Mr. Rogers' Syllabus for AP Physics C: Electricity & Magnetism

Amer. College Board | Common Syllabus | Mr R's Info | Southside High | intuitor.com

What to Expect:

In a word: magic. The world of E&M is the closest thing to magic a human can experience (without being a wizard). It is a hidden world which lights the darkness, enables communication over great distance, and heats, or cools on demand. It is a world which is only accessible through the concepts of physics using the tools of mathematics and calculus.

This is a calculus based, college level, physics class which covers mechanics for the American College Board AP Physics C Mechanics exam. Students passing this test may receive college credit. In addition, this class begins a two year course of IB Physics course. Again students will take an IB test which will count toward their IB diploma and can result in college credit.

The Psychology of Physics Problem Solving
A teacher can guide students through a complex physics problem merely by asking questions. By learning to ask questions of yourself, you can gain the same level of problem solving skill without having a teacher present. It's called metacognition and is a skill you will acquire.

Powerful physics problem solvers also frequently use a type of free association. By learning to associate small hints with a corresponding physics principle, they can often visualize an equation for a problem even before they have fully read it. Again it's a skill that can be learned.

Resources and Materials for Class

TextBook : Mr. Rogers will provide the following books:

Physics for Scientists and Engineers Volume II 4th Edition by Raymond A. Serway, **ISBN:** 0-03-015658-0—A calculus based book covering E&M along with modern physics.

Who Should Take this Class: Students with highly developed algebra skills and an interest in careers related to: **engineering, the computer professions, medicine, physics, chemistry, or math.**

Credit: One unit of lab science

Prerequisites: AP Physics C Mechanics and Calculus concurrent (no exceptions). Having taken AP Statistics or taking it concurrently will be helpful but is not required.

Use of Calculus: This course requires the use of calculus. A high level of skill in algebra is essential

Extra Credit Opportunity--Science Fair

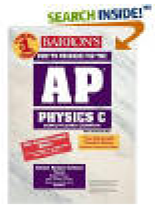
How to Succeed on AP Tests

Grading and Assignments

Grading: (For details see Mr. Rogers' Syllabus - Information Common to All Classes.) Tests will be the single largest item and will be written as close to AP exam standards as possible. Course work will generally be finished in the third quarter leaving the rest of the year for review and various physics investigations (labs). The first semester exam will be taken directly from old AP tests. The exam grade will give you an indication of your standing on the future AP exam in enough time to take corrective action if needed. The fourth quarter grade will consist primarily of practice AP test grades. Generally, there is a high correlation between the practice exams and your grade on the AP test.

Physics Investigations - Labs: We will be spending about 20% of our instructional time on various forms of practical activities. These include formal lab write ups, mini-labs (informal write ups), and a few after school labs.

Many E&M investigations will be conducted with computerized data collection using a wide range of



How to Prepare for the AP Physics C (Paperback)
by Robert A. Pelcovits, Joshua D. Farkas

Web Page Resources Provided by Mr. Mr. Rogers
All of the following are maintained by Mr. Rogers and can be reached via links from his teacher homepage.

1. **Objectives:** The daily objectives used in class along with homework assignments are all available online
2. **Practice Tests:** Self scoring online practice tests complete with explanations of the answers are available for each unit. In addition practice test questions without answers are also available online. You should have no surprises when you take tests.
3. **Study Guides:** Study guides are available online for each unit. These include the equations you must learn, problem solving tips, important concepts, vocabulary lists, and example problems to help you succeed on tests.
4. **Movie Physics:** Mr. Rogers maintains a web site with all kinds of movie physics information to assist you in your enrichment assignments.

Physics Software
Interactive physics software will be available in the physics classroom for conducting simulations and confirming solutions to problems

Materials for Class Provided by the Student

1. **A USB thumb drive** or other storage media for maintaining your electronic portfolio of physics assignments.We will attempt to be as close to a paperless classroom as possible.
2. **A bound composition book** for recording raw data and observations during physics investigations

Vernier Lab equipment. Other labs will use multimeters, power supplies, bread boards, E-field meters, oscilloscopes, and various forms of microwave equipment. We will measure the ratio of charge to mass of an electron and perform the Milliken experiment.

We will regularly use statistical tools like regression analysis and various forms of error analysis to help evaluate experimental data. Having taken AP Statistics or taking it concurrently will be helpful but is not required. Mr. Rogers will assist those who are unfamiliar with these techniques.

All physics investigation raw data and observations will be recorded in a bound composition notebook which will be periodically checked. Write ups will be maintained in an electronic portfolio (computer folder) and be submitted via the school's computer network.

Enrichment Assignment: You cannot master physics if you only think about it in the classroom. To encourage physics thinking in everyday life, once per quarter you are to review a Hollywood movie scene for physics content. The review will contain the following:

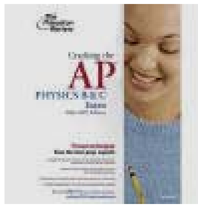
1. The movie's title and main stars.
2. A summary of the scene (about one good paragraph)
3. A summary of the scene's physics (about one good paragraph)
4. At least one calculation related to the scene's physics

To analyze movies you will have estimate many of the parameters used in your calculation, often based on the size of objects in the movie. Estimating is a real world skill which is often required for major engineering projects.

The analysis is to be submitted via the school's computer network as a computer file one week before the end of each quarter and will count as a lab grade. The file is to be labeled with the movie name and your name and can be either be an a Microsoft Word or Excel file.

Class Work
You cannot master physics by watching Mr. Rogers work problems, hence, you will be going to the front of the classroom and working problems on the white board in groups of 2 on a regular basis. Guided practice of this type is a powerful learning opportunity. In this class you will think physics, talk

3. **A set of dry erase markers**. You will frequently be working problems in class on a white board.
4. **A graphing calculator**
5. [Cracking the AP Physics B and C Exams, 2006-2007 Edition (College Test Prep) (Paperback)] by Princeton Review , **$12.35** from Amazon.com, can generally also be purchased locally. **Note: this book is the text for IB physics topics.**



physics, write physics, and yes at times even help teach physics to your fellow classmates.

Mr. Rogers' IB/AP Physics II: E&M Objectives

Syllabus	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter

AP Physics C E&M Standards

A. Electrostatics 30%

1. Charge, field, and potential
2. Coulomb's law and field and potential of point charges
3. Fields and potentials of other charge distributions

a. Planar
b. Spherical symmetry *
c. Cylindrical symmetry *

4. Gauss's law *

Charge

Essential Question: How is charge similar and different than mass?

1. Describe the nature of charge.
    - Like repel, opposites attract
    - Freely moves in conductors, not free in insulators
    - Conserved
    - Quantized
    - Analogous to mass in many equations
2. Explain the difference in charging an object by induction and charging it by conduction.
3. Calculate electrostatic forces using Coulomb's law.

Demo: Van de Graaff Generator

Using the Van de Graaff Generator, demonstrate:

- The nature of charge (see objectives)
- induction
- conduction

- One dimension
- 2 Dimension

4. For a hydrogen atom, calculate the ratio of electric to gravitational attraction forces.

> If the Van de Graaff Generator creates a voltage of on the order of magnitude of 100,000 volts, why is it not deadly?

Homefun: prob 1, 7, 9, 11 p.674-5 Serway

Mini-Lab Physics Investigation (Requires only Purpose, data, and conclusion)	
Title	Investigation of the Ionizing Effects of UV Radiation
Purpose	Can shielding prevent unwanted electric fields from producing noise signals in wires?
Overview	Charge the electroscope and measure the length of time it takes for the leaves to come back together (indicating that the charge has been drained from the electroscope). Repeat this process several times and calculate an average time. Repeat the first step except this time shine a UV light on the leaves. Note: do not look directly at the UV light.
Data, Calculations	Calculate a % difference between the UV and non UV cases for the time it takes to drain the charge off the electroscope. Use the averages of each in the calculation.
Questions, Conclusions	1. Explain why the UV light does or does not affect the length of time it takes to drain the charge off the electroscope. 2. Could an electroscope be used for indicating the presents of ionizing radiation?
Resources/Materials:	Electroscopes, stop watches, UV radiation source

AP Physics C E&M Standards

A. Electrostatics (continued)...30%

1. Charge, field, and potential
2. Coulomb's law and field and potential of point charges
3. Fields and potentials of other charge distributions

a. Planar
b. Spherical symmetry *
c. Cylindrical symmetry *

4. Gauss's law *

Electric Field

Essential Question: How is knowledge of electric fields useful?

5. State the general convention for the type of charge used in defining electrical phenomena.
6. Define electric field and state how its equation is analogous to F = ma.

- Map of force on a + test charge
- E-field is a vector
- F = q E

7. Draw the electric field lines around point charges.
8. State the meaning of the arrows and the spacing between lines in an electric field diagram.
9. Use Coulomb's law to calculate the electric field around a point charge.
10. Calculate the electric field due to a

- thin concentric charged ring
- concentric charged disk
- infinitely large flat surface

Video: Demonstration of Electrostatic Percipitator

Show video of an electrostatic precipitator demonstration.

Why would the electric field be particularly strong around a pointed electrode?

Why are lightning rods generally pointed?

Homefun: prob 15, 19, 23, 41, 43 p.675-6 Serway

Formal Physics Investigation	
Title	Millikan Oil-Drop Experiment
Purpose	Determine the charge on an electron
Models	Various
Overview	Conduct the Millikan Oil-Drop Experiment according to the instruction sheet provided.
Safety Issues	The experiment uses a high voltage source which can be a shock

	hazard
Equipment Limitations	As always, the equipment is fragile.
Resources/Materials:	Millikan Oil-Drop Experiment apparatus and high voltage power supply

---

Charged Particle Kinematics

Essential Question: How is the kinematics of charged particles used in TVs ?

11. State the value of the e-field and force on a charged particle placed at any location above an infinitely large flat surface with a uniform charge.
12. Solve kinematic problems for a charged particle in a uniform e-field.
13. Solve projectile motion problems for a charged particle in a uniform e-field.
14. Solve mechanical energy problems for a charged particle in a uniform e-field.

Homefun: prob 37, 45, 51, 53

Mini-Lab Physics Investigation (Requires only Purpose, data, and conclusion)	
Title	Beam strength vs. distance behavior of a microwave transmitter
Purpose	Will a horn type microwave transmitter act like a point source and obey the inverse square law.
Overview	A horn type microwave transmitter is designed to transmit a beam of electromagnetic radiation. However, since microwaves can be modeled as a wave phenomenon they should tend to spread out as they propagate. at a sufficient distance the beam should spread out enough so that the microwaves' intensity begin to obey the inverse square relationship. Place the microwave source on the floor and align it with the receiver at various distances across the room measure the relative beam intensity and draw a graph of relative intensity vs. distance.
Data, Calculations	Perform linear and power regression analysis to determine if an inverse square law relationship exists in the data. Use residuals to gauge whether a given regression equation is appropriate.
Questions, Conclusions	1. How can you test the receiver and transmitter for alignment? 2. How does the electric field of the transmitter differ from the electric field of a point charge?

	3. Does the microwave transmitter create a magnetic field as well as an electric field?
Resources/Materials:	Microwave transmitter and receiver.

AP Physics C E&M Standards

A. Electrostatics (continued)...30%

1. Charge, field, and potential
2. Coulomb's law and field and potential of point charges
3. Fields and potentials of other charge distributions

a. Planar
b. Spherical symmetry *
c. Cylindrical symmetry *

4. Gauss's law *

Chapter 24

Gauss's Law

Essential Question: Why is it sometimes necessary to shield against electric fields?

1. Define electric flux.

    - A is considered a vector whose direction is normal to the surface.
    - Dot product between E-field and surface
    - Flux = E A cos(theta)

2. State the relationship between electric flux through a closed surface and the enclosed charge.

Homefun: Questions 1-7 p.699; Problems 1, 3, 7 p. 700

E-Fields in and around: *planes, non-conductive spheres, conductive spheres, and cylinders*

3. Solve for the electric flux created by a point charge through an infinitely large plane.
4. Solve for the electric flux created by a point charge next to finite sized plane.
5. Using Gauss's law derive the E-field around a point charge.
6. Derive an expression for the electric field inside and outside a charged "fuzzy" sphere.
7. State the electric field inside a conductor in electrostatic equilibrium.
8. Derive an expression for the E-field inside and outside a charged hollow sphere.
9. Derive an expressions for the E-field inside and outside both very long fuzzy cylinders and conductive cylinders.

Demo: Shielding

1. Turn on a transistor radio and place it a atop a clean paint can lid.
2. Slowly lower a clean empty paint can over the radio until the can contacts the lid.

Why does the radio lose its signal?

How is does the radio and can demo different from the Gauss's Law analysis of shielding?

Homefun: Problems 11, 15, 27 p. 700

E-Fields in and around: *planes, non-conductive spheres, conductive spheres, and cylinders*

10. Be as one with the info in table 24.1 p. 697.
11. Be as one with the four magic box points on pages 693, 694.
12. Derive an expressions for the E-field inside and outside both fuzzy and conductive concentric spheres.
13. Derive an expressions for the E-field inside and outside both fuzzy and conductive concentric cylinders.

Homefun: Problems 31, 39, 51 p. 700

Mini-Lab Physics Investigation (Requires only Purpose, data, and conclusion)	
Title	Investigation of Shielding Effectiveness
Purpose	Can shielding prevent unwanted electric fields from producing noise signals in wires?
Overview	Wrap about 3 feet of unshielded single conductor wire into a coil about 10 inches in diameter. connect the two ends to an oscilloscope and place the coil atop a similar sized coil of an extension cord plugged into the wall. Observe the noise signal

	picked up by the single conductor wire. Wrap an aluminum foil shield around the single conductor wire and connect one end of it to the oscilloscope's ground. Again observe the noise signal.
Data, Calculations	Record your observations
Questions, Conclusions	1. What does Gauss's Law indicate about the e-field inside a charged conductive surface in electrostatic equilibrium? 2. How does the above situation relate to the conditions of the experiment? What is different?
Resources/Materials:	Microwave transmitter and receiver.

AP Physics C E&M Standards

C. Electric circuits 20%

1. Current, resistance, power
2. Steady-state direct current circuits with batteries and resistors only
3.Capacitors in circuits
a. Steady state
b. Transients in RC circuits *

Ohm's Law (Chap. 27 Serway)

Essential Question: How are houses wired?

1. Describe the nature of the following terms:
   - **voltage** - electrical potential per unit of charge. **Note: voltage is not a force!**
   - **current** - flow of charge
   - **resistance** - tendency to restrict the flow of charge
2. Calculate resistance of a conductor: given length, resistivity, and cross sectional area.
3. State the resistance of both an ideal ammeter and an ideal voltmeter.

- **Ideal Voltmeter Resistance** = Infinity

Demo: Hot Dog Cooker

Demonstrate that a hot dog can be cooked by plugging it into a the wall outlet.

Questions:

1. What do resistors do to

- **Ideal Ammeter Resistance** = Zero

2. Use Ohm's law to analyze simple circuits with a resistor and DC power source.

I = V / R

Note: V = the voltage difference across a resistance = R. A resistor can have a million volts on each side (voltage difference = 0) and the current is will be zero.

2. Use Ohm's law and the relationship power = V * **I** to derive two additional power equations.
3. Solve for the heat loss in a current carrying piece of wire.
4. Use the 3 power equations and Ohm's law to analyze various types of simple circuits with a resistor and DC power source.
5. Explain the difference between a parallel and series circuit.
6. Correctly connect voltmeters and ammeters.

    - **Volt Meter's Connection:** in parallel
    - **Ammeter Meter's Connection:** in series

Note: **do not expect to pass this course unless you know how to use voltmeters and ammeters**

2. Correctly describe the current, power, and voltage conditions for resistance series circuits.

    - current = min
    - power = min
    - current = same for all resistance elements

8. Correctly describe the current, power, and voltage conditions for parallel resistance circuits.

    - current = max
    - power = max
    - voltage = same for all resistance elements

9. Solve for voltage, current and power in pure series or parallel resistance circuits.
10. Solve problems with batteries in series or parallel

    - **parallel** - same voltage, longer battery life: example: storage for solar cells
    - **series** - higher voltage; example: flashlight

electrical energy?
2. From an energy standpoint, why do microwave ovens work faster than standard ovens?
3. Can an appliance like a ceiling fan be modeled as a resistor?
4. Do ceiling fans cool or warm up rooms?
5. Is it useful to leave a ceiling fan on when no one is home?

Homefun: Questions (page 790-791) 2-9, 17, 18, 20; Prob. (page 790-791)3, 15, 21, 25, 43, 53

<table>
<tr><th colspan="2">Formal Physics Investigation</th></tr>
<tr><td>Title</td><td>Does a light bulb follow Ohm's Law?</td></tr>
<tr><td>Purpose</td><td>Determine if a a light bulb follow Ohm's Law.</td></tr>
<tr><td>Models</td><td>Ohm's Law.</td></tr>
<tr><td>Overview</td><td>For a device following Ohm's Law, a plot of current vs. voltage drop across the device will be linear with a slope = 1 / R. Regression analysis can give us a curve of best fit for the data along with an indicator of the fit's quality (R-square). Residuals analysis can indicate whether a linear fit is or is not appropriate. If it is not then the device being tested does not follow Ohm's law. (Note: if you have not taken AP Statistics Mr. Rogers will assist you with making the statistical analysis.)

1. Connect a variable DC power supply ammeter and voltmeter to a low voltage light bulb. Remember, the light bulb, power supply, and ammeter will be in series. The voltmeter will be connected in parallel with the light bulb. Note the power supply should be turned off and adjusted to its lowest voltage setting.
2. Turn the power supply on and slowly adjust the voltage upward while collecting current vs. voltage data points. Stop when the light bulb is at its rated voltage and is glowing brightly.
3. Plot a current vs. voltage drop curve for the device and perform regression analysis as well as residuals analysis.
4. Repeat the process for a commercial resistor.</td></tr>
<tr><td>Safety Issues</td><td>Shorting out the power supply can damage the unit and burn up wires. Remember, an ideal ammeter has a resistance = 0. If you connect it across the power supply without placing the light bulb or resistor in the circuit, the power supply will be shorted out. Putting excessive current through the resistor will overheat it and create a burn hazard.

Note: To prevent overheating of the elements in your circuit, turn the power switch off and adjust the voltage knob on the variable power supply to its lowest setting before connecting wires. When ready to start the experiment, turn the power switch on and adjust the voltage up slowly while monitoring the temperature of</td></tr>
</table>

	the circuit.
Equipment Limitations	Subjecting the light bulb to more than its rated voltage will burn it out. Remember, a light bulb glows because it reaches very high temperatures. If the bulb glows brightly and is then turned off it will take some time for it to return to its original temperature. This could affect your results. **Note: TURN THE MULTIMETER OFF WHEN FINISHED!** It is battery operated.
Resources/Materials:	12 volt light bulb, a resistor designed for high power, variable DC power supply, ammeter, multimeter (voltmeter), wires

---

AP Physics C E&M Standards

A. Electrostatics 30%

1. Charge, field, and potential
2. Coulomb's law and field and potential of point charges
3. Fields and potentials of other charge distributions

a. Planar
b. Spherical symmetry *
c. Cylindrical symmetry *

4. Gauss's law *

Electric Potential (Chap. 25 Serway)

Essential Question: How are maps of voltage and topographical maps related?

1. State whether electric potential is a vector or scalar and give its units.
2. Explain the difference between negative and positive work.
3. Write the generic electric potential difference equation.

- equation 25.3 (page 708)

$$V_p = -\int_A^B E \cdot ds$$

4. Explain the negative sign in the above equation.
5. Calculate potential differences by moving a charge to different locations in a uniform electric field.
6. Calculate the electric potential due to a point charge.
7. Calculate the electric potential from more than one point charges. **(Note: voltages are not vectors. the positive and negative sign on them does not have anything to do with spatial direction. Positive charges generate positive voltages, negative charges negative voltages.)**
8. Relate the electric field to electric potential mathematically and conceptually.
9. Given electric field lines sketch electric potential lines.

Homefun: p.731: 1, 3, 11,12, 33

10. Draw analogies between topographical maps and electric potential and field lines.

- Direction and speed of water flow when it rains.
- Elevation

Homefun: page 733-738; 27, 45, 55(hint: charge will floe until voltages are equal), 76, 80, 57

Electric Potential Fun with Fuzzy and Non-fuzzy Spheres and Cylinders

(Fuzzy stuff dejavu, yippy!)

Essential Question: Why can a bird land on a high voltage wire and not be electrocuted ?

11. Derive an expression for the electric potential of a uniformly charged:

- ring
- disc

12. Be aware that current, if there is any, will always flow in the direction of the E-field or from high voltage to low voltage. (In a given region, if E-field = 0 then DV = 0 but the voltage at individual points in the region does not have to = 0.)
13. Derive an expression for the electric potential inside and outside a:

- charged solid conductive sphere
- charged hollow conductive sphere
- uniformly charged nonconductive ("fuzzy") sphere.

14. Derive expressions for the potential inside:

- conductive cylinders

15. Be as one with table 25.1 on page 729.
16. Calculate the charge distribution when a charged conductive sphere is connected to an uncharged one. (Note: the charge stops flowing when the the voltage is the same on both spheres. p. 723)

Homefun: page 733-738; 27, 45, 55(hint: charge will flow until voltages are equal), 76, 80, 57

Mini-Lab Physics Investigation (Requires only Purpose, data, and conclusion)	
Title	Analysis of Circuits with Resistors in Parallel and Series
Overview	1. Determine if the equations for calculating the total resistance of series an parallel circuits actually work. 2. Configure 3 resistors in series and measure the total resistance of the circuit. 3. Configure 3 resistors in parallel and measure the total resistance of the circuit. 4. Configure two different combination parallel and series circuit with a minimum of 5 resistors in each circuit. Measure the total resistance of the circuit. Be sure to record a drawing of each circuit. Note: use the color code to select resistors, keeping in mind that you will not be able to measure total resistance if the resistance is too high or too low. However, measure the resistance of each with the multimeter and use this number in your calculations. **Note: TURN THE MULTIMETER OFF WHEN FINISHED!** It's battery operated.
Data, Calculations	Calculate a total resistance for each circuit configuration and a % difference from the measured value
Questions, Conclusions	1. Why is it better to use the measured values for each resistor when calculating the total resistance rather than using the official manufacture's values? 2. Why would we use the term "% differences" rather than "% error" ? 3. What assumptions are implicit in the models you used to calculate the total resistance? 4. What additional experimental errors did you introduce when using the multimeter?
Resources/Materials:	multimeter, various resistors, solderless breadboard

AP Physics C E&M Standards

C. Electric circuits (continued)..20%

1. Current, resistance, power
2. Steady-state direct current circuits with batteries and resistors only
3.Capacitors in circuits
a. Steady state
b. Transients in RC circuits *

DC Resistance Circuits (Chap. 28 Serway)

Essential Question: Is charge conserved?

1. Calculate the total resistance of circuits containing a mixture of parallel and series resistors.
2. Compare the purpose of a capacitor to the purpose of a resistor.

   - **Resistor** - dissipates electrical energy from the circuit as heat, similar to the way friction dissipates mechanical energy as heat.
   - **Capacitor** - stores and releases electrical energy in a circuit, similar to the way a spring stores mechanical energy.

3. Calculate the total capacitance of circuits containing a mixture of parallel and series capacitors.
4. Analyze DC resistance circuits containing only a batteries and resistors using Ohm's and Kirchoff's laws. (These are based on conservation of energy and conservation of charge laws.)

   - at a junction, current in = current out
   - the sum of voltages around a closed loop = 0

Homefun: 19, 31, 33 p. 822 -824

Demo: Capacitor Demo

Charge the large sized capacitor and use it to light a light bulb.

Questions:

1. Could large capacitors be used as a substitute for batteries in electric cars or electric hybrids?

Mini-Lab Physics Investigation (Requires only Purpose, data, and conclusion)	
Title	Investigation of Kirchoff's law
Purpose	Determine if the sum of the voltage drops around a closed loop = zero
Overview	Set up a circuit with a power supply and 3 loops in it, one big overall loop and 2 small ones (similar to a "B"). Place a known resistor in each segment of each loop. Measure the voltage drops around each segment for each loop to see if the voltage drops do indeed add up to zero. **Be careful not to short out the power supply.**
Data, Calculations	Collect the information for all 3 loops.
Questions, Conclusions	1. Can you calculate a % error for the sum of the voltages? 2. What assumption are you making about the voltmeter which will cause an error?
Resources/Materials:	multimeter, various resistors, solderless breadboard, variable power supply

---

AP Physics C E&M Standards

D. Magnetostatics..20%

1. Forces on moving charges in magnetic fields
2. Forces on current-carrying wires in magnetic fields
3. Fields of long current-carrying wires
4. Biot-Savart and Ampere's law *

Magnetic Field (Chap 29 Serway)

Essential Question: Can an electric motor be more efficient than a heat engine and how might this relate to the future of transportation?

1. Draw the magnetic field lines on a bar magnet. **Arrows go from N to S pole**

2. Explain what the magnetic field lines indicate. **The force on the N pole of a magnet**
3. State an important difference between magnetic field lines and electric field lines.
4. Calculate the magnitude of the force on a moving charge given its velocity and the strength of the magnetic field.

   F = qvxB

5. Using the right hand thumb rule state the direction of the force.
6. Give the relationship of teslas to gausses. 1 tesla = 10,000 gauss
7. Calculate the force on a current carrying wire in a B-field.

   F = ILxB

8. Explain why the net force on a current carrying loop in a B-field is zero.
9. Calculate the torque and direction of rotation on a current carrying loop of wire in a B-field.
10. Determine the motion of a charged particle traveling at constant velocity in a magnetic field.
11. State why a B-field cannot do work on a moving charge.
12. Solve problems with charged particles moving in both magnetic and electric fields.

Demo: PVC Arrows and Lorentz Force Demonstrator

Use the arrows made out of PVC pipe to illustrate how forces are created on moving charged particles.

Use the Lorentz Force Demonstrator to actually show the effect on a moving stream of electrons.

Homefun 5, 6, 13, 15, page 856

Mini-Lab Physics Investigation (Requires only Purpose, data, and conclusion)	
Title	Investigation of a simple DC Electric Motor
Purpose	Determine how to fabricate the coil on a simple DC electric motor so that it rotates when supplied with a voltage source.
Overview	Wind the enamel coated copper wire around the mandrel to make a coil as shown in the handout provided. This coil will be placed in the holder provided and become the rotor for a simple electric motor. Correctly scrape off the enamel coating on the coils electrical contact points. Remember, for a DC motor to work, Either the current must be reversed every half turn or the current must be turned on for only half a turn. Otherwise the torque will flip-flop and prevent the motor from rotating. The simple motor will turn the

	current on for half a turn. This is accomplished by scraping off the enamel coating on half of the circumference of the wire that makes contact with the electric power supply posts. Do this wrong and the motor will not turn. Place the the coil in its rack, connect the battery and give the coil a slight push to get it spinning. Watch the motor spin and be amazed. Hold a second magnet above the fixed one in the motor's base an record your observations (see the questions below). Be careful not to hit the rotating coil while holding the second magnet.
Data, Calculations	There are no calculations. However, If your motor does not spin you will receive an "F". Every time you have to remake the coil, you grade will decline by one letter. The message: THINK carefully about how the motor woks before you scrape off the enamel to form contacts so that current can flow in the coil.
Questions, Conclusions	1. Did the direction you pointed the magnet (with respect to the magnet's north pole) affect the motor's motion? Explain your answer. 2. Did you feel a sideways force on the magnet? If so, describe and explain it.
Resources/Materials:	multimeter, various resistors, solderless breadboard, variable power supply

Essential Question: How are properties like temperature, pressure, etc. actually measured?

Using E&M Principles in Measuring Instruments

13. Design velocity selectors for charged particles. (These are used in mass spectrometers.)
14. Using the velocity selector calculations with centripetal motion and force on a moving charge calculations, make the basic design calculations for a mass spectrometer. (Note: mass spectrometers are considered one of the most sensitive and accurate ways to identify unknown substances or to measure very tiny amounts of a known substance, such as in air pollution monitoring.)
15. Describe the hall effect. (This effect is used in many forms of transducers including magnetic field measuring devices.)
16. Describe the effects of moving a conductor in a magnetic field.

Homefun 17, 21, 25, 29, page 857-8

Mini-Lab Physics Investigation (Requires only Purpose, data, and conclusion)	
Title	Investigation of Magnetic Fields with a Hall Effect Transducer
Purpose	Measure various magnetic fields with a Hall effect transducer.
Overview	1. Connect a hall effect transducer to the Labpro computer system. 2. Hold the probe vertically and slowly rotate it while having the computer graph the probe's output. 3. Connect a light bulb to the power supply and make the bulb glow brightly. Place the hall effect probe in close proximity to the one of the current carrying wires and measure the direction of the magnetic field around the wire.
Data, Calculations	1. Retain the plot from step 2 2. Sketch the magnetic field around the wire as indicated by the Hall effect probe.
Questions, Conclusions	1. Why does the plot from step 2 in the overview look like a sine wave (assuming you rotated the probe at constant rotational velocity)? 2. Did the magnetic field around the current carrying wire match with expectations?
Resources/Materials:	light bulb, computer system set up with Vernier LabPro software and Lab Pro units, variable power supply

Formal Physics Investigation	
Title	Measurement of the Mass to Charge ratio of an Electron
Purpose	Measure the mass to charge ratio of an electron using a Lorentz Force Demonstrator (looks like a giant light bulb).
Models	Various
Overview	In the Lorentz Force Demonstrator a stream of electrons are accelerated across a known voltage difference into a magnetic field perpendicular to the electron stream so that the electrons travel in a circular path. The magnetic field is provided by a pair of coils as follows:

	Radius = 280 mm Number of loops in each coil = 140 Distance between coil = 140 mm Measure the radius of the circulating electrons and calculate the charge to mass ratio of an electron. Have the teacher tilt the magnetic field so that it is no longer perpendicular to the electron's inlet velocity. Obsearver, record, and explain the effects as part of the lab write up.
Safety Issues	**Note:** The equipment is extremely expensive and extremely fragile do not move it from the position where it was placed by the teacher. Be careful not to stumble over the extension cord.
Equipment Limitations	The equipment is designed to operate for no more than an hour continuous.
Resources/Materials:	Lorentz Force Demonstrator (looks like a giant light bulb).

AP Physics C E&M Standards

D. Magnetostatics (continued)..20%

1. Forces on moving charges in magnetic fields
2. Forces on current-carrying wires in magnetic fields
3. Fields of long current-carrying wires
4. Biot-Savart and Ampere's law *

Sources of Magnetic Fields (Chap30 Serway)

Essential Question: Can the electric lines interfere with the telephone transmissions?

1. Describe the magnetic field around a long thin current carrying wire.
2. Calculate the magnetic field around a long thin current carrying wire.

3. Describe and calculate the forces on two parallel long thin current carrying wires.

    - current in same direction: wires pulled together

- current in opposite direction: wires pushed apart

4. Calculate the magnetic field along an axial line through the center of a loop of current carrying wire.
5. Explain the Biot Savort law.

   $dB = k_m I\ ds \times (r\text{-hat}) / r^2$

6. Relate k_m to μ_o the permeability of free space.

   $k_m = \mu_o / 4\pi$

7. Explain Ampere's law.
8. Apply all three right hand thumb rules.

Homefun 7, 29

Mini-Lab Physics Investigation (Requires only Purpose, data, and conclusion)	
Title	Investigation of "Twiddler's Delight"
Purpose	Determine the mechanism that accounts for the behavior of the blue and red "Twiddler's Delights"
Overview	A Twiddler's Delight comes in 2 varieties red and blue. They look like cylinders with a movable shaft protruding from each end. Twist one shaft and something happens to the other. Start by simply playing with the Twiddler's Delight and developing a hypothesis for how the device works. Next devise a simple experiments to test your hypothesis. Briefly record your procedure, what you observed, and what you learned from each experiment The rules are that you can do nothing invasive. For example, you can't remove parts. drill holes, or in any way disect or modify the device.
Data, Calculations	See above.
Questions, Conclusions	Record you conclusion about how the device works.
Resources/Materials:	red and blue "Twiddler's Delights"

AP Physics C E&M Standards

E. Electromagnetism 16%

1. Electromagnetic induction (including Faraday's law and Lenz's law)
2. Inductance (including LR and LC circuits) *
3. Maxwell's equations *

Sources of Magnetic Fields (continued)

Essential Question: Can a magnetic field be used to create a force on an object?

Solenoids

9. Calculate the B- Field inside a torrid p.873
10. Calculate the B- Field inside a solenoid p. 876.
11. Solve for the forces on a rectangular current carrying loop of wire next to a long thin current carrying wire in the same plane as the loop.(p.874).

Homefun Prob 23, 25 p.895

Magnetic Flux

11. Mathematically define magnetic flux.

$$\Phi_B = \int B \bullet dA$$

11. Explain briefly how a transformer works and why it requires an AC input.
12. Calculate the magnetic flux through a loop of wire next to a long thin current carrying wire in the same plane (p.878).
13. State Gauss's law for magnetism.

$$\oint B \bullet ds = 0$$

Demo: Tesla Coil

Use a Tesla coil to light up a florescent tube from a distance.

Questions:

1. Both a Tesla coil and a Van de Graaff Generator generate high voltages. What is the difference between a Van de Graaff Generator and Tesla coil?

Essential Question: How would society be different if Faraday's Law of induction did not exist ?

Faraday's Law (Chap31 Serway)

13. State and apply Faraday's Law of Induction. Describe how magnetic flux can be altered with respect to time. **(This is the principle of physics that enables us to generate electrical power.)**

$$\varepsilon = - d\Phi_B / dt$$

Homefun prob 1, 5 p.927

Formal Physics Investigation	
Title	Measurement of the acceleration due to gravity using a solenoid.
Purpose	To observe Faraday's law of induction by dropping a magnet through a solenoid.
Overview	1. Connect the terminals of the solenoid to the the LabPro voltage probe. 2. Place the tip of the magnet at the entrance to the solenoid 3. Drop the magnet completely through the solenoid and record the voltage transient. 4. Repeat the process several times except this time sop the magnet at various distances inside the solenoid using the ball of modeling clay. Again record the transient.
Data, Calculations	By comparing the recordings in step 4 with the original trace, it should be possible to identify the position of the magnet at any points in the voltage where the voltage crosses the axis an goes from positive to negative or vice versa (flips polarity). indicate the magnet's position at these points. Write a short explanation for the transient's appearance noting anything of interest including any points where the voltage flips polarity.
Questions, Conclusions	Magnets can become demagnetized by repeated impacts. Take appropriate precautions' to pad the impact of the magnet when it lands after falling through the solenoid.
Resources/Materials:	Solenoid, cow magnet, meter stick, ball of modeling clay, spacers, computer system set up with Vernier LabPro software and Lab Pro units

Lenz's Law - *There's no free lunch*

14. State the direction of current in a loop of wire passing through a magnetic field.
15. State Lenz's Law.

Demo: Lenz's Law

1. Drop a magnet down a

16. Use Lenz's Law to determine the direction of current flow in loops of wire with changing magnetic fluxes.

Homefun prob 49 p.933

copper tube and note the time to fall.
2. Drop a piece of steel the same size as the magnet down and compare the time of falling to the first case.
3. Note that the magnet drifts downward much more slowly than the non magnet

Generating Voltages With B-Fields

17. Solve motional EMF problems. For a bar of length L moving at constant velocity perpendicular to a B-field:

$F_E = q\, v\, B$,

ε = work done by F_E per unit of charge

$F_E (L) / q = v\, B\, L$

- Rotating bar (note: $v = r\,\omega$)
- Sliding bar (note: v = terminal velocity)
- Rotating loop (note: $\Phi_B = B\, A \cos\theta$)
- Loop sliding at constant velocity through a constant B-field (p. 917)

18. Use Lenz's Law to calculate forces in motional EMF problems.

Key Principle: mechanical power in = electrical power out (in other words rate of energy converted to heat by the circuit's resistance)

Demo: Hand Cranked Generator

1. Attach a hand cranked generator to a low voltage light bulb.
2. Crank the generator until the bulb glows brightly.
3. Crank the generator with nothing attached.

Questions:

1. Why is there a sense of resistance when cranking the generator while attached to the light bulb but not while attached to nothing?
2. The generator converts mechanical energy into electrical energy. Is it 100% efficient and could it ever be?
3. How is the energy conversion different with the generator vs. the process of converting heat to work done by a heat engine?

Homefun prob 23, 25, 27 p. 929

Formal Physics Investigation	
Title	Investigation of an AC alternator

Purpose	Determine the relationship between the frequency output and amplitude of an AC alternator spinning at various rates of rotation.
Overview	The modified 5 1/4 inch floppy drive has a DC motor with and integral AC alternator built into the back of the motor. The alternator generates a sine wave voltage output, which at one time was used as a speed control signal for the motor. The alternator is now attached to a BNC jack that can be connected with a coaxial cable to an oscilloscope. 1. Attach the alternator to the oscilloscope and a variable power supply to the DC motor. 2. Run the motor at various speeds and record the amplitude and frequency from the oscilloscope.
Data, Calculations	Plot the amplitude of the alternator's output vs. the frequency.
Questions, Conclusions	Why would the frequency be directly proportional to the alternator's rate of rotation? Why would the amplitude of the sine wave increase with the rate of rotation. Describe the relationship between the amplitude and frequency on your plot. Is it linear or non linear and why?
Resources/Materials:	Modified floppy drive, coaxial jumper, banana plug wires, variable power supplies, oscilloscope

Essential Question: Why is it essential to have mathematical models for wireless communication ?

Maxwell Equations

19. Describe the electric field from an EMF induced by a magnetic field and state its general form.

$$\oint E \bullet ds = - d\Phi_B / dt$$

20. Calculate the electric field for a circular loop with a variable current $I = I_o \cos \omega t$.
21. Be as one with the 4 Maxwell equations (p. 924).

Demo: Dipole Antennae

Use a dipole antennae connected to a business band radio transmitter to light a nearby florescent tube without making contact with it.

Questions:

1. Can power be transmitted wirelessly?

AP Physics C E&M Standards

C. Electric circuits (continued)..20%

1. Current, resistance, power
2. Steady-state direct current circuits with batteries and resistors only
3.Capacitors in circuits

a. Steady state
b. Transients in RC circuits *

Essential Question: What is a capacitor and why should we care?

How to Design Giant Capacitors (Chap26 Serway)

1. Define capacitance mathematically (p. 743).

   $C = Q/V$

2. Calculate capacitance for a parallel plate capacitor (p. 743).

   $C = K * \varepsilon_o * A/d$

3. Calculate the energy stored in a capacitor.

   U = 1/2 *C*V^2

4. Calculate and describe the E-field in a capacitor.
5. Solve capacitor circuit problems.
6. Solve problems in which dielectric material is inserted or removed (p.751).

   Battery Attached: voltage = constant, charge = variable
   Battery Detached: voltage = variable, charge = constant

Homefun: Questions 1-10 p. 762; prob. 11, 15, 29, 33, 73 p.764-769

Video: Demonstration of Electrostatic Percipitator

Show video of various capacitor demonstrations. Explain that a capacitor is an energy storage device like a spring.

Questions:

1. Why would a capacitor be useful in power supply designed to convert AC into DC?
2. What type of power do most electronic devices use internally?
3. What is the most obvious way to increase the capacitance of a capacitor without

changing the volume of the device. In other words, without making it large.

Essential Question: How are resistors, capacitors, and inductors analogous to elements in mechanics?

RC Circuits

5. State how a capacitor behaves at time = 0 and infinity.
6. Solve RC circuit problems using the above principle for how capacitors behave at time equals zero and infinity.
7. Use the above principles to sketch the following curve for a charging capacitor:

   - charge vs time
   - current vs time

8. Use the above principles to sketch the following curve for a discharging capacitor:

   - charge vs time
   - current vs time
   - voltage vs time

9. Using Kirchhoff's Law, write the differential equation for an RC circuit (p.808).

   $\varepsilon = q / C$ for a capacitor

   $\varepsilon - IR - q / C = 0$ for an RC circuit

10. For a charging RC circuit (p.808) Calculate the following:

    - charge vs time
    - current vs time
    - time constant

11. For a discharging RC circuit (p.808) Calculate the following:

    - charge vs time
    - current vs time

- voltage vs time
- time constant

12. Describe how time constant could be used to measure the capacitance of an unknown capacitor.

τ = RC

Homefun prob. 43, 44, 45 p. 824

Formal Physics Investigation	
Title	Investigation of the Discharging Curve for a Capacitor
Purpose	To estimate the capacitance of a capacitor using time constant and a voltage drop vs time curve for capacitor discharging through a known resistor.
Models	= RC, $v = v_o\ e^{-t / RC}$
Overview	1. Turn the power supply to its lowest voltage setting. (We will be using only DC voltage). 2. With the power supply off, connect the positive terminal of the capacitor to a resistor and the resistor to the positive terminal of the power supply. Complete the circuit by connecting the negative terminal of the power supply to the negative terminal of the capacitor. 3. Connect the Vernier voltage probes to the capacitor just like a voltmeter. 4. Turn on the power supply and charge the capacitor to 6 volts while collecting data on the charging curve. 5. Disconnect the power supply and discharge the capacitor through the resistor while collecting data with the Vernier system.
Safety Issues	Unlike batteries, capacitors can discharge their energy almost instantaneously. Shorting one out will very likely result in equipment damage and possibly a fire. **Capacitors must be both charged and discharged through a resistor or damage will result.**
Equipment Limitations	Do not exceed 10 volts. Higher voltages may damage the LabPro's electronics
Resources/Materials:	Large sized capacitor, resistor of known value, computer system set up with Vernier LabPro software and Lab Pro units, wires, power supply

AP Physics C E&M Standards

E. Electromagnetism (continued)..16%

1. Electromagnetic induction (including Faraday's law and Lenz's law)
2. **Inductance (including LR and LC circuits) ***
3. Maxwell's equations *

LR Circuits (Chap. 32 Serway)

**AP Physics C E&M Standards - ** E. Electromagnetism (16 %), 2. Inductance (including LR circuits)

13. State how an inductor behaves at time = 0 and infinity.
14. Solve LR circuit problems using the above principle for how capacitors behave at time equals zero and infinity.
15. Use the above principles to sketch the current vs time for a charging inductor:
16. Use the above principles to sketch the current vs time and voltage vs time curve for a discharging inductor:
17. For a charging LR circuit (p.944) Calculate the following:
    - current vs time
    - time constant
18. For a discharging LR circuit (p.944) Calculate the following:
    - current vs time
    - voltage vs time
    - time constant
19. Describe how time constant could be used to measure the inductance of an unknown inductor.

    τ = RC

20. Calculate the energy stored in an inductor.

Hollywood Video Clip: The Core

Show a video clip of the Virgil's crew communicating with the surface from deep within the Earth.

Questions:

1. How could a vehicle communicate with the surface from inside the Earth?
2. Is there such a thing as a radio controlled submarine?

The Skin Depth Equation (Wikipedia)

The current density J in an *infinitely thick* plane conductor decreases exponentially with depth δ from the surface, as follows:

$$J = J_S \, e^{-\delta/d}$$

where d is a constant called the *skin depth*. This is defined as the depth below the surface of the conductor at which the current density decays to 1/e (about 0.37) of the current density at the surface (J_S). It can be calculated as follows:

$$d = \sqrt{\frac{2\rho}{\omega\mu}}$$

where

ρ = resistivity of conductor

U_L = 1/2 L dI/dt

Homefun 17, 19, 21 p. 957

ω = angular frequency of current = 2π × frequency
μ = absolute magnetic permeability of conductor $= \mu_0 \cdot \mu_r$, where μ_0 is the permeability of free space and μ_r is the relative permeabilty of the conductor.

Essential Question: Can an electrical circuit resonate and why would this be important?

LC and RLC Circuits (Chap. 32 Serway)

20. Write an energy balance equation for an LC circuit. (see the Physics of Resonance - Electrical Circuits, also see p. 949 Serway))

$U = U_C + U_L$

$U = Q^2/(2C) + I^2 (L / 2)$

21. Calculate the frequency of an LC circuit.

$f = 1 / [2\pi (LC)^{0.5}]$

22. Draw an analogy between an LC circuit and a spring and mass system.
23. Draw an analogy between an RLC circuit and a spring and mass system.

Electrical		Mechanical	
Capacitance C	(1/C) q	Spring	(k) x
Resistance R	(R) dq/dt	Viscous damper	(b) dx/dt
Inductance L	(L) d^2q/dt^2	Inertia	(m) d^2x/dt^2

22. Explain the difference between dampening and damping.

Demo: Crystal Radio

Demonstration from The Physics of Resonance.

1. Briefly explain how a crystal radio works.
2. Connect a crystal radio to an oscilloscope. Inductively couple a DC power supply to the crystal radio and give it a pulse.
3. Observe the decaying sine wave.

The crystal radio is configured to resonate at the radio station's frequency it is tuned to. Subjecting the radio to a pulse is like striking a bell: these respective action cause the both the bell and the electrical circuits to resonate with the bell emitting sound at its natural frequencies and the radio emitting radio waves.

Questions:

1. Why does an extremely strong electromagnetic pulse of energy, such as would be produced by an atomic bomb tend to wipe out wireless communication?

AP Test Review

The AP Test Review Process

Most of the 4th quarter will be devoted to AP test Review. While a full quarter for review may sound like a lot, keep in mind that the test will be in May, hence, we will lose about a month of possible classroom time. Also we lose a week for spring break in the 4th quarter.

What it takes to Pass the AP Test

The AP Physics C test is the toughest test offered (based on correlations between PSAT scores and AP passing rates). Not only is it a difficult test but it has a great deal of time pressure. Do not be deceived by the low scores required for passing, the test is hard to pass.

On the other hand, with commitment, passing the AP Physics test is not only doable but is a

Passing the AP test is a goal worthy of review time, however, review is also an excellent way to gain a deeper understanding. Unlike earlier home work and class work problems, AP test problems often merge several problem types into a single problem with multiple steps. In many cases, it's not possible to work these problems until most of the subject has been covered.

See below for more details on the review process.

badge of honor that will be noticed by college recruiters. Whether you pass or not, you will definitely be better off for having made the effort.

AP Physics C Mechanics Scores

AP Grade	1988 % Correct	1993 % Correct	1998 % Correct	2004 % Correct
5	57-100	62-100	54-100	50-100
4	38-56	44-61	39-53	33-49
3	27-37	32-43	29-38	26-32
2	14-33	17-31	17-28	16-25
1	0-13	0-16	0-16	0-19

Free Response Question Preparation

Daily Class Work: You will work a minimum of 9 sets of free response problems from old tests in class on the white board at the front of the room under Mr. Rogers' guidance. All problems will be graded as you complete them. You will be asked to keep a running tally of your scores to continuously ascertain your extent of readiness. Mr. Rogers will re-teach material as deemed necessary. Problem sets can be found online at the AP Physics C Mechanics section of the American College Board site or will be provided by Mr. Rogers.

To get the best benefit from the in-class practice you will need to re-work as homework any problems you had difficulty with. It is often better to return to the same problem multiple times and completely understand it than work problem after problem with only partial understanding.

Quizzes: Mr. Rogers will periodically give quizzes on free response problems. These will consist of a free response problem selected at random from those that have been worked. Quizzes will not be curved and will count 15 points each just like those on the AP test.

Multiple Choice Question Preparation

Weekly In-Class Tests: An actual multiple choice AP test from previous a year will be given approximately once per week starting near the end of March (four tests total). These will count 100 points each toward your grade. They will be curved to approximate an AP grading system. At worst 50% correct will be a "C". In addition, each student will receive an estimate from 1 to 5 of their future grade based on each test.

Take-Home Tests: A minimum of 2 multiple choice AP-type take-home tests will be given. These will count 50 points each and be curved but not as generously as the in-class tests. Your work is to be turned in on each question. You may collaborate with other students and may compare answers but only if each person has actually worked the problem and written down their work. Allowing a student to simply copy your answers is strictly forbidden and may result in a grade of zero for both of the students involved.

The Good News: The highest in-class test will be cloned to help compensate for having a bad day. Take-home tests will not be cloned.

Out-of-Class Guided Study Sessions

Mr. Rogers will typically offer numerous after school and Saturday guided study sessions. He has free response test sets going back to 1973 as well as additional study books other than the Barron's and Princeton Review books. There is little chance of running out of materials. Anyone whose test and in class practice grades falls below those needed for passing the AP test is expected to attend.

Self Study

As mentioned on the first page, you will not reach your potential on the AP test without a lot of self study. This AP test study should start in December. At that time you should be practicing the multiple choice practice tests in the Barron's AP review book provided by Mr. Rogers. These questions are close to those actually found on AP tests.

In March you should begin working multiple choice practice problems in the Princeton Review book you have purchased. Mr. Rogers recommends that you read the entire section of the Princeton Review book's section on AP Physics C Mechanics some time in April.

After the AP Exam

Typically we will have a few weeks left after the AP Test. Students will be required to attend class during this time. First we will catch up on any investigations physics we are behind on. In the event that we are totally caught up, we will start on next years topics.