SYLLABUS DEVELOPMENT GUIDE

AP® Physics C: Electricity and Magnetism

The guide contains the following sections and information:

Curricular Requirements

The curricular requirements are the core elements of the course. A syllabus must provide explicit evidence of each requirement based on the required evidence statement(s). The Unit Guides and the “Instructional Approaches” section of the *AP® Physics C: Electricity and Magnetism Course and Exam Description* (CED) may be useful in providing evidence for satisfying these curricular requirements.

Required Evidence

These statements describe the type of evidence and level of detail required in the syllabus to demonstrate how the curricular requirement is met in the course.

Note: Curricular requirements may have more than one required evidence statement. Each statement must be addressed to fulfill the requirement.

Clarifying Terms

These statements define terms in the Syllabus Development Guide that may have multiple meanings.

Samples of Evidence

For each curricular requirement, three separate samples of evidence are provided. These samples provide either verbatim evidence or clear descriptions of what acceptable evidence could look like in a syllabus.

Curricular Requirements

CR1	Students and teachers have access to college-level resources including a college-level textbook and reference materials in print or electronic format.	*See page:* 3
CR2	The course provides opportunities to develop student understanding of the required content outlined in each of the Unit Guides of the AP Course and Exam Description.	*See page:* 4
CR3	The course provides opportunities for students to develop the skills related to Science Practice 1: Visual Interpretation.	*See page:* 6
CR4	The course provides opportunities for students to develop the skills related to Science Practice 2: Question and Method.	*See page:* 7
CR5	The course provides opportunities for students to develop the skills related to Science Practice 3: Representing Data and Phenomena.	*See page:* 8
CR6	The course provides opportunities for students to develop the skills related to Science Practice 4: Data Analysis.	*See page:* 9
CR7	The course provides opportunities for students to develop the skills related to Science Practice 5: Theoretical Relationships.	*See page:* 10
CR8	The course provides opportunities for students to develop the skills related to Science Practice 6: Mathematical Routines.	*See page:* 11
CR9	The course provides opportunities for students to develop the skills related to Science Practice 7: Argumentation.	*See page:* 12
CR10	The course provides students with opportunities to apply their knowledge of AP Physics concepts to real-world questions or scenarios to help them become scientifically literate citizens.	*See page:* 13
CR11	Students spend a minimum of 25 percent of instructional time engaged in a wide range of hands-on laboratory investigations with an emphasis on inquiry-based labs to support the learning of required content and development of science practice skills throughout the course.	*See page:* 14
CR12	The course provides opportunities for students to record evidence of their scientific investigations in a portfolio of lab reports or a lab notebook (print or digital format).	*See page:* 17

Curricular Requirement 1

Students and teachers have access to college-level resources including a college-level textbook and reference materials in print or electronic format.

Required Evidence

- ☐ The syllabus must cite the title, author, and publication date of a calculus-based, college-level textbook.

Samples of Evidence

1. *Physics for Scientists and Engineers*, Knight, 4th edition (2018).

2. Samuel J. Ling, Truman State University; William Moebs, Formerly of Loyola Marymount University; Jeff Sanny, Loyola Marymount University.

   OpenStax University Physics Volume 2, Oct 06, 2016.

   ISBN-10: 1-947172-21-2

   ISBN-13: 978-1-947172-21-0

3. The syllabus cites a calculus-based textbook from the example textbook list for AP Physics C: Electricity and Magnetism located on AP Central.

Curricular Requirement 2

The course provides opportunities to develop student understanding of the required content outlined in each of the Unit Guides of the AP Course and Exam Description.

Required Evidence

☐ The syllabus must include an outline of the course content using any organizational approach that demonstrates the inclusion of all required course topics and big ideas listed in the AP Course and Exam Description (CED). (See the "Course at a Glance" pages in the CED for charts showing units and their respective big ideas and topics.)

Samples of Evidence

1. Unit 1: Electrostatics
    a. Electric charge, Coulomb's law (ACT)
    b. Electric fields, Gauss's law, and electric fields of other charge distributions (FIE)
    c. Electric potential, electric potential due to point charges, and uniform fields (CNV)

    Unit 2: Capacitors, conductors, and dielectrics
    a. Electrostatics with conductors (ACT)
    b. Capacitors (CNV)
    c. Dielectrics (FIE)

    Unit 3: Electric Circuits
    a. Current, Resistance, and Power (FIE)
    b. Steady-state DC circuits with batteries and resistors only (CNV)
    c. RC circuits (CNV)

    Unit 4: Magnetic Fields
    a. Forces on Moving Charges in Magnetic Fields (CHG)
    b. Forces on Current Carrying Wires in Magnetic Fields (FIE)
    c. Fields of Long Current Carrying Wires (FIE)
    d. Biot-Savart Law and Ampère's Law (CNV)

    Unit 5: Electromagnetism
    a. Electromagnetic induction, including Faraday's Law and Lenz's Law (CNV, FIE)
    b. Inductance and RL circuits (CNV)
    c. Maxwell's equations (FIE)

2. Electrostatics (Unit 1) including charge and Coulomb's Law, Electric Field and Electric Potential, Electric Potential Due to Point Charges and Uniform Fields, Gauss's Law, and Fields and Potentials of other charge distributions

    In the Electricity part of this course, Big Ideas 2, 4 and 3 will be explored as we study charges in conductors and insulators, capacitors and dielectrics, respectively.

    Electric circuits (Unit 3) including current, resistance, power, steady state DC circuits with batteries and resistors only, and capacitors in circuits.

Magnetic Forces and Fields

Motion of a charged particle in a magnetic field (Big Idea 1)

Force on a current-carrying conductor in a magnetic field (Big Idea 3)

Biot-Savart Law and applications (Big Idea 4)

Ampère's Law and applications (Big Idea 4)

Electromagnetism (Unit 5) including electromagnetic induction, Faraday's Law, Lenz's Law, Inductance with RL circuits, and Maxwell's Equations

3. In unit 1 Coulomb's Law is taught alongside gravitation as part of AP Physics C: Mechanics. Electric fields of simple charge configurations as well as the use of Gauss' Law is covered. Calculus is used to relate electric fields and electric potential.
   - Big Idea Interactions is developed by investigating the behavior of charged particles near various other charge configurations.
   - Big Idea Fields is developed by plotting and interpreting electric field diagrams.

   In unit 2 capacitors and capacitance is covered. Capacitance as a function of geometric configurations of charges as well as dielectrics will be covered. Specifically, parallel plate, spherical, and cylindrical capacitors will be analyzed.
   - Big Idea Fields is developed by analyzing the electric field produced by a capacitor.
   - Big Idea Conservation is developed by analyzing the movement of charges within a capacitor.

   In unit 3 quantitative and qualitative analysis of current, resistance, and power in DC circuits is covered. Specifically included are circuits with multiple branches, combinations of resistors and capacitors and switches, as well as non-ideal batteries. Differential equations to describe current and electric potential in a charging or discharging RC circuit with respect to time will be covered.
   - Big Idea conservation is developed by analyzing the potential difference within circuits as well as current in various circuits

   In unit 4 topics such as magnetic fields, magnetic fields produced by moving charges, and the magnetic field produced by a current carrying wire will be covered. Calculus approaches to describing the magnetic field using the Biot-Savart Law as well as Ampère's Law will be covered.
   - Big Idea Change is developed by investigating the change in motion of charged particles as they move within a magnetic field.
   - Big Idea Fields is developed by qualitatively mapping the magnetic field of a current carrying wire with a magnetic compass.

   In unit 5 topics such as magnetic flux, Faraday's Law, Lenz's Law, Maxwell's equations, and solenoids are covered. Calculus is used to relate a time-varying magnetic field or flux to the resulting emf and electric current. Inductors are studied as an application of these laws, and their behavior in electric circuits is analyzed. RC and RL circuits are compared, and the relation of LC circuits to SHM studied in previous courses is discussed as an additional topic of interest.
   - Big Idea Interaction is developed by building a simple electric motor and observing the behavior of current, motion of the solenoid, and the steady magnetic fields.
   - Big Idea Conservation is developed by analyzing the energy of a cart-loop system as it passes through a magnetic field.

Curricular Requirement 3

The course provides opportunities for students to develop the skills related to Science Practice 1: Visual Interpretation, as outlined in the AP Course and Exam Description (CED).

Required Evidence

- ☐ The syllabus must include one assignment, activity, or lab describing how students analyze and/or use nonnarrative/nonmathematical representations of physical situations, excluding graphs.
- ☐ The assignment, activity, or lab must be labeled with the relevant skill(s) (e.g., "1.B") associated with Science Practice 1. As long as one skill under Science Practice 1 is represented, evidence is sufficient.

Samples of Evidence

1. As students learn about electric field, electric force, and electric potential, they will be provided with activities that help them move between different representations (for example, free-body diagrams of the charges, electric field, and potential diagrams). **(Skills 1.B, 1.C)**

2. Students will create a map of electric potentials in the lab and determine the direction of the electric fields from the equipotential lines. **(Skills 1.C, 1.D)**

3. Students will interpret and analyze free-body diagrams to determine the electric force between two charges hanging on a string. **(Skills 1.A, 1.D)**

Curricular Requirement 4

The course provides opportunities for students to develop the skills related to Science Practice 2: Question and Method, as outlined in the AP Course and Exam Description (CED).

Required Evidence

- ☐ The syllabus must include one assignment, activity, or lab describing how students determine scientific questions and methods.
- ☐ The assignment, activity, or lab must be labeled with the relevant skill(s) associated with Science Practice 2. As long as one skill under Science Practice 2 is represented, evidence is sufficient.

Samples of Evidence

1. **Electric Circuits Lab**

   In this guided inquiry-based laboratory investigation, students design and set up circuits to investigate and observe how modifications in circuits affect how elements of the circuits behave. Specifically, students will build and measure voltage, current, and resistance in electrical circuits and determine whether the behavior of these circuits is "ohmic." **(Skills 2.A, 2.B, 2.C, 2.D, 2.F)**

2. **Capacitance Investigation**

   Students design an experiment to verify the claim that increasing the distance between plates on a capacitor will decrease the capacitance. **(Skills 2.A, 2.B, 2.C, 2.D)**

3. **Science Fair Experiment**

   In this activity, Science Practice 2: Question and Method is emphasized, developed, and addressed with its corresponding skills.

   Students will identify a testable scientific question, claim, or problem gleaned from the AP Physics C: Electricity and Magnetism topics and/or enduring understandings. They will design and carry out the experiment and present their experiment at the school science fair in May. **(Skills 2.A, 2.B, 2.C, 2.D, 2.E, 2.F)**

Curricular Requirement 5

The course provides opportunities for students to develop the skills related to Science Practice 3: Representing Data and Phenomena, as outlined in the AP Course and Exam Description (CED).

Required Evidence

- ☐ The syllabus must include one assignment, activity, or lab describing how students create visual representations or models of physical situations.
- ☐ The assignment, activity, or lab must be labeled with the relevant skill(s) associated with Science Practice 3. As long as one skill under Science Practice 3 is represented, evidence is sufficient.

Samples of Evidence

1. Students will create free-body diagrams to determine the electric force between two charges hanging on a string. **(Skills 3.D)**

2. Students will determine the magnetic field of several magnets and graph an appropriate 3-D surface map to visualize the magnetic field. **(Skills 3.B, 3.D)**

3. Using a single resistor, students will sketch a graph of relevant physical quantities to verify Ohm's law and then measure and plot the identified quantities. **(Skills 3.A, 3.C)**

Curricular Requirement 6

The course provides opportunities for students to develop the skills related to Science Practice 4: Data Analysis, as outlined in the AP Course and Exam Description (CED).

Required Evidence

- ☐ The syllabus must include one assignment, activity, or lab describing how students analyze quantitative data represented in graphs.
- ☐ The assignment, activity, or lab must be labeled with the relevant skill(s) associated with Science Practice 4. As long as one skill under Science Practice 4 is represented, evidence is sufficient.

Samples of Evidence

1. Students will design an experiment using a variable power supply to convert a galvanometer into a voltmeter and calibrate it based on the collected data represented in graphical form. **(Skills 4.A, 4.D)**

2. While studying capacitors, students will use the data they have graphed to determine the equation for calculating capacitance. **(Skills 4.A, 4.D, 4.E)**

3. Students will design a lab with a solenoid to determine μ_0 by graphing. **(Skills 4.C, 4.D, 4.E)**

Curricular Requirement 7

The course provides opportunities for students to develop the skills related to Science Practice 5: Theoretical Relationships, as outlined in the AP Course and Exam Description (CED).

Required Evidence

- ☐ The syllabus must include one assignment, activity, or lab describing how students determine the effects on a quantity when another quantity or the physical situation changes.
- ☐ The assignment, activity, or lab must be labeled with the relevant skill(s) associated with Science Practice 5. As long as one skill under Science Practice 5 is represented, evidence is sufficient.

Samples of Evidence

1. Using Gauss's law, students determine the electric field in and around a charged insulating sphere of radius r. **(Skills 5.A, 5.E)**

2. Students will assemble a Wheatstone bridge and determine the resistance of an unknown resistor. Students will change the known resistors in the circuit to determine the relationship between the known resistors and the accuracy of the circuit. **(Skills 5.A, 5.E)**

3. For a DC circuit with resistors in series and parallel, students will analyze the changes in the current through each resistor when an ideal battery is replaced by a nonideal battery. **(Skills 5.C, 5.D)**

Curricular Requirement 8

The course provides opportunities for students to develop the skills related to Science Practice 6: Mathematical Routines, as outlined in the AP Course and Exam Description (CED).

Required Evidence

- ☐ The syllabus must include one assignment, activity, or lab describing how students solve problems of physical situations using mathematical relationships.
- ☐ The assignment, activity, or lab must be labeled with the relevant skill(s) associated with Science Practice 6. As long as one skill under Science Practice 6 is represented, evidence is sufficient.

Samples of Evidence

1. Students should be able to calculate wattage, current, voltage, and resistance for a simple circuit with given values. In this activity, these values are provided, and students will work in small groups to determine the wattages of bulbs when connected in series. Students will then write a test question based on the brightness of the bulbs in various orientations in the circuit. All questions will be shared and discussed with peer groups in the class. **(Skills 6.B, 6.C, 6.D)**

2. When studying electrostatics, students will use Gauss's law to calculate the electric field from charged objects that exhibit spatial symmetry. **(Skills 6.A, 6.B, 6.C)**

3. Students will design an experiment to verify Ohm's law. They will determine the current and potential difference of a circuit and compare the theoretical and experimental resistance of an unknown resistor. **(Skills 6.C)**

Curricular Requirement 9

The course provides opportunities for students to develop the skills related to Science Practice 7: Argumentation, as outlined in the AP Course and Exam Description (CED).

Required Evidence

- ☐ The syllabus must include one assignment, activity, or lab describing how students develop an explanation or a scientific argument.
- ☐ The assignment, activity, or lab must be labeled with the relevant skill(s) related to Science Practice 7. As long as one skill under Science Practice 7 is represented, evidence is sufficient.

Samples of Evidence

1. Students predict the direction of an induced current for several situations in which the magnetic flux is changing and justify their answers. **(Skills 7.A, 7.D)**

2. In Unit 2 (Conductors, Capacitors, and Dielectrics), students will construct arguments based on concepts and/or enduring understandings. For example, students will explain why it is that pure water has such a high dielectric constant. **(Skills 7.A, 7.D)**

3. Students will include error analysis in every laboratory report. The error analysis section will include a discussion of possible sources of error and the effects these errors might have on both the data collected and the experimental results. **(Skills 7.F)**

Curricular Requirement 10

The course provides students with opportunities to apply their knowledge of AP Physics concepts to real-world questions or scenarios to help them become scientifically literate citizens.

Required Evidence

- ☐ The syllabus must label and provide a description of at least one assignment or activity requiring students to apply their knowledge of AP Physics concepts to understand real-world questions or scenarios.

Samples of Evidence

1. Students are required to do a case study for which they are hired as consultants in a court case involving an electrical power surge in an apartment building that damaged many residents' electronic equipment. They are asked to analyze the circuit data to determine if the power company is at fault and to provide expert testimony with their results.

2. For a term paper, students will analyze an advertisement and/or product that makes scientific claims. The students must write a summary that would answer the following questions: What scientific principles are they using? (What is the scientific basis for this product?) What is correct or incorrect about their claims? Explain. What sources are used? Are those sources scientifically credible? Explain.

3. Students explain how inductors are used to trigger traffic lights at an intersection.

Curricular Requirement 11

Students spend a minimum of 25 percent of instructional time engaged in a wide range of hands-on laboratory investigations with an emphasis on inquiry-based labs to support the learning of required content and development of science practice skills throughout the course.

Required Evidence

- ☐ The syllabus must include an explicit statement that at least 25 percent of instructional time is spent engaged in hands-on laboratory investigations, with an emphasis on inquiry-based labs.

  AND
- ☐ Laboratory investigation titles must be listed along with a brief description.

Clarifying Terms

Guided-inquiry: at this level, students investigate a teacher-presented question using student designed/selected procedures.

Open-inquiry: at this level, students investigate topic-related questions that are formulated through student designed/selected procedures.

For more information on levels of inquiry, see Chapter 4 of AP Physics 1 and 2 Inquiry-Based Lab Investigations: A Teacher's Manual.

Samples of Evidence

1. Students will spend 25% of class time doing hands-on, inquiry-based labs for this semester-long course. Each lab takes the equivalent of 2–3 class periods. Labs included are as follows:
   - Induction/Polarization: Students determine how charges are transferred.
   - Coulomb's Law: Students determine the charge on two pith balls as they repel hanging from strings.
   - Equipotential Mapping: Students map the equipotential lines for various charged objects to determine the E-field.
   - Gauss's Law: Students determine relationships E and r for several continuous-charge density shapes.
   - Capacitance: Students design experiments to determine capacitance equation. (G.I.)
   - Capacitance: Students design experiments to determine the behavior of combinations of capacitors. (G.I.)
   - Capacitance: Students design experiments to determine the effect of inserting a dielectric into a capacitor. (G.I.)
   - DC Circuits: Students analyze the behavior of circuits with various combinations of resistors.
   - DC Circuits: Students analyze mystery circuits to determine how the circuit is wired. (G.I.)
   - RC Circuits: Students design a lab to determine the time constant for various RC circuits. (G.I.)
   - LR circuits: Students design a lab to determine the time constant for various LR circuits. (G.I.)
   - Magnetism: Students study the magnetic field of magnets of various shapes.

- Solenoid: Students design an experiment with a solenoid to determine the value of μ_0. (G.I.)
- EM Induction (Faraday/Lenz): Students design a lab to show Faraday's law and Lenz's law. (G.I.)

2. Students in this course are engaged in laboratory work more than 25% of the instructional time. All lab work is hands-on.

   The laboratory investigations Include:

   - Resistivity of Play-Doh Lab: (GI) Students determine factors that affect the resistance of a wire while determining the resistivity of Play-Doh.
   - Complex Circuits Lab: Students predict the behavior of bulbs in a complex circuit.
   - Mystery Circuits: (GI) Students must determine how a set of mystery circuits are wired.
   - Unknown Resistance: (GI) Students must determine the value of an unknown resistor in a complex circuit.
   - Capacitor Variables: (GI) Students determine what/how variables affect the capacitance of a capacitor.
   - RC Circuits Lab: (GI) Students predict and experimentally verify the time constant for an RC circuit charging and discharging.
   - LR Circuits Lab: (GI) Students predict and experimentally verify the time constant for an LR circuit.
   - LC Circuits Lab: (GI) Students predict and experimentally verify the behavior of an LC circuit.
   - Electrostatics Labs: Students determine how charges are transferred between materials.
   - Electric Fields/Electric Field Hockey (PhET) Lab – Simulation: Students determine how charges create electric fields and how those electric fields affect the motion of charges.
   - Equipotential Lines Lab: Students create a 3-D model of equipotential lines around charge distributions.
   - Magnetic Field Mapping: Students create model of magnetic field lines around different-shaped magnets.
   - Solenoids: (GI) Students determine the value of μ_0 using a slinky solenoid.
   - Variables Affecting Induced EMF: (GI) Students determine what/how certain variables affect the induced emf.
   - Faraday/Lenz: (GI) Students design a lab to show Faraday's law/Lenz's law.

3. Students in this course are engaged in laboratory work more than 25% of the instructional time. Labs are done when it is most appropriate for them to be done. Students are given a general question to answer and will work in small groups of 2–3 to develop their own procedures. Students will have their procedures approved by the instructor before they begin. The course will include the following labs:

   - Charging an electroscope by induction and conduction
   - Investigating electric field using conductive paper
   - Making a tangential galvanometer
   - Converting a galvanometer to an ammeter and calibrating it (G.I.)
   - Converting a galvanometer into a voltmeter and calibrating it (G.I.)
   - Investigating Ohm's law to determine the resistance of an unknown resistor (G.I.)

- Investigating the factors affecting the amount of current produced by a magnet. (G.I.)
- Mapping the magnetic field of a magnet
- Determining the equivalent resistance of multiple circuits (G.I.)
- Determining the resistivity of a wire (G.I.)
- Investigating a Wheatstone Bridge
- Investigating an RC time constant (G.I.)
- Constructing a motor
- Investigating an RLC circuit (G.I)

Curricular Requirement 12

The course provides opportunities for students to record evidence of their scientific investigations in a portfolio of lab reports or a lab notebook (print or digital format).

Required Evidence

- ☐ The syllabus must include the components of the written reports required of students for all laboratory investigations.

  AND

- ☐ The syllabus must include an explicit statement that students are required to maintain a lab notebook or portfolio (hard copy or electronic) that includes all their lab reports.

Samples of Evidence

1. Students are required to keep a lab portfolio. Each lab is to be included in the portfolio and must contain questions, predictions, equipment, procedures, data, data analysis, error analysis, statistics, and a conclusion. This portfolio may include reports presented in both poster format and video format.

2. Students will write formal lab reports for every lab that includes the objective, equipment, procedure, data, data analysis, error analysis, and a conclusion. Students will keep all lab reports in a portfolio to show colleges for potential credit.

3. Students will complete a paper lab report for each lab done in class consisting of an abstract, introduction/background section, purpose statement, equipment, procedure, data, sample calculations, results, discussion of results, conclusions, and bibliography.