AP® Physics 1 Sample Syllabus 1

Syllabus 1066422v1

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.	1
CR2a	The course design provides opportunities for students to develop understanding of the foundational principles of kinematics in the context of the big ideas that organize the curriculum framework.	1
CR2b	The course design provides opportunities for students to develop understanding of the foundational principles of dynamics in the context of the big ideas that organize the curriculum framework.	1
CR2c	The course design provides opportunities for students to develop understanding of the foundational principles of gravitation and circular motion in the context of the big ideas that organize the curriculum framework.	2
CR2d	The course design provides opportunities for students to develop understanding of the foundational principles of simple harmonic motion in the context of the big ideas that organize the curriculum framework.	2
CR2e	The course design provides opportunities for students to develop understanding of the foundational principles of linear momentum in the context of the big ideas that organize the curriculum framework.	2
CR2f	The course design provides opportunities for students to develop understanding of the foundational principle of energy in the context of the big ideas that organize the curriculum framework.	2
CR2g	The course design provides opportunities for students to develop understanding of the foundational principles of rotational motion in the context of the big ideas that organize the curriculum framework.	3
CR2h	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
CR2i	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
CR2j	The course design provides opportunities for students to develop understanding of the foundational principles of mechanical waves in the context of the big ideas that organize the curriculum framework.	3
CR3	Students have opportunities to apply AP Physics 1 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.	9
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.	9
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.	4
CR6a	The laboratory work used throughout the course includes investigations that support the foundational AP Physics 1 principles.	4, 5, 6, 7, 8
CR6b	The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.	4, 5, 6, 7, 8
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.	4
CR8	The course provides opportunities for students to develop written and oral scientific argumentation skills.	10

RESOURCES

TEXTBOOK

Etkina, Eugenia, Michael Gentile, and Alan Van Heuvelen. *College Physics*. San Francisco, CA: Pearson, 2014. **[CR1]**

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

TEACHING RESOURCES

Christian, Wolfgang, and Mario Belloni. *Physlet® Physics: Interactive Illustrations, Explorations and Problems for Introductory Physics*. Upper Saddle River, NJ: Prentice Hall, 2004.

Hieggelke, Curtis, David Maloney, and Stephen Kanim. *Newtonian Tasks Inspired by Physics Education Research: nTIPERs*. Upper Saddle River, NJ: Pearson, 2012.

Hieggelke, Curtis, David Maloney, Tomas O'Kuma, and Stephen Kanim. *E&M TIPERs: Electricity & Magnetism Tasks*. Upper Saddle River, NJ: Pearson, 2006.

Knight, Randall D., Brian Jones, and Stuart Field. *College Physics: A Strategic Approach*. 2nd ed., AP® ed. Boston: Pearson, 2013.

INSTRUCTIONAL STRATEGIES

The AP Physics 1 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 multi-step problems, design investigations, and reflect on knowledge construction through self-assessment rubrics.

In most labs, the students use probeware technology in data acquisition. In the classroom, they use graphing calculators and digital devices for interactive simulations, Physlet-based exercises, collaborative activities, and formative assessments.

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

COURSE SYLLABUS

UNIT 1. KINEMATICS [CR2a]

- Kinematics in one-dimension: constant velocity and uniform accelerated motion
- Vectors: vector components and resultant
- Kinematics in two-dimensions: projectile motion

Big Idea 3
Learning Objectives: 3.A.1.1, 3.A.1.2, 3.A.1.3

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

UNIT 2. DYNAMICS [CR2b]

- Forces, types, and representation (FBD)
- Newton's First Law

- Newton's Third Law
- Newton's Second Law
- Applications of Newton's Second Law
- Friction
- Interacting objects: ropes and pulleys

Big Ideas 1, 2, 3, 4
Learning Objectives: 1.C.1.1, 1.C.1.3, 2.B.1.1, 3.A.2.1, 3.A.3.1, 3.A.3.2, 3.A.3.3, 3.A.4.1, 3.A.4.2, 3.A.4.3, 3.B.1.1, 3.B.1.2, 3.B.1.3, 3.B.2.1, 3.C.4.1, 3.C.4.2, 4.A.1.1, 4.A.2.1, 4.A.2.2, 4.A.2.3, 4.A.3.1, 4.A.3.2

UNIT 3. CIRCULAR MOTION AND GRAVITATION [CR2c]

- Uniform circular motion
- Dynamics of uniform circular motion
- Universal Law of Gravitation

Big Ideas 1, 2, 3, 4
Learning Objectives: 1.C.3.1, 2.B.1.1, 2.B.2.1, 2.B.2.2, 3.A.3.1, 3.A.3.3, 3.B.1.2, 3.B.1.3, 3.B.2.1, 3.C.1.1, 3.C.1.2, 3.C.2.1, 3.C.2.2, 3.G.1.1, 4.A.2.2

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

UNIT 4. ENERGY [CR2f]

- Work
- Power
- Kinetic energy
- Potential energy: gravitational and elastic
- Conservation of energy

Big Ideas 3, 4, 5
Learning Objectives: 3.E.1.1, 3.E.1.2, 3.E.1.3, 3.E.1.4, 4.C.1.1, 4.C.1.2, 4.C.2.1, 4.C.2.2, 5.A.2.1, 5.B.1.1, 5.B.1.2, 5.B.2.1, 5.B.3.1, 5.B.3.2, 5.B.3.3, 5.B.4.1, 5.B.4.2, 5.B.5.1, 5.B.5.2, 5.B.5.3, 5.B.5.4, 5.B.5.5, 5.D.1.1, 5.D.1.2, 5.D.1.3, 5.D.1.4, 5.D.1.5, 5.D.2.1, 5.D.2.3

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

UNIT 5. MOMENTUM [CR2e]

- Impulse
- Momentum
- Conservation of momentum
- Elastic and inelastic collisions

Big Ideas 3, 4, 5
Learning Objectives: 3.D.1.1, 3.D.2.1, 3.D.2.2, 3.D.2.3, 3.D.2.4, 4.B.1.1, 4.B.1.2, 4.B.2.1, 4.B.2.2, 5.A.2.1, 5.D.1.1, 5.D.1.2, 5.D.1.3, 5.D.1.4, 5.D.1.5, 5.D.2.1, 5.D.2.2, 5.D.2.3, 5.D.2.4 , 5.D.2.5, 5.D.3.1

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

UNIT 6. SIMPLE HARMONIC MOTION [CR2d]

- Linear restoring forces and simple harmonic motion
- Simple harmonic motion graphs
- Simple pendulum
- Mass-spring systems

Big Ideas 3, 5

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

Learning Objectives: 3.B.3.1, 3.B.3.2, 3.B.3.3, 3.B.3.4, 5.B.2.1, 5.B.3.1, 5.B.3.2, 5.B.3.3, 5.B.4.1, 5.B.4.2

UNIT 7. ROTATIONAL MOTION [CR2g]

- Torque
- Center of mass
- Rotational kinematics
- Rotational dynamics and rotational inertia
- Rotational energy
- Angular momentum
- Conservation of angular momentum

Big Ideas 3, 4, 5

Learning Objectives: 3.F.1.1, 3.F.1.2, 3.F.1.3, 3.F.1.4, 3.F.1.5, 3.F.2.1, 3.F.2.2, 3.F.3.1, 3.F.3.2, 3.F.3.3, 4.A.1.1, 4.D.1.1, 4.D.1.2, 4.D.2.1, 4.D.2.2, 4.D.3.1, 4.D.3.2, 5.E.1.1, 5.E.1.2, 5.E.2.1

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

UNIT 8. MECHANICAL WAVES [CR2j]

- Traveling waves
- Wave characteristics
- Sound
- Superposition
- Standing waves on a string
- Standing sound waves

Big Idea 6

Learning Objectives: 6.A.1.1, 6.A.1.2, 6.A.1.3, 6.A.2.1, 6.A.3.1, 6.A.4.1, 6.B.1.1, 6.B.2.1, 6.B.4.1, 6.B.5.1, 6.D.1.1, 6.D.1.2, 6.D.1.3, 6.D.2.1, 6.D.3.1, 6.D.3.2, 6.D.3.3, 6.D.3.4, 6.D.4.1, 6.D.4.2, 6.D.5.1

CR2j— The course design provides opportunities for students to develop understanding of the foundational principles of mechanical waves in the context of the big ideas that organize the curriculum framework.

UNIT 9. ELECTROSTATICS [CR2h]

- Electric charge and conservation of charge
- Electric force: Coulomb's Law

Big Ideas 1, 3, 5

Learning Objectives: 1.B.1.1, 1.B.1.2, 1.B.2.1, 1.B.3.1, 3.C.2.1, 3.C.2.2, 5.A.2.1

CR2h— 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.

UNIT 10. DC CIRCUITS [CR2i]

- Electric resistance
- Ohm's Law
- DC circuits
- Series and parallel connections
- Kirchhoff's Laws

Big Ideas 1, 5

Learning Objectives: 1.B.1.1, 1.B.1.2, 1.E.2.1, 5.B.9.1, 5.B.9.2, 5.B.9.3, 5.C.3.1, 5.C.3.2, 5.C.3.3

CR2i— 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.

LABORATORY INVESTIGATIONS AND THE SCIENCE PRACTICES

The AP Physics 1 course devotes over **25% of the time** to hands-on laboratory investigations. **[CR5]** The laboratory component of the course allows the students to demonstrate the seven **science practices** through a variety of investigations in all of the foundational principles.

The students use **guided–inquiry (GI)** or **open–inquiry (OI)** in the design of their laboratory investigations. Some labs focus on investigating a physical phenomenon without having expectations of its outcomes. In other experiments, the student has 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. Students also investigate topic-related questions that are formulated through student designed/selected procedures.

All investigations are reported in a **laboratory journal**. Students are expected to record their observations, data, and data analyses. 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. **[CR7]**

UNIT	**LAB INVESTIGATION OBJECTIVE(S)** (Investigation identifier: Guided–Inquiry: **GI** Open–Inquiry: **OI**)
UNIT 1. KINEMATICS [CR6a]	**1. Meeting Point** To predict where two battery-powered cars will collide if they are released from opposite ends of the lab table at different times. Science Practices 1.1, 1.2, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	2. Match the Graph (GI) [CR6b] To determine the proper placement of an air track, a glider, and a motion detector to produce a motion that matches a set of given graphs: position, velocity, and acceleration versus time. Science Practices 1.2, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	3. Free-Fall Investigation To determine and compare the acceleration of two objects dropped simultaneously. Science Practices 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	4. Vector Addition (GI) [CR6b] To determine the value of a resultant of several vectors, and then compare that value to the values obtained through graphical and analytical methods. Science Practices 1.1, 1.2, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2

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.

CR6a— The laboratory work used throughout the course includes investigations that support the foundational AP Physics 1 principles.

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

	5. Shoot the Target (GI) [CR6b] To determine the initial velocity of a projectile, the angle at which the maximum range can be attained, and predict where the projectile will land. Science Practices 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	6. Chase Scenario (GI) [CR6b] *Lab Practicum:* Students use a battery cart and a fan cart to recreate a chase scenario (police-thief) to predict the position where the 'thief' will be caught and the final speeds of both cars. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2

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

UNIT 2. DYNAMICS [CR6a]	**7. Inertial and Gravitational Mass (GI) [CR6b]** To determine the difference (if any) between inertial mass and gravitational mass. Science Practices 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	8. Forces Inventory (GI) [CR6b] Qualitative and quantitative investigation on a variety of interactions between objects. Science Practices 1,1, 1.4, 1.5, 2.1, 2.2, 3.3, 4.1, 4.2, 4.3, 5.1, 6.1, 6.2, 6.4, 7.2
	9. Static Equilibrium Challenge To determine the mass of a hanging object in a setup with three strings at various angles. Science Practices 1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	10. Newton's Second Law (OI) [CR6b] To determine the variation of the acceleration of a dynamics cart in two scenarios: (1) the total mass of the system is kept constant while the net force varies, and (2) the net force is kept constant while the total mass of the system varies. Science Practices 1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	11. Coefficient of Friction (GI) [CR6b] To determine the maximum coefficient of static friction between a shoe and a wooden plank. Science Practices 1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	12. Atwood's Machine (GI) [CR6b] To determine the acceleration of a hanging mass and the tension in the string. Science Practices 1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2

CR6a— The laboratory work used throughout the course includes investigations that support the foundational AP Physics 1 principles.

UNIT 3. CIRCULAR MOTION AND GRAVITATION [CR6a]	**13. Flying Toy (GI) [CR6b]** To determine the tension in the string and the centripetal acceleration of the flying toy. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
UNIT 4. ENERGY [CR6a]	**14. Roller Coaster Investigation (GI) [CR6b]** To design a simple roller coaster using provided materials to test whether the total energy of the system is conserved if there are no external forces exerted on it by other objects. Science Practices 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.2, 6.4, 7.2
	15. Work Done in Stretching a Spring (GI) [CR6b] To determine the work done on the spring from force-versus-distance graph of the collected data. Science Practices 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	16. Energy and Non-Conservative Forces (GI) [CR6b] To determine the energy dissipated by friction of a system consisting of a modified Atwood's machine. Science Practices 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 6.5, 7.2
UNIT 5. MOMENTUM [CR6a]	**17. Bumper Design (GI) [CR6b]** To design a paper bumper that will soften the impact of the collision between a cart and a fixed block of wood. Their designs are evaluated by the shape of an acceleration-versus-time graph of the collision. Science Practices 1.4, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	18. Impulse and Change in Momentum (GI) [CR6b] To measure the change in momentum of a dynamics cart and compare it to the impulse received. Science Practices 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	19. Elastic and Inelastic Collisions (OI) [CR6b] To investigate conservation of momentum and conservation of energy using a ballistic pendulum to determine the type of collision. Science Practices 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	20. Forensic Investigation (OI) [CR6b] *Lab Practicum:* Apply principles of conservation of energy, conservation of momentum, the work-energy theorem, and a linear model of friction to find the coefficient of kinetic friction. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2

CR6a— The laboratory work used throughout the course includes investigations that support the foundational AP Physics 1 principles.

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

UNIT 6. SIMPLE HARMONIC MOTION [CR6a]	**21. Finding the Spring Constant (GI) [CR6b]** To design two independent experiments to determine the spring constants of various springs of equal length. Science Practices 1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	22. Graphs of an Oscillating System (GI) [CR6b] To analyze graphs of position, velocity, and acceleration versus time for an oscillating system to determine how velocity and acceleration vary at the equilibrium position and at the endpoints. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	23. Simple Pendulum Investigation (GI) [CR6b] To investigate the factors that affect the period of a simple pendulum and test whether the period is proportional to the pendulum's length, the square of its length, or the square root of its length. Science Practices 1.2, 1.4, 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
UNIT 7. ROTATIONAL MOTION [CR6a]	**24. Torque and the Human Arm (OI) [CR6b]** To design and build an apparatus that replicates the forearm and biceps muscle system to determine the biceps tension when holding an object in a lifted position. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.1, 7.2
	25. Rotational Inertia (GI) [CR6b] To determine the rotational inertia of a cylinder from the slope of a graph of an applied torque versus angular acceleration. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	26. Conservation of Angular Momentum (GI) [CR6b] To investigate how the angular momentum of a rotating system responds to changes in the rotational inertia. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
UNIT 8. MECHANICAL WAVES [CR6a]	**27. Mechanical Waves (GI) [CR6b]** To model the two types of mechanical waves with a spring toy to test whether or not these characteristics affect the speed of a pulse: frequency, wavelength, and amplitude. Science Practices 1.2, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.2, 6.4, 7.2
	28. Speed of Sound (GI) [CR6b] Design two different procedures to determine the speed of sound in air. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2

CR6a— The laboratory work used throughout the course includes investigations that support the foundational AP Physics 1 principles.

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

	29. Wave Boundary Behavior (GI) [CR6b] To compare what happens to the phase of a transverse wave on a spring toy when a pulse is reflected from a boundary and when it is reflected and transmitted from various boundaries (spring to string). Science Practices 1.4, 3.1, 4.1, 4.2, 4.3, 5.1, 6.1, 6.4, 7.2
	30. Standing Waves (GI) [CR6b] Given a specified tension, students predict the length of the string necessary to generate the first two harmonics of a standing wave on the string. Then they perform the experiment and compare the outcome with their prediction. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
UNIT 9. ELECTROSTATICS [CR6a]	**31. Static Electricity Interactions (GI) [CR6b]** Students use sticky tape and a variety of objects to make qualitative observations of the interactions when objects are charged, discharged, and recharged. Science Practices 1.2, 3.1, 4.1, 4.2, 5.1, 6.2, 7.2
	32. Coulomb's Law (GI) [CR6b] To estimate the charge on two identical, equally charged spherical pith balls of known mass. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
UNIT 10. DC CIRCUITS [CR6a]	**33. Brightness Investigation (GI) [CR6b]** To make predictions about the brightness of light bulbs in a variety of series and parallel circuits when some of the bulbs are removed. Science Practices 1.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	34. Voltage and Current (GI) [CR6b] To determine the relationship between the current through a resistor and the voltage across the resistor. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	35. Resistance and Resistivity (GI) [CR6b] To investigate the effects of cross-sectional area and length on the flow of current through a roll of Play-Doh. Science Practices 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1,5.3, 6.1, 6.4, 7.2
	36. Series and Parallel Circuits (GI) [CR6b] To investigate the behavior of resistors in series, parallel, and series-parallel circuits. The lab should include measurements of voltage and current. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.4, 7.2

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

CR6a— The laboratory work used throughout the course includes investigations that support the foundational AP Physics 1 principles.

INSTRUCTIONAL ACTIVITIES

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. Examples of activities are described below.

CR3— Students have opportunities to apply AP Physics 1 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.

1. PROJECT DESIGN [CR3]

Students engage in hands-on activities outside of the laboratory experience that support the connection to more than one Learning Objective.

ACTIVITY: Roller Coaster Investigation
DESCRIPTION:
Working in groups of three, students design a simple roller coaster using provided materials (a track with a vertical loop and toy cars) to test whether the total energy of a car-Earth system is conserved if there are no external forces exerted on it by other objects. Students include multiple representations of energy to provide **evidence** for their **claims**. Students use a bar chart, the mathematical expression of conservation of energy represented by the graph, and the corresponding calculations to evaluate whether the outcome of the experiment supports the idea of energy conservation**.** This activity is designed to allow students to apply the following Learning Objectives:

Learning Objective 5.B.3.1
The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.

Learning Objective 5.B.3.2
The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.

Learning Objective 5.B.3.3
The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.

Learning Objective 5.B.4.2
The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.

Learning Objective 4.C.1.1
The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.

Learning Objective 4.C.1.2
The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system.

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.

2. REAL WORLD APPLICATION

ACTIVITY: Torque and the Human Arm [CR4]

DESCRIPTION:

This activity provides an opportunity for students to make an **interdisciplinary connection** to biological systems by investigating the structure and function of a major muscle (biceps) in the human body.

Students design and build an apparatus that replicates the forearm and biceps muscle system. The objective is to determine the biceps tension when holding an object in a lifted position. Students may use the Internet to research the structure of the biceps muscle. They can use readily available materials in the classroom, such as a meter stick, a ring stand, weight hangers, an assortment of blocks, and a spring scale. In their lab journal, students are required to document the different stages of their design. Required elements include design sketches, force diagrams, mathematical representations of translational and rotational equilibrium, and numerical calculations.

Learning Objective 3.F.1.1

The student is able to use representations of the relationship between force and torque.

Learning Objective 3.F.1.2

The student is able to compare the torques on an object caused by various forces.

Learning Objective 3.F.1.3

The student is able to estimate the torque on an object caused by various forces in comparison to other situations.

Learning Objective 3.F.1.4

The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system.

Learning Objective 3.F.1.5

The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction).

3. SCIENTIFIC ARGUMENTATION

In the course, students become familiar with the three components of **scientific argumentation**. The first element is the claim, which is the response to a prediction. A claim provides an explanation for why or how something happens in a laboratory investigation. The second component is the evidence, which supports the claim and consists of the analysis of the data collected during the investigation. The third component consists of questioning, in which students examine and defend one another's claims. 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 **[CR8]**.

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

ACTIVITY 1: Formative Assessment: Changing Representations in Energy

DESCRIPTION:

Students work in pairs to create exercises that involve translation from one representation to another. Some possible translations are:

- from a bar chart to a mathematical representation
- from a physical situation diagram to a bar chart
- from a given equation to a bar chart

Each pair of students exchanges their exercises with another pair. After the students work through the exercises they received, the pairs meet and offer constructive criticism (**peer critique**) on each other's solutions.

Learning Objective 5.B.4.1

The student is able to describe and make predictions about the internal energy of everyday systems.

Learning Objective 5.B.4.2

The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.

ACTIVITY 2. Laboratory Investigation: Speed of Sound

DESCRIPTION:

Working in small groups, students design two different procedures to determine the speed of sound in air. They brainstorm their approaches and write them on the whiteboard. Each of the teams presents their ideas to the class. They receive feedback from their peers and then conduct their experiments. They record the revised procedures in their lab journals. During the post-lab discussion, the students discuss their results (**evidence**) by examining and defending one another's **claims**. Then as a class we reach consensus about the estimated value for the speed of sound.

Learning Objective 6.A.2.1

The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples.

Learning Objective 6.A.4.1

The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example.

Learning Objective 6.B.4.1

The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.