CollegeBoard AP

SAMPLE SYLLABUS #1

AP® Physics 2

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 and related big ideas outlined in Unit 1: Fluids as described in the AP Course and Exam Description (CED).	*See page:* 4
CR3	The course provides opportunities to develop student understanding of the required content and related big ideas outlined in Unit 2: Thermodynamics as described in the CED.	*See page:* 5
CR4	The course provides opportunities to develop student understanding of the required content and related big ideas outlined in Unit 3: Electric Force, Field, and Potential as described in the CED.	*See page:* 6
CR5	The course provides opportunities to develop student understanding of the required content and related big ideas outlined in Unit 4: Electric Circuits as described in the CED.	*See page:* 7
CR6	The course provides opportunities to develop student understanding of the required content and related big ideas outlined in Unit 5: Magnetism and Electromagnetic Induction as described in the CED.	*See page:* 7
CR7	The course provides opportunities to develop student understanding of the required content and related big ideas outlined in Unit 6: Geometric and Physical Optics as described in the CED.	*See page:* 8
CR8	The course provides opportunities to develop student understanding of the required content and related big ideas outlined in Unit 7: Quantum, Atomic, and Nuclear Physics as described in the CED.	*See page:* 8
CR9	The course provides opportunities for students to develop the skills related to Science Practice 1: Modeling.	*See page:* 10
CR10	The course provides opportunities for students to develop the skills related to Science Practice 2: Mathematical Routines.	*See page:* 10
CR11	The course provides opportunities for students to develop the skills related to Science Practice 3: Scientific Questioning.	*See page:* 10

CR12	The course provides opportunities for students to develop the skills related to Science Practice 4: Experimental Methods.	*See page:* 11
CR13	The course provides opportunities for students to develop the skills related to Science Practice 5: Data Analysis.	*See page:* 11
CR14	The course provides opportunities for students to develop the skills related to Science Practice 6: Argumentation.	*See page:* 11
CR15	The course provides opportunities for students to develop the skills related to Science Practice 7: Making Connections.	*See page:* 12
CR16	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:* 12
CR17	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:* 13
CR18	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:* 13

Advanced Placement Physics 2 Sample Syllabus #1

Textbook

- Etkina, Eugenia, Gorazd Planinsic, and Alan Van Heuvelen. *College Physics.* 2nd ed., AP ed. San Francisco: Pearson, 2019. **CR1**

CR1
The syllabus must cite the title, author, and publication date of an algebra-based, college-level textbook.

Teaching Resources

- Hieggelke, Curtis J, Stephen E Kanim, Thomas L O'Kuma, and David P Maloney. 2015. *TIPERs: Sensemaking Tasks for Introductory Physics.* Boston: Pearson.
- Hieggelke, Curtis J, Stephen E Kanim, Thomas L. O'Kuma, and David P Maloney. 2006. *E&M TIPERs: Electricity and Magnetism Tasks.* Upper Saddle River, NJ: Pearson.
- O'Kuma, Thomas L., Curtis Hieggelke, and David P Maloney. 2003. *Ranking Task Exercises in Physics.* Boston: Pearson/Addison Wesley.
- Knight, Randall D., Brian Jones, and Stuart Field**.** 2018. *College Physics: A Strategic Approach***.** 4th ed., AP® ed. Boston: Pearson.
- **PIVOT Interactives:** High production quality videos of hard to replicate physical phenomena. Vernier student subscription.

Instructional Strategies

The AP® Physics 2 course is conducted using inquiry-based instructional strategies that focus on experimentation to develop students' conceptual understanding of physics principles. The students begin studying a topic by making observations and discovering patterns of natural phenomena. The next steps involve developing, testing, and applying models. Throughout the course, the students construct and use multiple representations of physical processes, solve multistep problems, design investigations, and reflect on knowledge construction through self-assessment rubrics.

In most labs, the students use electronic sensor technology in data acquisition.

In the classroom, students use graphing calculators and digital devices for interactive simulations and collaborative activities.

Throughout each unit, **Topic Questions** will be provided to help students check their understanding. The Topic Questions are especially useful for confirming understanding of difficult or foundational topics before moving on to new content or skills that build upon prior topics. Topic Questions can be assigned before, during, or after a lesson, and as in-class work or homework. Students will get rationales for each **Topic Question** that will help them understand why an answer is correct or incorrect, and their results will reveal misunderstandings to help them target the content and skills needed for additional practice.

At key points within a unit, **Personal Progress Checks** will be provided in class or as homework assignments in AP Classroom. Students will get a personal report with feedback on every topic, skill, and question that they can use to chart their progress, and their results will come with rationales that explain every question's answer. One to two class periods are set aside to re-teach skills based on the results of the Personal Progress Checks.

COURSE OUTLINE CR2

UNIT	Topic	Science Practices	TEXTBOOK CHAPTER(S)
UNIT 1. FLUIDS CR2	1.1 Fluid Systems	1.1, 1.4*, 7.1*	**Chapter 13. Static Fluids:** density, pressure, buoyancy **Chapter 14. Fluids in Motion:** flow rate, continuity equation, Bernoulli's equation
	1.2 Density	4.1, 4.2, 6.4	
	1.3 Fluids: Pressure and Forces	1.1, 1.4, 6.1*, 6.2, 6.4, 7.2	
	1.4 Fluids and Free-Body Diagrams	1.1, 1.4, 1.5, 2.2, 6.4, 7.2	
	Assign PPC Unit 1, MCQ Part A		
	1.5 Buoyancy	6.1, 6.2	
	Assign PPC Unit 1, MCQ Part B		
	1.6 Conservation of Energy in Fluid Flow	2.2, 6.2	
	1.7 Conservation of Mass Flow Rate in Fluids	2.1, 2.2, 7.2	
	Assign PPC Unit 1, MCQ Part C		
	Assign PPC Unit 1, FRQs		

CR2

The syllabus must include the Unit 1 content listed below with the associated Big Ideas 1, 3, 5, and 7: Systems (SYS), Force Interactions (INT), Conservation (CON), and Probability (PRO):

- Pressure and Density
- Fluid Statics
- Fluid Dynamics

UNIT	Topic	Science Practices	TEXTBOOK CHAPTER(S)
UNIT 2. THERMODYNAMICS CR3	2.1 Thermodynamic Systems	1.1*, 1.4*, 7.1*	**Chapter 12. Gases:** Temperature, ideal gas law, speed distribution, kinetic theory **Chapter 15. First Law of Thermodynamics:** internal energy, heating and work, PV diagrams, gas processes, heating mechanisms **Chapter 16. Second Law of Thermodynamics:** irreversible processes, entropy
	2.2 Pressure, Thermal Equilibrium, and the Ideal Gas Law	1.4, 2.2, 3.2, 4.2, 5.1, 6.4, 7.1*, 7.2	
	2.3 Thermodynamics and Forces	1.1*, 1.4, 6.1*, 6.2*, 6.4, 7.2	
	2.4 Thermodynamics and Free-Body Diagrams	1.1, 1.4, 1.5, 2.2, 6.4, 7.2*	
	Assign PPC Unit 2, Part A		
	2.5 Thermodynamics and Contact Forces	6.1*, 6.2*	
	2.6 Heat and Energy Transfer	6.4	
	2.7 Internal Energy and Energy Transfer	1.1, 1.2, 1.4, 2.1, 2.2, 4.2, 5.1, 6.4, 7.2*	
	Assign PPC Unit 2, MCQ Part B		
	2.8 Thermodynamics and Elastic Collisions: Conservation of Momentum	2.1*, 2.2, 6.4, 7.2*	
	2.9 Thermodynamics and Inelastic Collisions: Conservation of Momentum	2.1*, 2.2, 6.4, 7.2	
	2.10 Thermal Conductivity	4.1*, 4.2, 5.1	
	2.11 Probability, Thermal Equilibrium, and Entropy	6.2, 7.1	
	Assign PPC Unit 2, MCQ Part C		
	Assign PPC Unit 2, FRQ		

CR3

The syllabus must include the Unit 2 content listed below with the associated Big Ideas 1, 3, 4, and 5: Systems (SYS), Force Interactions (INT), Change (CHA), and Conservation (CON):

- First and Second Laws of Thermodynamics
- Kinetic Theory
- Thermal Conductivity
- Ideal Gas Law

UNIT	Topic	Science Practices	TEXTBOOK CHAPTER(S)
UNIT 3. ELECTRIC FORCE, FIELD AND POTENTIAL CR4	3.1 Electric Systems	1.1*, 1.4*, 7.1*	**Chapter 17. Electric Charge, Force, and Energy:** electrostatic interactions, conductors and insulators, Coulomb's Law, electric potential energy **Chapter 18. The Electric Field:** electric field, electric potential, capacitors
	3.2 Electric Charge	6.2, 6.4, 7.2	
	3.3 Conservation of Electric Charge	4.1, 4.2*, 5.1, 6.4	
	3.4 Charge Distribution, Friction, Conduction, and Induction	1.1, 1.4, 3.2, 4.1, 4.2, 5.1, 5.3, 6.4, 7.2	
	Assign PPC Unit 3, MCQ Part A		
	3.5 Electric Permittivity		
	3.6 Introduction to Electric Forces	1.1, 1.4, 6.1*, 6.2, 6.4*, 7.2*	
	3.7 Electric Forces and Free-Body Diagrams	1.1, 1.4, 1.5*, 2.2, 6.4*, 7.2*	
	3.8 Describing Electric Force	2.2, 6.4, 7.2	
	Assign PPC Unit 3, MCQ Part B		
	3.9 Gravitational and Electromagnetic Forces	7.1	
	3.10 Vector and Scalar Fields		
	3.11 Electric Charges and Fields	1.1, 1.4, 2.2, 6.2, 6.4, 7.1*, 7.2	
	3.12 Isolines and Electric Fields	1.4, 2.2, 6.4, 7.2	
	Assign PPC Unit 3, MCQ Part D		
	3.13 Conservation of Electric Energy	1.4, 2.1, 2.2, 6.4, 7.2*	
	Assign PPC Unit 3, MCQ Part C		
	Assign PPC Unit 3, FRQ		

CR4

The syllabus must include the Unit 3 content listed below with the associated Big Ideas 1–5: Systems (SYS), Fields (FLD), Force Interactions (INT), Change (CHA), and Conservation (CON):

- Charge and Electric Force
- Electric Field
- Electric Potential
- Electric Potential Energy

UNIT	Topic	Science Practices	TEXTBOOK CHAPTER(S)
UNIT 4. ELECTRIC CIRCUITS CR5	4.1 Definition and Conservation of Electric Charge	6.1*, 6.2*, 6.4*, 7.2*	**Chapter 19. DC Circuits:** electric current, DC circuits, Ohm's law, Kirchhoff's rules, RC circuits, resistivity
	4.2 Resistivity and Resistance	4.1	
	4.3 Resistance and Capacitance	2.2, 4.1, 4.2, 5.1, 6.1, 6.4	
	4.4 Kirchhoff's Loop Rule	1.5, 2.1, 2.2, 4.1, 4.2, 5.1, 5.3, 6.4	
	4.5 Kirchhoff's Junction Rule and the Conservation of Electric Charge	1.4, 2.2, 6.4, 7.2	
	Assign PPC Unit 4, MCQ Part A		
	Assign PPC Unit 4, MCQ Part B		
	Assign PPC Unit 4, FRQ		
UNIT 5. MAGNETISM AND ELECTROMAGNETIC INDUCTION CR6	5.1 Magnetic Systems	1.1, 1.4*, 7.1	**Chapter 20. Magnetism:** magnetic interactions, magnetic field, magnetic forces **Chapter 21. Electromagnetic Induction:** magnetic flux, Faraday's law, Lenz's law, motional emf
	5.2 Magnetic Permeability and Magnetic Dipole Moment		
	5.3 Vector and Scalar Fields		
	5.4 Monopole and Dipole Fields	2.2*, 6.4, 7.2*	
	5.5 Magnetic Fields and Forces	1.1, 1.2, 1.4, 2.2	
	5.6 Magnetic Forces	1.4, 4.2, 5.1	
	Assign PPC Unit 5, MCQ Part A		
	5.7 Forces Review	1.1, 1.4*, 6.1, 6.2, 6.4, 7.2*	
	5.8 Magnetic Flux	1.1, 1.4, 2.2*, 6.4	
	Assign PPC Unit 5, MCQ Part B		
	Assign PPC Unit 5, FRQ		

CR5

The syllabus must include the Unit 4 content listed below with the associated Big Ideas 1, 2, 4, and 5: Systems (SYS), Fields (FLD), Change (CHA), and Conservation (CON):

- Ohm's Law
- Kirchhoff's Rules
- Complex DC Circuits
- Steady-State RC Circuits

CR6

The syllabus must include the Unit 5 content listed below with the associated Big Ideas 1–4: Systems (SYS), Fields (FLD), Force Interactions (INT), and Change (CHA):

- Magnetic Fields
- Magnetic Forces
- Faraday's Law
- Lenz's Law

UNIT	Topic	Science Practices	TEXTBOOK CHAPTER(S)
UNIT 6. GEOMETRIC AND PHYSICAL OPTICS CR7	6.1 Waves	1.2, 5.1, 6.2, 6.4, 7.2	**Chapter 11. Mechanical Waves:** mathematical description of a wave, wave interference, superposition **Chapter 22. Reflection and Refraction:** reflection, refraction, Snell's law, total internal reflection **Chapter 23. Mirrors and Lenses:** image formation by mirrors and lenses, mirror equation, thin lens equation **Chapter 24. Wave Optics:** Young's double slit experiment, diffraction gratings, thin-film interference **Chapter 25. Electromagnetic Waves:** electromagnetic spectrum, polarization, mathematical description of waves
	6.2 Electromagnetic Waves	1.1, 6.4, 7.2	
	6.3 Periodic Waves	1.5	
	6.4 Refraction, Reflection, and Absorption	1.1, 1.4, 4.1, 5.1, 5.2, 5.3, 6.4, 7.2	
	6.5 Images from Lenses and Mirrors	1.4, 2.2, 3.2, 4.1, 5.1, 5.2, 5.3	
	Assign PPC Unit 6, MCQ Part A		
	Assign PPC Unit 6, MCQ Part C		
	6.6 Interference and Diffraction	1.4, 6.4, 7.2	
	Assign PPC Unit 6, MCQ Part B		
	Assign PPC Unit 6, FRQ		
UNIT 7. QUANTUM, ATOMIC AND NUCLEAR PHYSICS CR8	7.1 Systems and Fundamental Forces	1.1, 7.1, 7.2	**Chapter 27. Quantum Optics:** blackbody radiation, photoelectric effect, De Broglie wavelength **Chapter 28. Atomic Physics:** early atomic models, Bohr's model, spectral analysis **Chapter 29. Nuclear Physics:** radioactivity, half-life, nuclear force and binding energy, nuclear reactions, radioactive decay
	7.2 Radioactive Decay	2.1, 2.2, 6.4, 7.2	
	7.3 Energy in Modern Physics (Energy in Radioactive Decay and $E = mc^2$)	1.2, 1.4, 2.1, 2.2, 6.4, 7.2	
	7.4 Mass-Energy Equivalence	2.2, 2.3, 6.3, 7.2	
	Assign PPC Unit 7, MCQ Part B		
	7.5 Properties of Waves and Particles	1.4, 6.1, 6.3, 6.4, 7.1, 7.2	
	7.6 Photoelectric Effect	6.4, 7.1	
	7.7 Wave Functions and Probability	1.1, 1.2, 1.4, 6.4	
	Assign PPC Unit 7, MCQ Part A		
	Assign PPC Unit 7, MCQ Part C		
	Assign PPC Unit 7, FRQ		

*Indicates a science practice not assessed with its paired topic on this unit's Personal Progress Check

CR7

The syllabus must include the Unit 6 content listed below with the associated Big Idea 6: Waves (WAV):

- Reflection and Refraction
- Lenses and Mirrors
- Interference, Diffraction, and Polarization

CR8

The syllabus must include the Unit 7 content with the associated Big Ideas 1, 3, 4, 5, 6, and 7: Systems (SYS), Force Interactions (INT), Change (CHA), Conservation (CON), Waves (WAV), and Probability (PRO).

Big Ideas In AP Physics 2

BIG IDEAS	UNITS
Big Idea 1: Properties. Objects and systems have properties such as mass and charge. Systems may have internal structure.	In **Unit 3.** *Electric Charge* and **Unit 7.** *Atomic Physics* students explore the concepts of fundamental particles with no internal structure such as electrons, and systems built from fundamental particles such as protons and neutrons.
Big Idea 2: Fields. Fields existing in space can be used to explain interactions.	In **Unit 3.** *Electric Field* and **Unit 5.** *Magnetism* students conduct experiments to investigate the nature of electric fields and magnetic fields
Big Idea 3: Force Interactions. The interactions of an object with other objects can be described by forces.	In **Unit 1.** *Fluids*, **Unit 3.** *Electric Force* and **Unit 5.** *Magnetism* students use free body diagrams to represent the buoyant force, electric force, and magnetic force that result from interactions between particles or objects of a system.
Big Idea 4: Systems. Interactions between systems can result in changes in those systems.	In **Unit 2.** *Thermodynamics* students learn examples of how the mechanisms of thermal energy transfer conduction, convection, and radiation work in our everyday lives.
Big Idea 5: Conservation. Changes that occur as a result of interactions are constrained by conservation laws.	The students solve problems in **Unit 1.** *Fluids*, **Unit 2.** *Thermodynamics*, **Unit 5.** *DC Circuits* and **Unit 7.** *Quantum Physics* by applying Bernoulli's equation, the first law of thermodynamics, Kirchhoff's loop rule, and the photoelectric effect respectively, and realize the universal nature of conservation of energy across topics.
Big Idea 6: Waves. Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.	In **Unit 6.** *Geometric Optics* students investigate applications of wave behavior like reflection and refraction through experiments in image formation in mirrors and lenses.
Big Idea 7: Probability. The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems.	In **Unit 7.** *Atomic Physics* students conduct research to investigate how energy transitions due to emission or absorption of photons provide the foundation of how lasers work.

Science Practices

Science Practice 1: Modeling. CR9

The student can use representations and models to communicate scientific phenomena and solve scientific problems.

ACTIVITY: Thermodynamic Processes

The students consistently use **multiple representations** to solve physics problems. For example, when analyzing thermodynamic processes, the students **model** the system as an ideal gas, determine whether any interactions of the environment with the system are relevant, and draw an energy bar chart to help visualize and apply the first law of thermodynamics. The students use the information given to draw a PV (pressure vs. volume) diagram to represent the processes and use the mathematical model of the first law of thermodynamics to solve for the unknown quantities.

Learning Objective 5.B.7.2. Science Practice 1.1

'The student is able to create a plot of pressure versus volume for a thermodynamic process from given data.'

Learning Objective 5.B.7.3. Science Practices 1.1, 1.4, and 2.2

'The student is able to use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based on conservation of energy principles (i.e., the first law of thermodynamics).'

Science Practice 2: Mathematical Routines. CR10

The student can use mathematics appropriately.

In all the units of study the students engage in problem-solving activities that require the application of algebra and trigonometry **mathematical routines**.

ACTIVITY: Electric Field

When solving a problem involving the electric field due to multiple electric charges, the students first sketch an electric field vector diagram to help them determine the x and y-components of the electric field. Students perform the component vector addition method and use the Pythagorean Theorem to calculate the magnitude of the net electric field.

Learning Objective 2.C.4.2. Science Practices 1.4 and 2.2

'The student is able to apply mathematical routines to determine the magnitude and direction of the electric field at specified points in the vicinity of a small set (2–4) of point charges, and express the results in terms of magnitude and direction of the field in a visual representation by drawing field vectors of appropriate length and direction at the specified points.'

Science Practice 3: Scientific Questioning. CR11

The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP Physics 2 course.

ACTIVITY: How do we know when to use the wave model or the particle model?
DESCRIPTION: The PhET Quantum Wave Interference simulation (http://phet.colorado.edu/en/simulation/wave-interference) helps students visualize the behavior of photons, electrons, and atoms as particles and as waves through a double slit.

The students work in small groups through a series of 'experiments' that confront students with the basic conflict between the wave model and particle model. The groups have to gather **evidence** that will allow them to justify how the double slit interference pattern is consistent with both the classical wave view and the photon view. After the class discussion, the students should be able to articulate how the wave view is related to the photon view.

Science Practice 3.

Learning Objective 1.D.1.1

'The student is able to explain why classical mechanics cannot describe all properties of objects by articulating the reasons that classical mechanics must be refined and an alternative explanation developed when classical particles display wave properties.'

Learning Objective 6.G.1.1

'The student is able to make predictions about using the scale of the problem to determine at what regimes a particle or wave model is more appropriate.'

CR9

The syllabus must include one assignment, activity, or lab describing how students use representations and models to communicate scientific phenomena and solve scientific problems. The assignment, activity, or lab must be labeled with the relevant practice(s) (e.g., "1.2") associated with Science Practice 1.

As long as one practice under Science Practice 1 is represented, evidence is sufficient.

CR10

The syllabus must include one assignment, activity, or lab describing how students use mathematics appropriately. The assignment, activity, or lab must be labeled with the relevant practice(s) associated with Science Practice 2.

As long as one practice under Science Practice 2 is represented, evidence is sufficient.

CR11

The syllabus must include one assignment, activity, or lab describing how students engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course. The assignment, activity, or lab must be labeled with the relevant practice(s) associated with Science Practice 3.

As long as one practice under Science Practice 3 is represented, evidence is sufficient.

Science Practice 4: Experimental Methods. CR12

The student can plan and implement data collection strategies in relation to a particular scientific question.

In all units of study students plan and implement procedures to collect data.

ACTIVITY: Capacitance investigation

DESCRIPTION: Students design a simple capacitor with aluminum foil, a textbook, wires, and capacitance meter to determine the factors that affect the capacitance of a parallel-plate capacitor. The students **plan a data collection strategy** to determine the following:

Relationship between capacitance and area

Relationship between capacitance and plate separation

The dielectric constant of paper

LO 4.E.4.2. Science Practices 4.1 and 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.'

Science Practice 5: Data Analysis. CR13

The student can perform data analysis and evaluation of evidence.

In all lab investigations in this course, students are expected to perform analysis of the data collected.

ACTIVITY: Concave Mirrors

Students **analyze** data to determine the focal length of a concave mirror and determine two locations where a magnified image can be formed using a concave mirror.

LO 6.E.4.1. Science Practices 3.2, 4.1, 5.1, 5.2, 5.3

'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.'

Science Practice 6: Argumentation. CR14

The student can work with scientific explanations and theories.

In the course, students become familiar with the three components of **scientific argumentation**: **claim, evidence, and reasoning**. Students receive explicit instruction in posing meaningful questions that include questions of clarification, questions that probe assumptions, and questions that probe implications and consequences. As a result of the scientific argumentation process, students are able to revise their claims and make revisions as appropriate.

ACTIVITY: Nuclear Energy: Friend or Foe

DESCRIPTION: In addition to the physics concepts, this project requires the evaluation of ethical concerns in order to arrive at a decision regarding nuclear energy. This project is meaningful and engaging to students as it requires the use of **evidence-based reasoning** through **dialogue** and provides a context for understanding scientific information.

Students work in teams of two to investigate the socioscientific issue about the pros and cons of the use of nuclear energy. The research includes an explanation of the process of nuclear fission, the basic operation of a nuclear reactor, how a chain reaction works, and how magnetic and inertial confinements can provide thermonuclear power. Students have to discuss safety, cost-effectiveness, and environmental impact including wildlife and human health. The culmination activity is a **debate** moderated by the students themselves.

Learning Objective 5.G.1.1. Science Practice 6.4

'The student is able to apply conservation of nucleon number and conservation of electric charge to make predictions about nuclear reactions and decays such as fission, fusion, alpha decay, beta decay, or gamma decay.'

CR12

The syllabus must include one assignment, activity, or lab describing how students plan and implement data collection strategies in relation to a particular scientific question. The assignment, activity, or lab must be labeled with the relevant practice(s) associated with Science Practice 4.

As long as one practice under Science Practice 4 is represented, evidence is sufficient.

CR13

The syllabus must include one assignment, activity, or lab describing how students perform data analysis and evaluation of evidence. The assignment, activity, or lab must be labeled with the relevant practice(s) associated with Science Practice 5.

As long as one practice under Science Practice 5 is represented, evidence is sufficient.

CR14

The syllabus must include one assignment, activity, or lab describing how students work with scientific explanations and theories. The assignment, activity, or lab must be labeled with the relevant practice(s) associated with Science Practice 6.

As long as one practice under Science Practice 6 is represented, evidence is sufficient.

Science Practice 7: Making Connections. CR15

The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

ACTIVITY: Laser Applications

DESCRIPTION: Students first investigate how a laser works using the PhET Laser simulation (**http://phet.colorado.edu/en/simulation/lasers**). The simulation helps the students understand how absorption and spontaneous and stimulated emission work.

Students will be able to explain how these factors—intensity and wavelength of the lamp, the mirror reflectivity, and the lifetimes of the excited states of the atom—influence the laser.

After writing their observations they conduct online research to submit a paper that will demonstrate their ability to read and synthesize scientific literature about the applications of lasers in modern medicine. Common research topics of applications include vision correction (LASIK surgery), tattoo removal, and varicose vein treatments.

Learning Objective 5.B.8.1. Science Practices 1.2 and 7.2

'The student is able to describe emission or absorption spectra associated with electronic or nuclear transitions as transitions between allowed energy states of the atom in terms of the principle of energy conservation, including characterization of the frequency of radiation emitted or absorbed.'

Real-World Applications CR16

Throughout the course the students engage in a variety of activities designed to build the students' reasoning skills and deepen their conceptual understanding of physics principles. Students conduct activities and projects that enable them to connect the concepts learned in class to real world applications.

Activity: Fluid Applications

DESCRIPTION: Students write a series of questions that they wonder about related to buoyancy and density in real-world contexts. In teams of two, the students select one research question. They have two class periods to post their results of the research on a Google Doc. Each team presents their information and any sources of data found to the class. Sample questions are:

- How do metal ships float?
- Will a ship full of oil float differently than an empty ship?
- If an oil tanker develops a leak, why does it sink?
- How will a ship float in fresh water as opposed to salt water?
- How do hot air balloons work?

Would hydrogen balloons float better than balloons filled with hot air?

Learning Objective 1.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]'

Learning Objective 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]'

Learning Objective 3.C.4.2

'The student is able to explain contact forces (tension, friction, normal, ***buoyant****, spring) as arising from interatomic electric forces and that they therefore have certain directions. [SP 6.2]'*

CR15

The syllabus must include one assignment, activity, or lab describing how students connect and relate knowledge across various scales, concepts, and representations in and across domains. The assignment, activity, or lab must be labeled with the relevant practice(s) associated with Science Practice 7.

As long as one practice under Science Practice 7 is represented, evidence is sufficient.

CR16

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.

Laboratory Investigations CR17

The AP Physics 2 course devotes over **25% of the time** to laboratory investigations.

The laboratory component of the course allows the students to demonstrate the seven **science practices** through a variety of **hands-on** investigations in **all** of the units of study.

The students use **guided inquiry (GI)** or **open inquiry (OI)** in the design of half of their laboratory investigations. Some labs focus on investigating a physical phenomenon without having expectations of its outcomes. In other experiments, the students have an expectation of its outcome based on concepts constructed from prior experiences. In application experiments, the students use acquired physics principles to address practical problems.

Lab Report CR18

Students report all of the lab investigations in a **laboratory journal**. For each lab, students are expected to record an investigation question, list of equipment, step-by- step procedure, data, data analysis, error analysis, and conclusions. Data analyses include identification of the sources and effects of experimental uncertainty, calculations, results and conclusions, and suggestions for further refinement of the experiment as appropriate.

UNIT	LAB INVESTIGATION OBJECTIVE(S) Investigation identifier: Guided Inquiry: GI or Open Inquiry: OI
UNIT 1. FLUIDS	**1. Archimedes' Principle** To determine the densities of two unknown liquids by using the method that is attributed to Archimedes.
	2. Torricelli's Theorem (GI) To determine the exit velocity of a liquid and predict the range attained with holes at varying heights using a clear 2 L plastic bottle.
	3. Water Fountain Lab To determine the exit angle and speed of the water, radius of the fountain's exit hole, and flow volume rate
UNIT 2. THERMODYNAMICS	**4. Gas Laws** To verify the relationships between pressure, temperature, and volume of a gas (air).
	5. Thermal Conductivity (GI) To determine the thermal conductivity of a material by comparing the difference in temperature across one material to the difference in temperature across a second material of known thermal conductivity.
	6. Heat Engine To determine how the work done by an engine to raise an object of mass m during each of its cycles is related to the area enclosed by its P-V graph.
	7. Thermal Speed and Maxwell Distribution To investigate how molecular mass affects molecular speeds at different temperatures and to plot Maxwell Distributions using applets from The Physics Aviary.

CR17
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 investigations must be listed with a title and brief description. Guided- and open-inquiry labs must be labeled.

CR18
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.

<table>
<tr><th>UNIT</th><th>LAB INVESTIGATION OBJECTIVE(S)
Investigation identifier: Guided Inquiry: GI or
Open Inquiry: OI</th></tr>
<tr><td rowspan="4">UNIT 3. ELECTRIC FORCE, FIELD, AND POTENTIAL</td><td>8. Electrostatics Investigations (GI)
To investigate the behavior of electric charges, charging processes, and the distribution of charge on a conducting object.</td></tr>
<tr><td>9. The Electroscope (GI)
To make qualitative observations of the behavior of an electroscope when it is charged by conduction and by induction.</td></tr>
<tr><td>10. Coulomb’s Law (OI)
To estimate the net charge on identical spherical pith balls by measuring the deflection (angle and separation) between two equally charged pith balls.</td></tr>
<tr><td>11. Electric Field and Equipotentials
To map equipotential isolines around charged conducting electrodes painted with conductive ink and construction of isolines of electric fields.</td></tr>
<tr><td rowspan="4">UNIT 4.
ELECTRIC CIRCUITS</td><td>12. Resistance and Resistivity (OI)
To explore the microscopic and macroscopic factors that influence the electrical resistance of conducting materials. Students will investigate how geometry affects the resistance of an ionic conductor using Play-Doh.</td></tr>
<tr><td>13. DC Circuits: Brightness (GI)
To make predictions about the brightness of light bulbs in a variety of DC circuit configurations (series, parallel and series-parallel) when some of the bulbs are removed.</td></tr>
<tr><td>14. DC Circuits: Resistors (OI)
To investigate the behavior of resistors in series, parallel and series- parallel DC circuits. The lab includes measurements of currents and potential differences.</td></tr>
<tr><td>15. RC Circuits: Resistors and Capacitors (GI)
This investigation consists of two parts:
An observational experiment where the students make qualitative descriptions of the charging and discharging of a capacitor.
To investigate the behavior of resistors in a series-parallel combination with a capacitor in series. Their investigation includes measurement of currents and potential differences at steady states.</td></tr>
<tr><td rowspan="3">UNIT 5. MAGNETISM AND ELECTROMAGNETIC INDUCTION</td><td>16. Magnetic Field of the Earth
To measure the horizontal component of the Earth’s magnetic field using a solenoid and a compass.</td></tr>
<tr><td>17. Magnetic Force on a Current-Carrying Wire (GI)
To determine the magnitude and direction of the magnetic force exerted on a current-carrying wire.</td></tr>
<tr><td>18. Electromagnetic Induction (GI)
The students move a bar magnet in and out of a solenoid and observe the deflection of the galvanometer. They examine the effects of a changing magnetic field by observing currents induced in a solenoid and determine whether the observations agree with the theory of electromagnetic induction and Lenz’ law.</td></tr>
</table>

UNIT	LAB INVESTIGATION OBJECTIVE(S) Investigation identifier: Guided Inquiry: GI or Open Inquiry: OI
UNIT 6. GEOMETRIC AND PHYSICAL OPTICS	**19. Reflection (GI)** Students design an investigation to answer the following question: Are there any patterns in the way plane mirrors and curved mirrors reflect light?
	20. Concave Mirrors This investigation has two parts: ▪ To determine the focal length of a concave mirror. ▪ To determine two locations where a magnified image can be formed using a concave mirror.
	21. Snell's Law (OI) To determine the index of refraction of an acrylic block.
	22. Lenses This investigation has two parts: ▪ To directly determine the focal length of a converging lens. ▪ To determine the focal length of a diverging lens by combining it with a converging lens.
	23. Double-Slit Interference and Diffraction This investigation has three parts: ▪ To determine the wavelength of a green laser using a double slit. ▪ The students apply the results of the previous experiment to predict the location of bright and dark fringes when a red laser of known wavelength is used. ▪ The students determine the spacing in a diffraction grating using either the green or the red laser.
UNIT 7. QUANTUM, ATOMIC AND NUCLEAR PHYSICS	**24. Spectroscopy** Students use a quantitative analysis spectroscope to analyze flame tests and spectrum tubes.
	25. Photoelectric Effect To determine Planck's constant from data collected from a circuit with an LED color strip.
	26. Radioactive Decay and Half-Life (GI) In this investigation students simulate radioactive decay and determine half-life using pennies and dice.