AP® Physics C – Electricity and Magnetism

Course Outline

1. The roles of electric fields (Week 1)
    a. Reading: Fields, Forces, Energy, and Potentials in Physics
    b. Exerting forces: $\mathbf{F} = q\mathbf{E}$
    c. Storing energy: $U = qV$
    d. Experiment: Mapping electrical potentials in two dimensions for various configurations (2 days, hands on)
    e. The relationship between field and potential: $\mathbf{E} = -\left(\frac{\partial V}{\partial x}\hat{\mathbf{i}} + \frac{\partial V}{\partial x}\hat{\mathbf{j}} + \frac{\partial V}{\partial x}\hat{\mathbf{k}}\right)$
2. Metallic bond model for metals; covalent bond model for dielectrics (Week 1)
    a. Reading: Atomic-scale Models for Materials: Metals and Covalently Bonded Materials
    b. Electroscopes
    c. Electrophorus
    d. Triboelectric series
    e. Experiment: Explaining the positioning of static electric charge in metals and dielectrics with electric forces and potential (1 day, hands on)
    f. Project: Selection of wave or light phenomenon to study for end-of-semester project

3. Modeling electric fields using Coulomb's Law (Weeks 2 and 3)
    a. Chapter 22 assignments
        i. 22a pp. 598-604: 1, 3, 6, 7, 12, 13
        ii. 22b pp. 598-604: 32, 39, 17, 19
    b. Field created by an electrically charged particle
        i. Field line representation
        ii. Equipotential line representation
        iii. Vector field representation
        iv. Mathematical representation: Coulomb's Law
    c. Field created by two electrically charged particles
        i. The field created by identically charged particles in various representations
        ii. The field created by oppositely charged particles: The electric dipole in various representations
    d. The field created by extended distributions of charge
        i. Field of a linear segment of uniformly charged material
        ii. Field at the center of a circular arc of uniformly charged material
        iii. Axial field of a charged ring
        iv. Axial field of a charged disk
    e. Electric dipole in a uniform electric field
        i. Describing an electric dipole: Dipole moment

   ii. Explaining the motion of a dipole moment
      A. Forces and torques
      B. Energy

4. Modeling electric fields using Gauss' Law (Weeks 4 and 5)
   a. Chapter 23 assignments
      (Note: charged particles as projectiles in a uniform **E** field were dealt with in semester 1 AP C Mechanics.)
      i. 23b pp. 620-621: 3, 4, 5, 7, 10
      ii. 23c pp. 621-627: 2, 4, 8, 25, 26
      iii. 23d pp. 621-627: 29, 43, 44, 45
   b. Electric flux
   c. Gauss' Law
   d. Fields produced by a charged conductor
      i. Inside
         A. $\mathbf{E} = 0$
         B. V = constant
      ii. Outside
         A. **E** is normal to the surface
         B. Surface is an equipotential in static state
   e. Field produced by a charged metal plate
      i. Isolated metal plate
      ii. Pair of oppositely charged metal plates
   f. Field produced by a uniformly charged dielectric sheet
   g. Field produced by a linear charged distribution
      i. Wire
      ii. Cylinder
   h. Field produced by a spherically symmetric charge distribution
      i. Particle
      ii. Sphere

5. Describing electric fields using electric potential (Week 6)
   a. Chapter 24 assignments
      i. 24a pp. 646-647: 2, 4, 6, 7, 8
      ii. 24b pp. 647-655: 3, 4, 7, 9, 33, 37
   b. Calculating V from **E**: $V_{a,b} = -\int_a^b \mathbf{E} \cdot d\mathbf{l}$
      i. Potential due to a charged particle
      ii. Potential due to an electric dipole
      iii. Potential due to a linear segment of charge
      iv. Axial potential due to a ring of charge
      v. Axial potential due to a charged disk
         A. Metal sphere
         B. Dielectric sphere
   c. Electric potential energy in a system of charged particles
      i. General charged particles

ii. Experiment: Determining α particle KE, given data leading to ionization energy (w-value) for air molecules, Hans Geiger's 1909 ionization data for α particles in air, and $^{210}_{84}Po$ sample in a cloud chamber. The goal is to provide evidence for tunneling (α's $r_0 \approx 6r_{nucleus}$) and a limit to the validity of classical concepts. (2 days + postlab, hands on, some data provided for analysis)

6. Modeling capacitors (Week 7)
    a. Chapter 25 assignments
        i. 25a pp. 674-675: 2, 3, 4, 5, 7, 8, 9
        ii. 25b pp. 675-681: 5, 8, 10, 12, 22, 36
    b. Capacitor models
        i. Parallel plate capacitor
        ii. Cylindrical capacitor
        iii. Spherical capacitor
    c. Capacitors in a DC circuit
        i. Series
        ii. Parallel
    d. Energy stored in electric fields
    e. Capacitors containing dielectrics

7. Electric fields in metals (Week 8)
    a. Chapter 26 assignments
        i. 26a pp. 700-704: 4, 12, 15, 17, 20
        ii. 26b pp. 700-704: 31, 32, 33, 34, 35, 36, 9, 26
    b. Metallic bond model for metals
    c. Conventional current
    d. Model for metals elaborated
        i. Current density
        ii. Drift velocity
        iii. Resistivity
    e. Experiment: V/I curves for nichrome, diodes, and light bulbs (2 days, hands on)
    f. Experiment: How the current through the filament of a lamp, the resistance of the filament, its temperature, and the power supplied to it vary with the potential difference across it. (2 days + 1 day postlab discussion, hands on)
    g. Drude model for metals
    h. Energy transfers in electric circuits
        i. Energy transfer in a power supply
        ii. Potential energy associated with electrons "falling" through a circuit
            A. In wire
            B. In resistor

8. Electric circuits: Systems of models (Week 9)

a. Chapter 27 assignments
    i. 27a pp. 724-725: questions 1, 2, 3; problems 2, 4, 5, 10, 18
    ii. 27b pp. 725-734: 17, 21, 23, 31, 32, 33, 51, 55
b. Ideal power supply
c. Real battery
    i. Chemical energy lost
    ii. Thermal energy gained (internal resistance)
    iii. Electrical energy gained
d. Tracking conserved quantities in circuits
    i. Energy: Kirchoff's loop rule
    ii. Charge: Kirchoff's junction rule
e. Single and multiloop circuit analysis
f. RC circuits
    i. Kirchoff's loop rule: a differential equation
    ii. Solving for $q(t)$
        A. Charging
        B. Discharging
g. Experiment: Determining C by measuring RC (1 day, hands on)
h. Experiment: How flash rate depends on R and C in a simple relaxation oscillator (1 day, hands on)

9. Forces caused by magnetic fields (Week 10)
    a. Chapter 28 assignment
    (Note: $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ was introduced and used in Mechanics along with other instances in which there was a central net force. Crossed **E** and **B** fields were also dealt with in Mechanics along with zero net force situations.)
        i. 28d pp. 758-763: 16, 34, 35, 39, 48, 37, 47
    b. Describing a magnetic field
        i. Source
        ii. Strength
        iii. Direction
    c. Newtonian Interaction Laws
        i. Forces on individual, moving charged particles: $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$
        ii. Forces on currents: $\mathbf{F} = i\mathbf{l} \times \mathbf{B}$
            A. Forces on straight wires
            B. Forces on current loops
            C. Potential energy in loop-field system
    d. Experiment: Building a simple electric motor (2 days, hands on)
    e. Hall effect

10. Models of magnetic fields created by currents (Week 10)
    a. Chapter 29 assignments
        i. 29a pp. 781-782: questions 1, 2, 3; problems 1, 2, 4, 6, 8, 9, 10
        ii. 29b pp. 782-790: 23, 30, 31, 40, 43
        iii. 29c pp. 782-790: 29, 32, 50
    b. Modeling magnetic fields using the Biot-Savart Law
        i. Fields due to straight currents

    ii. Fields due to circular currents
  c. Experiment: Measuring the magnetic field in and around a solenoid (2 days, hands on)
  d. Modeling magnetic fields using Ampere's Law
    i. Fields created with straight currents
      A. Outside of wire
      B. Within wire
    ii. Fields created by solenoids
    iii. Fields created by toroids

11. Faraday's Law: Modeling electric fields created by changing magnetic fields (Weeks 11 and 12)
  a. Chapter 30 assignments
    i. 30a pp. 816-817: questions 3, 4, 7, 8, 9
    ii. 30b pp. 817-825: problems 1, 2, 4, 7, 27, 32
    iii. 30c pp. 817-825: 40, 41, 42, 46, 47, 49
    iv. 30d pp. 817-825: 8, 17, 18, 24, 28, 53, 54
  b. Faraday's Law described
    i. Magnetic flux
    ii. Induced EMF
    iii. Lenz's rule
  c. Energy transfers due to electromagnetic induction
  d. Faraday's Law explained: induced electric fields
    i. Closed loops
    ii. Solenoids
    iii. Toroids
  e. Faraday's Law explained: motional EMF
  f. *RL* circuits
    i. Kirchoff's loop rule: a differential equation
    ii. Solving for *i(t)*
  g. Energy stored in magnetic fields

12. LC circuits (Week 12)
  a. Chapter 31 assignment
    i. 31a pp. 853-854: questions 3, 5, 6
    ii. 31b pp. 853-854: problems 1, 2, 3, 4, 8, 11, 13
  b. Kirchoff's loop rule: a differential equation
  c. Solving for *q(t)* for capacitors in *LC* circuits: an SHO analog
  d. Experiment: Electromagnetic oscillations in an *LRC* circuit (2 days + 1 day postlab discussion, hands on)
13. Maxwell's Equations: Core theory for electric and magnetic systems (Week 13)
  a. Chapter 32 assignment
    i. 32a pp. 884-885: 3, 16
  b. Gauss' Law (E) $\oiint \mathbf{E} \cdot d\mathbf{A} = \frac{q_{encl}}{\varepsilon_0}$
  c. Gauss's Law (B) $\oiint \mathbf{B} \cdot d\mathbf{A} = 0$

d. Faraday's Law $\oint \mathbf{E} \cdot d\mathbf{l} = \frac{d\phi_B}{dt}$

e. Ampere-Maxwell Law $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 \varepsilon_0 \frac{d\phi_E}{dt} + \mu_0 i_{encl}$

14. AP Exam (week 15)

15. Wave and light projects (Weeks 16 and 17)
    Students demonstrate phenomena and findings to class and turn in a report resulting from their investigation of a wave or light phenomenon.