring of charge
  - Uniformly charged disk
- Motion of a charged particle in an E-field
  - Single charge particle
  - Electric dipole (torque calculation)
- Electric flux $\Phi=\int \mathbf{E}d\mathbf{A}$
  - With constant E-field
  - With variable E-field in one dimension
  - Through curved surfaces
- Gauss' law $\Phi=\int \mathbf{E}d\mathbf{A}=Q/\varepsilon_o$
  - Infinite line of charge
  - infinite plane of charge
  - Spherical shell of charge
  - Solid sphere of charge
- Electric potential energy and electric potential
  - $V=U/q$ (use the F.O.R. wherein V=0 at $r=\infty$)
  - $\Delta U=-q\int E\cdot \mathbf{ds}$ along the path a to b
  - $\Delta V=-\int E\cdot \mathbf{ds}$ along the path a to b
- Uniform E-field
  - $\Delta V=-Ed$ (where d is the distance along the field line)
  - $W_{field}=qEd=\Delta K=-\Delta U$
- Non-Uniform E-field caused by point charges
  - $V_P=k\sum(q/r)$
  - $W_{ext.\ agent}=\Delta U$ (to achieve a new arrangement of charges)
- Generalized potential energy function ($U(r)=kqq/r$)
  - Sum over all pairs for total U
- Potential gradient $-E=dV/dr$
- Equipotential surfaces $(dV/dr)=0$
  - Analyze various charge distribution equipotentials
  - Analyze equipotential maps
- Electric potential as a function of distance from continuous charge distributions
  - Ring of charge
  - Flat disk of charge
  - Sphere (shell and solid)

- Line of charge
- Cylinder (shell and solid)

Lab Activities:

- Basic electrostatics stuff (plastic, fur, electroscopes, etc.)
- E-field mapping (equipotentials and field lines via computer simulations)

Time Frame: 4 weeks

Structure of the exam:

- multiple choice conceptual questions
- free response questions, each containing multiple parts

AP Physics C (EM) Unit 2 Topics: Conductors, Capacitors, Dielectrics

- The concepts of electrostatic equilibrium
  - E-fields, using Gauss' Law, charge distribution, etc….
- The definition of capacitance
- The isolated spherical capacitor
- The parallel plate capacitor
  - E-field and charge density
  - Geometric considerations
- The cylindrical capacitor
  - E-field and potential gradient derivation (calculus)
  - Geometry considerations
- The spherical capacitor (calculus)
  - E-field and potential gradient derivation
  - Geometry considerations
- The variable air capacitor
- Energy stored by a capacitor
  - Basic calculations
  - Energy density (calculus)
- Combinations of capacitors
  - Series and parallel connections
- Types of capacitors
  - Tubular, electrolytic
- Dielectric materials
  - Benefits
  - Polarization and effect on charge density

- Dielectric breakdown
- Introduction of a conductor inside a capacitor
- Partially filled capacitors
- The effect on energy storage

Lab Activities:

- Combinations of capacitors
  - Series and parallel connections (use of the voltmeter)
  - Charge redistribution (use of the voltmeter)
- Investigation of the parallel plate capacitor

Time Frame: 3 weeks

Structure of the exam:

- multiple choice conceptual questions

AP Physics C (EM) Unit 3 Topics: Current, Resistors and RC Circuits

- The concept of current ($I=dq/dt$)
- Understand drift velocity as distinguished from E-field signal ($v_d=I/qnA$)
- n = #carriers/volume (Needed: density and molar mass)
- Current density ($\mathbf{J}=I/\mathbf{A}$)
- Ohm's law ($\mathbf{J}=\sigma\,\mathbf{E}$)
- The concept of resistance ($V=(\rho L/A)I$)
- The effect of temperature on resistivity ($\rho = \rho_o[1 + \alpha(T-T_o)]$)
- Graphical analysis of voltage vs. current for ohmic and non-ohmic materials (ex: diodes)
- Radial resistance (calculus) ($R= (\rho/2\pi L)\ln(b/a)$
- Analysis of different shaped resistors (calculus… $dR= \rho\, dx/A$)
- A model for electrical conduction…determination of mean free path
- Electrical power ($P=IV=I^2R=V^2/R$) and the cost for electrical energy
- Alternating current ($I=I_o\sin(2\pi ft)$) ($P_{ave}=I_{rms}V_{rms}$) ($I_{rms}=0.707\, I_o$)
- Simple circuit analysis with series and parallel resistors with one battery
- Complex circuit analysis using Kirchoff's rules and matrix math
- Determination of potential difference between two points in a circuit (V_{AB})
- Analysis of RC circuits at initial condition and at steady state
- Transient analysis of RC circuits (calculus)
  - Charge, current and voltage as a function of time for the charging cycle
  - Charge, current and voltage as a function of time for the discharging cycle
  - graphical analysis

- Use of electrical instruments and their effects on the circuit
    - Voltmeter
    - Ammeter

Lab Activities:

- Ohm's law (circuit boards and electrical meters)
- Simple circuit analysis with series and parallel resistors with one battery
- Complex circuit analysis using Kirchoff's rules and matrix math
- Analysis of RC circuits at initial condition and at steady state (along with time constant measurements)
- Use of electrical instruments and the effects on circuit analysis (analog meters, digital multimeters, Pasco GLX data collection devices)

Time frame: 3 weeks

Structure of the exam:

- multiple choice conceptual questions
- extended free response question with many parts

AP Physics C (EM) Unit 4 Topics: Magnetostatics

- The history of magnetism
- Fundamental ideas in magnetism
- The concept of magnetic field
    - Sketches with bar magnets
- Magnetic force ($\mathbf{F}$=q$\mathbf{v}$x$\mathbf{B}$) on a moving charged particle
    - Application of the RHR
    - Work done by a B-field
- Force on a straight current carrying wire in a B-field ($\mathbf{F}$=I$\mathbf{L}$x$\mathbf{B}$)
- Force on a curved current carrying wire in a B-field (calculus…d$\mathbf{F}$=Id$\mathbf{s}$x$\mathbf{B}$)
    - Segment of wire ($\mathbf{F}_B$=I$\mathbf{L'}$x$\mathbf{B}$ where $\mathbf{L'}$ is the net length in the field)
    - Loop of wire (F_B=0)
- Torque on a current carrying loop (τ =I$\mathbf{A}$x$\mathbf{B}$)
    - $\mathbf{A}$=area vector whose direction is defined by the RHR
    - I$\mathbf{A}$= μ =magnetic dipole moment for one loop
    - τ = μ x$\mathbf{B}$
    - For a loop of N-turns τ = N(μ x$\mathbf{B}$)
- The motion of a charged particle in a B-field
    - Simple case r = mv/qB and T=2πm/qB

- The cyclotron
- The mass spectrometer
- The velocity selector
- The Hall effect
- The helical path
- The magnetic bottle (The Van Allen radiation belts)

➢ The Biot-Savart Law (calculus...$d\mathbf{B} = \mu_o I(ds \times \check{\mathbf{r}})/4\pi r^2$)
- Very long wire ($B = \mu_o I/2\pi r$)
- Curved wire segment at center ($B = \mu_o I\,\theta/4\pi r$)
- Loop of wire at center ($B = \mu_o I/2r$)
- On axis of current carrying loop ($B = \mu_o IR^2/[2(R^2+x^2)^{3/2}]$)

➢ Magnetic force between parallel conductors ($F/L = \mu_o I_1 I_2/2\pi d$)

➢ Ampere's Law (calculus...$\int \mathbf{B} \cdot d\mathbf{s} = \mu_o I$ for any closed path)
- B-field within a current carrying wire
- B-field within an ideal solenoid
- B-field within an ideal toroid
- B-field created by an infinite current carrying sheet

Lab Activities:

➢ Magnetic field mapping with permanent magnets
➢ Magnetic effects using loops and solenoids
➢ Magnetic force using a current balance
➢ Magnetic force between parallel conductors ($F/L = \mu_o I_1 I_2/2\pi d$)

Time Frame: 3 weeks

Structure of the exam:

➢ multiple choice conceptual questions
➢ free response questions

AP Physics C (EM) Unit 12 Topics: Electromagnetic Induction

➢ The concept of magnetic flux
➢ Gauss' law for magnetism and its meaning
➢ Use integration to determine the magnetic flux through loop (arbitrary shape) within a non-uniform B-field
➢ Understand and explain the concept of displacement current
➢ Explain, interpret and utilize the Ampere-Maxwell law
➢ Explain, interpret and utilize Faraday's law of induction

- Determine the potential difference across a bar moving in a B-field (motional emf)
- Analyze a situation wherein a bar is in a B-field sliding on rails
- Utilize Lenz's law to determine the induced emf polarity and direction of the induced current in a loop of wire whose magnetic flux is changing.
- Distinguish between a source emf and an induced emf.
- Derive and use the generalized form of Faraday's law so that the induced E-field can be determined.
- The concept of self-inductance (back emf). What does it resist?
- Derive and apply the expressions for self-inductance for an ideal solenoid. Including those based on geometry.
- Be able to analyze RL circuits. Be able to write and solve a differential equation (using Kirchoff's rules) regarding the RL circuit which can be solved to find the relationship between current and time.
- Be able to analyze RL circuits using graphical interpretations.
- Derive the expression for a simple RL circuit which determines the energy stored in the B-field of an inductor.
- Be able to qualitatively (including graphical interpretation) and quantitatively describe the oscillations of a resistance-free LC circuit. Be able to use a mechanical analogy to answer questions regarding the behavior of the circuit.
- Be able to comment (again possibly using graphs) on the energy stored in a resistance-free LC circuit.
- Be able to qualitatively describe Maxwell's equations and discuss their importance in relation to EM radiation.

Lab Activity:

- Investigating Lenz's law using solenoids and magnets
- Investigating induced emf in loops of wire

Time Frame: 3 weeks

Structure of the exam

- multiple choice conceptual questions
- free response questions