AP® Physics 1 Syllabus, Syllabus

A. Requirements

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

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.

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.

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.

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

B. A Few Things To Note

About This AP Physics Course

This is an online course covering 13 chapters and is designed to cover all the curricular elements for AP Physics 1 designated by the College Board. It is equivalent to an introductory algebra based college/university physics course. The emphasis in the course is on the understanding of the concepts and skills, and using these concepts and formulae to solve problems.

This course is a student centered, inquiry based course with a strong laboratory component involving 14 hands on labs, two math labs, two strobe photo labs, one video lab, and four query based Virtual labs. There will also be two projects for students to design and create their own laboratory exploration: one in mechanics, and one in the remainder of the course. Every student has regular access to the teacher (phone, email, Skype, etc.) for inquiry led discussion, demonstration of physics knowledge and understanding of concepts, and help.

The students are required to have a hard cover laboratory notebook, use notations only in ink, and are not allowed to insert or remove any pages. Details of experimental write-ups are included after the list of laboratories.
There is a student forum where students post questions, answers, and lab discussions. There are philosophical and ethical questions posted as discussion starters. These forums are an integral part of the course.

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. They use graphing calculators and digital devices for interactive simulations, Physlet-based exercises, collaborative activities, and formative assessments. In laboratory investigations, students use guided–inquiry (GI) or open–inquiry (OI) in the design of their laboratory investigations.(More on Labs and Activities later.)

Unique Lesson Instruction

The Online Textbook powered by StudyForge technology consists of lessons which are delivered through multimedia flash videos with video and audio components, as well as interactive applets or other features built into every lesson, encourages the taking of guided, detailed notes for each lesson and doing a large variety of practice questions afterwards, and a separate book which contains detailed solutions for every practice question. In regards to the interactive nature of each lesson, this includes use of various applets (for example, the student can select different masses and the frictional coefficients of [horizontal] table Atwoods etc…), and interactive flash animations of an animated object in motion is changed into a motion map and then into a series of graphs with respect to time including displacement, velocity and acceleration. It also contains other interactive features such as built in pauses during each lesson for the students to stop and reflect on the material, work on a question for themselves before viewing the answer, or rewind the video and go through a section of the lesson again. (Note that at any time the student can pause the video, rewind, and even view at ½ speed if desired.)

Available Resources

- Urone, P. and Hinrichs, R. *College Physics*. Houston, TX: Open Stax College.
- *College Physics Workbook*, Hewko Education, Cranbrook, British Columbia, 2012.
    - Note: The author is a college Physics professor with over 35 years of classroom teaching experience at the College level (not to mention having taught for years at the high school level, including presently), with vast experience in curriculum and course development. There are over 1000 college-level questions with very detailed solutions for all questions.
- MIT Open Courseware – *Physics*: http://ocw.mit.edu/courses/physics/
- Fletcher, Craig. *Physics with Calculus*. The books come in two volumes, designed as a self-teaching course. http://faculty.polytechnic.org/cfletcher/
- APlusPhysics.com - a great collection of resources, from problems to podcasts to blogs and for educators and students alike, with especially strong content for AP, Honors, and Regents exam curricula
- AP Physics Lectures - a collection of links to YouTube videos covering the major topics in AP Physics
- Thermo Spoken Here - a great resource from Jim Pohl, with nicely detailed explanations of fundamental areas in Mechanics
- J. Walker's *Physics: an introduction*
- The Physics Classroom - an excellent collection of online Physics resources

C. Course Syllabus

UNIT 1. MATHEMATICAL PREPARATION

Chapter 1: Units, dimensionality, simple trigonometry, vectors

UNIT 2. Mechanics [CR2a]

Part 1: Kinematics

Chapter 2. Kinematics in one-dimension: constant velocity and uniform accelerated motion, "the linear model"
Chapter 3. Kinematics in two-dimensions: projectile motion, relative motion in two dimensions, "the quadratic model"

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

Part 2: Dynamics

Chapter 4. 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

Note on Big Idea 4: Students will learn that when systems are in contact, or connected by pulleys, they interact influencing each other in many ways including friction.

Chapter 5. CIRCULAR MOTION AND GRAVITATION [CR2c]

Uniform circular motion
Dynamics of uniform circular motion
Universal Law of Gravitation
The cyclic model

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

Note on Big idea 4: Students will learn that systems can be profoundly affected by the interaction of their masses through gravitation so that their internal and external motions are strongly changed including tidal effects.

Part 3. ENERGY [CR2f]

Chapter 6: Work and Energy

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

Note on Big Idea 4: Students will learn that when systems touch or are connected by otter systems, they can exchange energy, which can have drastic effects on both systems.

Part 4. MOMENTUM [CR2e]

Chapter 7. Impulse and Momentum

Conservation of linear momentum

Elastic and inelastic collisions

Big Ideas 3, 4, 5

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

Note on Big Idea 4: Students will learn that collisions between systems can cause massive changes to the systems involved, such as in the collision of two automobiles. However, the linear momentum of the total system must still be conserved, even though the linear momentum of each system can change.

Part 5. ROTATIONAL MOTION AND STATICS [CR2g]

Chapter 8. Rotational kinematics,

Chapter 9: Rotational dynamics and rotational inertia

Torque, Center of mass, statics

Rotational energy

Angular momentum

Conservation of angular momentum

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

Part 6. SIMPLE HARMONIC MOTION [CR2d]

Chapter 10 Elasticity and Simple harmonic motion

Stress and Strain in materials

Linear restoring forces and simple harmonic motion
Simple harmonic motion graphs
Simple pendulum, physical pendulum, rotational SHM
Mass-spring systems

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

Note on Big idea 4: Students will learn that vibrations can be changed into sound waves and back again.

Part 7. MECHANICAL WAVES [CR2j]

Chapter 11: Waves and Sound

Traveling waves
Wave characteristics
Sound
Superposition
Standing waves on a string
Standing sound waves
Interference of waves
Doppler effect
The wave model

Big Ideas 4, 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

Note on Big idea 4: Students will learn that vibrations can be changed into sound waves and back again into vibrations of other systems, such as sound waves striking the eardrum, or being produced by musical instruments, speakers, and microphones.

UNIT 3. ELECTROSTATICS AND DYNAMICS [CR2h]

Part 1 Electrostatics

Chapter 12

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

Part 2. DC CIRCUITS [CR2i]

Chapter 13

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

D. Connections between enduring concepts

An important part of the course is the ongoing connections between various enduring concepts and these are studied in essays and exercises throughout the course.

For example, students are asked to connect the time and range of a projectile to the initial velocity (speed and angle) of the projection or calculating the mass of the earth from the distance and sidereal period of the moon. Another example is the special case essay "The Anatomy of a Collision" where the colliding solid objects are treated like springs with their stresses and strains being discussed in detail including how Newton's third law has to be maintained, and how that relates to conservation of energy, and conservations of linear and angular momentum. Or how these compression forces cause sound waves to travel down the object away from the collision plane at the speed of sound, and how these waves are reflected, absorbed and are transferred to the air causing a shockwave travelling in the air at the speed of sound away from the collision. The absorption causes heating in the material and how this heating travels by conduction, and radiation, and in the air, by convection. The shockwave disperses at the speed of sound traveling outward from the collision site in a sphere whose intensity obeys the same inverse square law as light waves, and gravitational and electrical fields, and for the same geometric reasons.

E. Big Idea 4
The above essay and other comments in the course also contribute to the understanding of "Big Idea 4". The two solids colliding are actually two systems of ions, atoms, molecules, and free electrons, and their complex electric fields. The dramatic changes to their macroscopic and microscopic structures are easy for students to see and understand: interacting systems really do cause dramatic changes to their internal structures.

F. Laboratory Investigations and the Science Practices

The AP Physics 1 course devotes over **25% of the time** to 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. An eighth practice involving understanding, calculating and minimizimg measurement errors is also taught.

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. Students also use and try various mathematical models in their investigantions. 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]

Lab Investigation Objective(s)

Note:	Investigation identifiers:	Guided–Inquiry: GI Open–Inquiry: OI
2nd Note:	Science Practice 8.1 is “proper handling of measurement error.”	

1. 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

2. Measurement and Error
To learn and practice proper methods of error estimation, the propagation of errors, and the correct way to display measurements and results.

- Science practices 8.1

3. Constant Velocity
To understand the implications of constant speed, distance and time
To predict where two battery-powered cars will collide if they are released from opposite ends of the room 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, 8.1

4. 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, 8.1

5. Projectile motion on a ramp[CR6b]

To determine the initial velocity of a projectile, the angle at which it was shot from its time aloft and range. Predict the maximum height gained.

- 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. Analyzing projectile Motion in Table Tennis
Determine gravity and air friction by examining the motion of a table tennis ball.

- 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, 8.1

7. Newton's Second Law (OI) [CR6b]
To determine the variation of the acceleration of a dynamics cart in three 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
and (3) the relationship between force and mass when the acceleration is kept constant.

- 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

8. Free body diagrams (GI) [CR6b]
Learning to draw and use one of the most important tools of mechanics

- 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. 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

10. 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

11. 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

12. Deformation and elasticity in collisions (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

13. 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 to data from a automobile collision. Determine the speeds at impact of the colliding vehicles.

- 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

14. Forensic determination of speed and coefficients of friction from tread marks
As the title suggests.

- 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

15. 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

16. Simple Pendulum Investigation (GI) [CR6b]
To investigate the factors that affect the period of a simple pendu¬lum 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, 8.1

17. Physical Pendulum
To investigate the factors that affect the period of a simple pendu¬lum 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, 8.1

18. Angular Acceleration (GI) [CR6b]
To determine the acceleration of a rotating disc.

- 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, 8.1

19. 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

20. Standing Waves on stringed instruments (GI) [CR6b]
Using a stringed instrument determine the importance of wire density and tension and string length to pitch.

- 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

21. 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

22. 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

23. 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

24. Series, Parallel, and Complex 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

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. Types of activities include:

> **<u>Project Design</u> (students engage in hands-on activities outside of the laboratory experience that support the connection to more than one Learning Objective**)
>
> Students will design an experiment using household materials that will demonstrate the transfer of energy from one system to another while showing that the total energy remains constant.
>
> **<u>Real World Application Project</u> (making interdisciplinary connections by applying Physics concepts and skills to further exploring and understanding (and potentially replicating a model of) real world phenomena across various scientific disciplines)**
>
> Students will develop a method of data collection at a vehicle crash site that will allow forensic determination of the initial velocity of the two vehicles.
>
> **<u>Scientific Argumentation</u> (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].)

Students will develop a scientific argument on a particular topic of their choosing from a list of ten possible topics.

These activities are designed to further allow students to explore, understand and apply the Learning Objectives in the course.