AP® Physics 2 Sample Syllabus 1

Born On: August, 2017
Current Revision: August, 2023
Board Approval: 8/28/23

Curricular Requirements		Page(s)
CR1	Students and teachers have access to college-level resources including college-level textbooks and reference materials in print or electronic format.	13
CR2a	The course design provides opportunities for students to develop understanding of the foundational principles of thermodynamics in the context of the big ideas that organize the curriculum framework.	2
CR2b	The course design provides opportunities for students to develop understanding of the foundational principles of fluids in the context of the big ideas that organize the curriculum framework.	2
CR2c	The course design provides opportunities for students to develop understanding of the foundational principles of electrostatics in the context of the big ideas that organize the curriculum framework.	3
CR2d	The course design provides opportunities for students to develop understanding of the foundational principles of electric circuits in the context of the big ideas that organize the curriculum framework.	3
CR2e	The course design provides opportunities for students to develop understanding of the foundational principles of magnetism and electromagnetic induction in the context of the big ideas that organize the curriculum framework.	3
CR2f	The course design provides opportunities for students to develop understanding of the foundational principles of optics in the context of the big ideas that organize the curriculum framework.	4
CR2g	The course design provides opportunities for students to develop understanding of the foundational principles of modern physics in the context of the big ideas that organize the curriculum framework.	5
CR3	Students have opportunities to apply AP Physics 2 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.	14
CR4	The course provides students with opportunities to apply their knowledge of physics principles to real world questions or scenarios (including societal issues or technological innovations) to help them become scientifically literate citizens.	15
CR5	Students are provided with the opportunity to spend a minimum of 25 percent of instructional time engaging in hands-on laboratory work with an emphasis on inquiry-based investigations.	6
CR6a	The laboratory work used throughout the course includes a variety of investigations that support the foundational AP Physics 2 principles.	7
CR6b	The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.	7, 8, 9, 10, 11, 13
CR7	The course provides opportunities for students to develop their communication skills by recording evidence of their research of literature or scientific investigations through verbal, written, and graphic presentations.	6
CR8	The course provides opportunities for students to develop written and oral scientific argumentation skills.	7

Course Overview

Introduction

Advanced Placement (AP) Physics 2 is offered at our school as the second year of a two-year sequence following AP Physics 1. AP Physics 2 is a college-level course that uses advanced algebra skills and some calculus based on a college-level text.

The teacher has numerous demonstrations for each unit of study—some simple devices purchased from scientific catalogs to illustrate specific concepts, but most constructed by the teacher from easily available materials. Class demonstrations (inspired by ideas from such AAPT publications as The Physics Teacher, String and Sticky Tape Experiments, A Demonstration Handbook for Physics, and Turning the World Inside Out) are used to clarify concepts and generate interest for students. In every case, the demonstration is meant to inspire questions and responses from students in an open discussion that reinforces concepts, brings out misconceptions, and illustrates real-world applications.

The class meets 250 minutes per week—an average of 50 minutes per day—in nine meeting sessions; i.e., the class drops once each 10-day cycle and meets once for 100 minutes in each 10-day cycle. Students perform an average of six laboratory experiments per quarter, spending approximately 75 minutes per week working in the laboratory. Experiments in the Physics 2 course typically use conventional physics equipment due to the topics involved, such as electricity and optics. Students use more advanced computer skills and graphical analysis techniques in laboratory work, taking a major role in experimental design as they advance through the course. In most situations, the experimental question is provided and equipment provided; students then work in groups to design the setup, experimental procedure, and analysis. All experimental work is recorded in a laboratory journal, which is evaluated quarterly and assigned a grade based upon appropriate design elements, thoroughness, and clarity of presentation of data (including Excel graphs), as well as depth and clarity of the critical analysis.

Homework

Homework problem sets are assigned for each chapter, collected at the end of that chapter study, and assigned a score based upon clarity of the presentation of basic physics principles leading to the solution. Ten to twelve problems have been selected from each chapter—either because they are excellent AP examples or because they illustrate and reinforce important concepts—or both. Students also spend a significant amount of time outside of class completing the analysis of laboratory experiments in their journals, which includes calculations, graphing, and writing critical analyses.

Testing

Summative quizzes are given weekly, usually a 15-20 minute free-response question or several multiple-choice questions over concepts studied most recently. Full period tests are given at mid-quarter and at end of quarter, and a two-hour comprehensive exam is given at the end of the first semester. The mid-quarter, quarter, and semester exams "spiral" earlier material studied so that students review from the beginning of the year for all major tests. A full two-hour examination at the end of first semester is designed as a 2/3 AP, with one full hour of comprehensive multiple-choice questions and one full hour of free-response questions. This exam counts one-fifth of the first semester grade. In the second semester, students are exempted from a semester exam and the grade is the average of the third and fourth quarter grades. All students in the class are required to take the AP Physics 2 Examination at the end of the year.

Formative assessments are most commonly in the form of sample free-response questions given individually or in teams during class to determine students' mastery of concepts and/or readiness for tests. Students generally work together on these, with the goal of review, observation by the teacher, and peer teaching.

Timeline

Chart 1: Course Timeline with Topics Correlated to Physics 2 Curriculum Framework
[Topics are correlated to learning objectives (LO) unless there are cases where specific language in the essential knowledge (EK) needs to be incorporated into the lesson. See Addendum 1 for a sample lesson that connects learning objectives.]

Time	Topic/Subtopics	Correlation to Curriculum Framework
3 weeks	**FLUIDS [CR2b]**	Big Ideas: 1, 3, and 5
	Properties of Fluids—Gases and Liquids	
	Hydrostatic Pressure and Pascal's Principle	LO 5.B.10.2 (SP 2.2)
	Buoyancy (Archimedes' Principle)	LO 3.C.4.1 (SP 6.1) LO 3.C.4.2 SP 6.2)
	Fluid Flow Continuity (Conservation of Mass)	LO 5.F.1.1 (SP 2.1, 2.2, and 7.2)
	Conservation of Energy and Bernoulli's Principle	LO 5.B.10.1 (SP 2.2) LO 5.B.10.2 (SP 2.2) LO 5.B.10.3 (SP 2.2) LO 5.B.10.4 (SP 6.2)
4 weeks	**THERMODYNAMICS [CR2a]**	Big Ideas: 1, 4, 5, and 7
	Temperature	LO 4.C.3.1 (SP 6.4) LO 5.B.6.1 (SP 1.2) LO 7.A.3.1 (SP 6.4 and 7.2)
	Pressure	LO 7.A.1.1 (SP 6.4 and 7.2) LO 7.A.1.2 (SP 1.4 and 2.2)
	Heat/Energy Transfer	LO 4.C.3.1 (SP 6.4) LO 5.B.6.1 (SP 1.2)
	Ideal Gases	LO 7.A.3.1 (SP 6.4 and 7.2) LO 7.A.3.2 (SP 3.2 and 4.2) LO 7.A.3.3 (SP 5.1)

CR2b— The course design provides opportunities for students to develop understanding of the foundational principles of fluids in the context of the big ideas that organize the curriculum framework.

CR2a— The course design provides opportunities for students to develop understanding of the foundational principles of thermodynamics in the context of the big ideas that organize the curriculum framework.

Time	Topic/Subtopics	Correlation to Curriculum Framework
	Kinetic Theory	LO 7.A.2.1 (SP 7.1) LO 7.A.2.2 (SP 7.1)
	Laws of Thermodynamics	LO 5.B.7.1 (SP 6.4 and 7.2)
	Entropy	LO 7.B.2.1 (SP 7.1)
	PV Diagrams	LO 5.B.7.2 (SP 1.1) LO 5.B.7.3 (SP 1.1, 1.4, and 2.2) LO 5.B.5.6 (SP 4.2 and 5.1)
	Probability and Thermal Equilibrium	LO 7.B.1.1 (SP 6.2)
13 weeks	**ELECTRICITY AND MAGNETISM [CR2c] [CR2d] [CR2e]**	Big Ideas: 1, 2, 3, 4, and 5
	Elementary Charges and Fundamental Particles	LO 1.A.2.1 (SP 1.1 and 7.1) LO 1.A.5.2 (SP 1.1, 1.4, and 7.1) LO 1.B.2.1 (SP 6.2) LO 1.B.2.2 (SP 6.4 and 7.2) LO 1.B.2.3 (SP 6.1) LO 1.B.3.1 (SP 1.5, 6.1, and 7.2)
	Charging and Redistribution of Charge	LO 4.E.3.1 (SP 6.4) LO 4.E.3.2 (SP 6.4 and 7.2) LO 4.E.3.3 (SP 1.1, 1.4, and 6.4) LO 4.E.3.4 (SP 1.1, 1.4, and 6.4) LO 5.C.2.1
	Electric Force (Coulomb's Law) and Electric Field	EK 2.A.1 LO 2.C.1.1 (SP 6.4 and 7.2) LO2.C.1.2 (SP 2.2) EK 2.C.2 LO 2.C.2.1 (SP 2.2 and 6.4) LO 3.C.2.1 (SP 2.2 and 6.4) LO 3.C.2.2 (SP 7.2) LO 3.C.2.3 (SP 2.2) LO 2.C.3.1 (SP 6.2) LO 2.C.4.1 (SP 2.2, 6.4, and 7.2) LO 2.C.4.2 (SP 1.4 and 2.2) LO 2.C.5.1 (SP 1.1 and 2.2) LO 2.C.5.2 (SP 2.2) LO 2.C.5.3 (SP 1.1, 2.2, and 7.1)
	Electric Potential, Potential Difference, and Potential Energy	EK 2.A.2 LO 2.E.3.1 (SP 2.2) LO 2.E.3.2 (SP 1.4 and 6.4) LO 5.B.2.1 (SP 1.4 and 2.1)
	Equipotentials	LO 2.E.1.1 (SP 1.4, 6.4, and 7.2) LO 2.E.2.1 (SP 6.4 and 7.2) LO 2.E.2.2 (SP 6.4 and 7.2) LO 2.E.2.3 (SP 1.4)

CR2c— The course design provides opportunities for students to develop understanding of the foundational principles of electrostatics in the context of the big ideas that organize the curriculum framework.

CR2d— The course design provides opportunities for students to develop understanding of the foundational principles of electric circuits in the context of the big ideas that organize the curriculum framework.

CR2e— The course design provides opportunities for students to develop understanding of the foundational principles of magnetism and electromagnetic induction in the context of the big ideas that organize the curriculum framework.

Time	Topic/Subtopics	Correlation to Curriculum Framework
	Electric Dipoles	LO 2.C.4.1 (SP 2.2, 6.4, and 7.2)
	Electric Current Simple DC Circuits (Ohm's Law/ Kirchhoff's Laws) Steady-State RC Circuits	LO 4.E.5.1 (SP 2.2 and 6.4) LO 4.E.5.2 (SP 6.1 and 6.4) LO 4.E.5.3 (SP 2.2, 4.2, and 5.1) LO 5.B.9.5 (SP 6.4) LO 5.B.9.8 (SP 1.5) LO 5.C.3.1 (SP 6.4 and 7.2) LO 5.C.3.2 (SP 4.1, 4.2, and 5.1) LO 5.C.3.3 (SP 1.4 and 2.2) LO 5.C.3.4 (SP 6.4 and 7.2) LO 5.C.3.5 (SP 1.4 and 2.2) LO 5.C.3.6 (SP 1.4 and 2.2) LO 5.C.3.7 (SP 1.4 and 2.2)
	Magnetism and Sources of Magnetic Fields Magnetic Forces	EK 1.E.6 LO 2.C.4.1 (SP 2.2, 6.4, and 7.2) LO 2.D.2.1 (SP 1.1) LO 2.D.3.1 (SP 1.2) LO 2.D.4.1 (SP 1.4) LO 4.E.1.1 (SP 1.1, 1.4, and 2.2)
	Charged Particles Moving in Magnetic Fields	LO 2.D.1.1 (SP 2.2) LO 3.C.3.1 (SP 1.4) LO 3.C.3.2 (SP 4.2 and 5.1)
	Electromagnetic Induction (Faraday and Lenz's Laws)	LO 4.E.2.1 (SP 6.4)
	AC Circuits (introduction with transformers and other practical applications)	LO 4.E.2.1 (SP 6.4)
4 weeks	**OPTICS [CR2f]**	Big Idea 6
	Nature of Light and Electromagnetism	LO 6.B.3.1 (SP 1.5) LO 6.F.1.1 (SP 6.4 and 7.2) EK 6.F.2 LO 6.F.2.1 (SP 1.1)
	Reflection, Mirrors, and Critical Angle	LO 6.E.1.1 (SP 6.4 and 7.2) LO 6.E.2.1 (SP 6.4 and 7.2) EK 6.E.3 LO 6.E.4.1 (SP 3.2, 4.1, 5.1, 5.2, and 5.3) LO 6.E.4.2 (SP 1.4 and 2.2)
	Refraction and Lenses	LO 6.E.1.1 (SP 6.4 and 7.2) LO 6.E.3.1 (SP 1.1 and 1.4) LO 6.E.3.2 (SP 4.1, 5.1, 5.2, and 5.3) LO 6.E.3.3 (SP 6.4 and 7.2) LO 6.E.5.1 (SP 1.4 and 2.2) LO 6.E.5.2 (SP 3.2, 4.1, 5.1, 5.2, and 5.3)

CR2f— The course design provides opportunities for students to develop understanding of the foundational principles of optics in the context of the big ideas that organize the curriculum framework.

Time	Topic/Subtopics	Correlation to Curriculum Framework
	Total Internal Reflection	LO 6.E.1.1 (SP 6.4 and 7.2) LO 6.E.4.2 (SP 1.4 and 2.2)
	Thin Film Interference	LO 6.C.1.1 (SP 6.4 and 7.2) LO 6.C.1.2 (SP 1.4)
	Polarization	LO 6.A.1.3 (SP 5.1 and 6.2) LO 6.E.1.1 (SP 6.4 and 7.2)
	Interference and Diffraction	LO 6.C.2.1 (SP 1.4, 6.4, and 7.2) LO 6.C.3.1 (SP 1.4 and 6.4) LO 6.C.4.1 (SP 6.4 and 2.2)
4 weeks	**MODERN PHYSICS [CR2g]**	Big Ideas: 1, 3, 4, 5, 6, and 7
	Brief History and Development of Modern Physics in the Late 19th and Early 20th Centuries	
	Fundamental Forces	LO 3.G.1.2 (SP 7.1) LO 3.G.3.1 (SP 7.2) EU 3.6
	Theory of Photons and Photoelectric Effect	EK 1.A.2 EU 6.F EK 6.F.3 LO 6.F.3.1 (SP 6.4)
	Nuclear Physics: Radioactivity, Nuclear Reactions, Radiations, and Half Life	LO 5.C.1.1 (SP 6.4 and 7.2) LO 5.C.2.1 (SP 6.4) LO 5.C.2.2 (SP 4.2 and 5.1) LO 5.C.2.3 (SP 4.1) LO 5.G.1.1 (SP 6.4) LO 7.C.3.1 (SP 6.4)
	Mass-Energy Equivalence	LO 1.C.4.1 (SP 6.3) LO 4.C.4.1 (SP 2.2,2.3, and 7.2) LO 5.B.11.1 (SP 2.2 and 7.2)
	Quantized Energy States for Electrons in Atoms	LO 5.B.8.1 (SP 1.2 and 7.2) LO 7.C.2.1 (SP 1.4) LO 7.C.3.1 (SP 6.4)
	Energies of Photon Emission and Absorption	LO 5.B.8.1 (SP 1.2 and 7.2) LO 7.C.4.1 (SP 1.1 and 1.2)
	Wave Particle Duality, de Broglie Wavelength	EK 1.D.2 EU 5.D LO 6.G.1.1 (SP 6.4 and 7.1) LO 7.C.2.1 (SP 1.4)
	Electron Diffraction	LO 6.G.2.1 (SP 6.1) LO 6.G.2.2 (SP 6.4)

CR2g— The course design provides opportunities for students to develop understanding of the foundational principles of modern physics in the context of the big ideas that organize the curriculum framework.

Time	Topic/Subtopics	Correlation to Curriculum Framework
	Photon Momentum and Photon/Particle Collisions	LO 5.D.1.6 (SP 6.4) LO 5.D.1.7 (SP 2.1 and 2.2) LO 5.D.2.5 (SP 2.1 and 2.2) LO 5.D 2.6 (SP 6.4 and 7.2) LO 5.D.3.2 (SP 6.4) LO 5.D.3.3 (SP 6.4)
	Wave Functions and Probability	LO 7.C.1.1 (SP 1.4)

Goals for Laboratory Work

Laboratory goals set by the teacher and reinforced in work throughout the course include:

1. Provide opportunities in the laboratory so that student work best reinforces concepts, develops a positive attitude toward scientific inquiry, and prepares students to work at the college level.
2. Provide opportunities for hands-on laboratory inquiries so that students of varying backgrounds and with varying learning styles make equivalent gains.
3. Require students to create a bound journal of all experiments to keep as a permanent record of each student's research, simulating the methods scientific researchers use to record data.

Student skills to be developed through laboratory work are defined by the Science Practices listed in Table 2.

Laboratory Assessment

- Six to eight experiments will be performed by students as pairs and in larger groups during each quarter of the year, with students spending over 25% of class meeting time on hands-on laboratory work. **[CR5]** All experiments are either guided-inquiry or open-inquiry. Most involve calculations, many involve derivations as part of the background for the experiment, and most involve producing and interpreting graphs.
- In addition to laboratory work, students record observations, calculations and conclusions from some teacher-led investigations, which are noted as such in the journal.
- Journals are collected each quarter, read by the teacher, and assigned a grade according to a rubric, based upon parameters such as clarity in presentation of method and equipment used, derivation of master formulas (where appropriate), discussion of error control during the experiment, clear presentation of data, and thorough analysis of results (including graphs, calculations, and development of equations). **[CR7]**

CR5— Students are provided with the opportunity to spend a minimum of 25 percent of instructional time engaging in hands-on laboratory work with an emphasis on inquiry-based investigations.

CR7— The course provides opportunities for students to develop their communication skills by recording evidence of their research of literature or scientific investigations through verbal, written, and graphic presentations.

Scientific Argumentation

For each guided-inquiry lab, students are expected to present their findings to the class and defend their conclusion based on their findings. Students will have the opportunity to redesign the lab and redo it if they so choose. **[CR8]**

CR8— The course provides opportunities for students to develop written and oral scientific argumentation skills.

Chart 2: Student Laboratory Experiments and Correlation to Science Practices [CR6a]

[Lab time estimation includes class meeting time and does not include time students spend outside of class processing and analyzing data. See Addendum 2 for a sample lab that combines multiple concepts.]

CR6a— The laboratory work used throughout the course includes a variety of investigations that support the foundational AP Physics 2 principles.

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

Unit Topic and Lab	Correlation to Learning Objectives and Science Practices
Fluids – Static Fluids (100 min) Guided-Inquiry **[CR6b]** Design an experiment that uses fluid pressure to determine the density of an unknown oil.	LO1.E.1.1: The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction. [SP 4.2 and 6.4] LO 1.E.1.2: The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. [SP 4.1 and 6.4]
Fluids – Static Fluids (100 min) Using the balanced forces on a hovering helium-filled balloon, determine the density of helium.	LO 3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [SP 1.1] LO 1.E.1.2: The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. [SP 4.1 and 6.4]
Thermodynamics – Energy Transfer (100 min) Use the Electrical Equivalent of Heat basic apparatus to design an experiment to determine the electrical equivalent of heat. Discuss how energy loss to the environment was limited.	EK 4.C.3: Energy is transferred spontaneously from a higher temperature system to a lower temperature system. The process through which energy is transferred between systems at different temperatures is called heat.

Unit Topic and Lab	Correlation to Learning Objectives and Science Practices
	LO 5.B.6.1: The student is able to describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation. [SP 1.2] EU 5.B: The energy of a system is conserved. *Boundary Statement: Conservation principles apply in the context of the appropriate Physics 1 and Physics 2 courses. Work, potential energy, and kinetic energy concepts are related to mechanical systems in Physics 1 and electric, magnetic, thermal, and atomic and elementary particle systems in Physics 2.*
Thermodynamics – Ideal Gas Equation (100 min) Guided-Inquiry **[CR6b]** Use the pressure/volume syringe or the Pasco pressure/volume interface to design an experiment related to the ideal gas equation.	LO 7.A.3.2: The student is able to design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables. [SP 3.2 and 4.2] LO 7.A.3.3: The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$. [SP 5.1] LO 5.B.5.6: The student is able to design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are needed to determine the work done on or by the object or system. [SP 4.2 and 5.1]
Thermodynamics – Thermal Conductivity (50 min) Select a material and design an experiment to determine its thermal conductivity.	LO 1.E.3.1: The student is able to design an experiment and analyze data from it to examine thermal conductivity. [SP 4.1, 4.2, 5.1]

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

Unit Topic and Lab	Correlation to Learning Objectives and Science Practices
Electricity – Charge Transfer (50 min) Guided-Inquiry **[CR6b]** Design an experiment to determine the type of charge on a surface, using a process involving at least two steps.	LO 5.C.2.2: The student is able to design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze that data. [SP 4.2 and 5.1] LO 5.C.2.3: The student is able to justify the selection of data relevant to an investigation of the electrical charging of objects and electric charge induction on neutral objects. [SP 4.1] LO 4.E.3.5: The student is able to plan and/or analyze the results of experiments in which electric charge rearrangement occurs by electrostatic induction, or is able to refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure. [SP 3.2, 4.1, 4.2, 5.1, 5.3]
Electricity - Equipotentials and Fields (100 min) Mapping Equipotentials and Electric Fields.	LO 2.E.2.1: The student is able to determine the structure of isolines of electric potential by constructing them in a given electric field. [SP 6.4 and 7.2]
Electricity – Circuits (50 min) "What's Watt?" Teacher led examination of bulbs in series and parallel circuits.	LO 5.B.9.8: The student is able to translate between graphical and symbolic representations of experimental data describing relationships among power, current, and potential difference across a resistor. [SP 1.5]
Electricity – Circuits (100 min) Guided-Inquiry **[CR6b]** Design an experiment to determine the internal resistance of a battery.	LO 5.B.9.7: The student is able to refine and analyze a scientific question for an experiment using Kirchhoff's Loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor. [SP 4.1, 4.2, 5.1, 5.3]

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

Unit Topic and Lab	Correlation to Learning Objectives and Science Practices
Electricity – Capacitors (100 min) Guided-Inquiry **[CR6b]** Design an experiment to test the marked value of capacitance for a capacitor. Background should include derivation of the mathematical functions and analysis of the graphical relationships for potential difference, charge, and current as functions of time.	LO 4.E.4.2: The student is able to design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors. [SP 4.1,4.2] LO 4.E.4.3: The student is able to analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors. [SP 5.1] LO 4.E.5.3: The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors. [SP 2.2, 4.2, and 5.1] LO 5.B.9.4: The student is able to analyze experimental data including an analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff's loop rule. [SP 5.1] LO 5.B.9.7: The student is able to refine and analyze a scientific question for an experiment using Kirchhoff's Loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor. [SP4.1, 4.2, 5.1,5.3] LO 5.B.9.8: The student is able to translate between graphical and symbolic representations of experimental data describing relationships among power, current, and potential difference across a resistor. [SP 1.5]

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

Unit Topic and Lab	Correlation to Learning Objectives and Science Practices
Electricity – Circuits (100 min) Guided-Inquiry **[CR6b]** Circuit Boards and Breadboards: Design an Experiment to Qualitatively Compare Components in Different Arrangements in Series and Parallel.	LO 4.E.4.2: The student is able to design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors. [SP4.1,4.2] LO 4.E.4.3: The student is able to analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors. [SP 5.1] LO 4.E.5.3: The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors. [SP 2.2, 4.2, and 5.1]
Electricity/Magnetism – Induction (50 min) Guided-Inquiry **[CR6b]** Measuring Input and Output Current and Voltage for a Small Transformer.	LO 4.E.3.5: The student is able to plan and/or analyze the results of experiments in which electric charge rearrangement occurs by electrostatic induction, or is able to refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure. [SP 3.2, 4.1, 4.2, 5.1, 5.3]
Magnetism – Fields (50 min) Guided-Inquiry **[CR6b]** Set up various arrangements of current carrying wires and compasses to map magnetic fields. (May use magnetic probe with a Slinky.)	LO 3.C.3.2: The student is able to plan a data collection strategy appropriate to an investigation of the direction of the force on a moving electrically charged object caused by a current in a wire in the context of a specific set of equipment and instruments and analyze the resulting data to arrive at a conclusion. [SP 4.2 and 5.1]

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

Unit Topic and Lab	Correlation to Learning Objectives and Science Practices
Light and Optics – Diffraction (100 min) Design a diffraction experiment to determine of wavelength of HeNe, red diode, and green diode lasers.	LO 6.C.2.1: The student is able to make claims about the diffraction pattern produced when a wave passes through a small opening, and to qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave. [SP 1.4, 6.4, 7.2]
Optics – Reflection (50min) Reflection and Mirrors	LO 6.E.4.1: The student is able to plan data collection strategies, and perform data analysis and evaluation of evidence about the formation of images due to reflection of light from curved spherical mirrors. [SP 3.2, 4.1, 5.1, 5.2, 5.3]
Light and Optics – Refraction (100 min) Determine the index of refraction of lucite by graphing data for angles of incidence and refraction.	LO 6.E.3.2: The student is able to plan data collection strategies as well as perform data analysis and evaluation of the evidence for finding the relationship between the angle of incidence and the angle of refraction for light crossing boundaries from one transparent material to another (Snell's law). [SP 4.1, 5.1, 5.2, 5.3] LO 6.E.5.2: The student is able to plan data collection strategies, perform data analysis and evaluation of evidence, and refine scientific questions about the formation of images due to refraction for thin lenses. [SP 3.2, 4.1, 5.1, 5.2, 5.3]
Optics – Total Internal Reflection (50 min) Use the concept of total internal reflection to determine the critical angle for water and one other liquid.	LO 6.E.1.1: The student is able to make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed. [SP 6.4 and 7.2]
Optics – Dispersion (50 min) Examine color dispersion by measuring angles of refraction for color components of incident white light.	LO 6.F.1.1: The student is able to make qualitative comparisons of the wavelengths of types of electromagnetic radiation. [SP 6.4 and 7.2]

Unit Topic and Lab	Correlation to Learning Objectives and Science Practices
Light and Optics – Diffraction (100 min) Design an experiment to demonstrate the differences between single and double slit interference patterns (both qualitative and quantitative).	LO 6.C.2.1: The student is able to make claims about the diffraction pattern produced when a wave passes through a small opening, and to qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave. [SP 1.4, 6.4, 7.2]
Optics and Waves – Optics and Waves (50 min) Demonstrate polarization of light and of a mechanical wave and develop a written analysis comparing them.	LO 6.A.1.3: The student is able to analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation. [SP 5.1 and 6.2]
Modern Physics – Nuclear Radiation, Charged Particles and Magnetic Fields (100 min) Guided-Inquiry **[CR6b]** Design an experimental method (such as a cloud chamber) to determine the type of charge on a radioactive particle emitted from a known radioactive sample.	LO 3.C.3.2: The student is able to plan a data collection strategy appropriate to an investigation of the direction of the force on a moving electrically charged object caused by a current in a wire in the context of a specific set of equipment and instruments and analyze the resulting data to arrive at a conclusion. [SP 4.2 and 5.1]
Modern Physics - Photoelectric Effect (50 min) Using light emitting diodes, set up a process for gathering and processing data to determine an experimental value of Planck's constant.	LO 6.F.3.1: The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect. [SP 6.4]

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

Resources

Print Resources Used by Students:

- Walker, James S. *Physics*. 4th ed. New Jersey: Pearson-Prentice Hall, 2012. **[CR1]**
- Student Companion Guide for AP Physics 2 to be developed by the teacher in 3-ring or bound form, which includes selected assigned problems and the charts shown above (also available on school website).

CR1— Students and teachers have access to college-level resources including college-level textbooks and reference materials in print or electronic format.

Print Resources Used by the Teacher

- Fundamentals of Physics, Haliday, Resnick, and Walker, 7th ed., Wiley
- Physics for Scientists and Engineers, Serway and Beichner (Wiley)
- Physics for Scientists and Engineers, Randall Knight
- AP Physics Lab Manual, Patrick Polley, published by College Board
- Published AP Physics B and C Exams: available from College Board and downloaded from AP Central
- Curriculum Framework and other related print resources for AP Physics 2 from College Board available at http: apcentral.collegeboard.org
- AP Test Prep Series: AP Physics B, Pearson Prentice Hall, 2007 [Section III: "The Laboratory"], by C. Wells
- Focus booklet: "Graphing Skills", published by College Board, 2007
- Focus booklet "Electrostatics", published by College Board, 2008
- String and Sticky Tape Experiment , AAPT
- Demonstration Handbook of Physics , Freier and Anderson, AAPT
- Turning the World Inside Out , Ehrlich, Princeton Press

Web and Video Resources

- The Mechanical Universe, video series, Annenberg Project
- www.phet.university of Colorado.edu
- www.apcentral.collegeboard.org (AP tests)
- www.physics.sa.umich.edu/demolab/em.asp (Physlets)
- webphysics.Davidson.edu/physlet_resources (Physlets)
- DVD series: "Mechanical Universe Series" (CPB Annenberg, et al.) www.learner.org

ADDENDUM 1. Sample lesson that connects Learning Objectives [CR3]

In a lesson on thin film interference, students gain understanding of why thin films such as those observed in soap bubbles, layers on oil on water, insect wings, and protective films on eyeglasses can produce a display of visible colors. To explain this phenomenon, the concepts of phase, reflections at boundaries, refraction, and interference are all included. Students reinforce concepts that a 180 degree phase shift occurs upon reflection from a boundary between lower index of refraction to higher index of refraction—but not vice versa. They must include the concept that wavelength and speed—but not frequency—change as the light enters a different medium. They must include the concept that the light does not change phase upon refraction, regardless of change in index of refraction. Finally, they must include the idea of constructive or destructive interference of the light reflected from the first two surfaces of the film.

CR3— Students have opportunities to apply AP Physics 2 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.

Learning Objective (6.E.1.1):

The student is able to make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed.

Learning Objective (6.E.3.1):

The student is able to describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media.

Learning Objective (6.C.1.1):
The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap.

Learning Objective (6.E.3.1):
The student is able to describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media.

ADDENDUM 2. Sample lesson with real-world applications [CR4]
After studying the concepts and calculations related to conservation of energy in fluid flow (i.e., Bernoulli's Principle), students observe a demonstration that applies that principle, along with other principles, to the question of "What provides lift for an airplane"? A model Styrofoam airplane is set up so that a rod through the nose of the model allows it to pivot. Streamers are glued to the front edges of the wings. As a leaf blower is tilted at the proper angle ("angle of attack"), the plane lifts upward. Students make observations and then discuss and relate what they have observed to one of the explanations of the lift of an airplane. Note: They observe that the streamers "hug" the upper surface of the wings (i.e., streamline air flow) and are turbulent behind the wings at the point of maximum lift. They should be able to relate the angle of attack to Bernoulli's equation as it creates differences in air speed (and thus air pressure) above and below the wing—then relate differences in pressure to lift force. They then should be able to describe the forces on the plane. Additionally, students can apply conservation of momentum principles to movement of air backward and downward off the back of the wing.

CR4— The course provides students with opportunities to apply their knowledge of physics principles to real world questions or scenarios (including societal issues or technological innovations) to help them become scientifically literate citizens.

Learning Objective (3.A.2.1): The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

Learning Objective (5.B.10.1):
The student is able to use Bernoulli's equation to make calculations related to a moving fluid.

Learning Objective (5.B.10.2):
The student is able to use Bernoulli's equation and/or the relationship between force and pressure to make calculations related to a moving fluid.

Learning Objective (5.B.10.3):
The student is able to use Bernoulli's equation and the continuity equation to make calculations related to a moving fluid.

Enduring Understanding (5.D) and Boundary Statement:
The linear momentum of a system is conserved.
Boundary Statement: Items involving solution of simultaneous equations are not included in either Physics 1 or Physics 2, but items testing whether students can set up the equations properly and can reason about how changing a given mass, speed, or angle would affect other quantities are included.