

SYLLABUS DEVELOPMENT GUIDE

AP[®] Physics C: Mechanics

The guide contains the following sections and information:

Curricular Requirements

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

Required Evidence

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

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

Clarifying Terms

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

Samples of Evidence

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

Curricular Requirements

CR1	Students and teachers have access to college-level resources including a college-level textbook and reference materials in print or electronic format.	<i>See page:</i> 3
CR2	The course provides opportunities to develop student understanding of the required content outlined in each of the Unit Guides of the AP Course and Exam Description (CED).	<i>See page:</i> 4
CR3	The course provides opportunities for students to develop the skills related to Science Practice 1: Visual Interpretation.	<i>See page:</i> 6
CR4	The course provides opportunities for students to develop the skills related to Science Practice 2: Question and Method.	<i>See page:</i> 7
CR5	The course provides opportunities for students to develop the skills related to Science Practice 3: Representing Data and Phenomena.	<i>See page:</i> 8
CR6	The course provides opportunities for students to develop the skills related to Science Practice 4: Data Analysis.	<i>See page:</i> 9
CR7	The course provides opportunities for students to develop the skills related to Science Practice 5: Theoretical Relationships.	<i>See page:</i> 10
CR8	The course provides opportunities for students to develop the skills related to Science Practice 6: Mathematical Routines.	<i>See page:</i> 11
CR9	The course provides opportunities for students to develop the skills related to Science Practice 7: Argumentation.	<i>See page:</i> 12
CR10	The course provides students with opportunities to apply their knowledge of AP Physics concepts to real-world questions or scenarios to help them become scientifically literate citizens.	<i>See page:</i> 13
CR11	Students spend a minimum of 25 percent of instructional time engaged in a wide range of hands-on laboratory investigations with an emphasis on inquiry-based labs to support the learning of required content and development of science practice skills throughout the course.	<i>See page:</i> 14
CR12	The course provides opportunities for students to record evidence of their scientific investigations in a portfolio of lab reports or a lab notebook (print or digital format).	<i>See page:</i> 19

Curricular Requirement 1

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

Required Evidence

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

Samples of Evidence

1. Textbook: *Fundamentals of Physics*; Halliday, Resnick & Walker, Extended 10th Edition, August 2013, Wiley. This is a calculus-based, college-level textbook.
2. *University Physics with Modern Physics*, 14th Edition, Young and Freedman, Pearson, 2016.
3. The main textbook for this course, which will be supplemented with other materials, is *Physics for Scientists and Engineers: A Strategic Approach with Modern Physics*, Randall Knight, Addison-Wesley, 2010.

Curricular Requirement 2

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

Required Evidence

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

Samples of Evidence

1. Unit 1: 1-D and 2-D Kinematics. Big Idea 1.

Unit 2: Forces. Big Idea 2

Unit 3: Work, Energy, and Power. Big Ideas 2 and 4.

Unit 4: Momentum. Big Ideas 1, 2 and 4.

Unit 5: Rotation. Big Ideas 1, 2 and 4

Unit 6: Oscillations. Big Idea 2

Unit 7: Gravitation. Big Ideas 3 and 4

2. Course covers topics in 1-D and 2-D kinematics as well as Big Idea CHA.

Course covers Newton’s first, second, and third laws and circular motion, as well as Big Idea INT.

Course covers conservation laws including work, power, energy, conservation of energy, momentum and impulse, conservation of momentum, collisions, and center of mass (system of particles), and Big Ideas CHA, INT, and CON.

Course covers torque and rotational statics, rotational kinematics, rotational dynamics and energy, and angular momentum and its conservation, and Big Ideas CHA, INT, and CON.

Course covers oscillations, including simple harmonic motion, masses on springs, and pendulums. Big Idea INT.

Course covers gravitational forces and orbits of planets and satellites. Big Ideas FLD and CON.

3. In Unit 1 topics such as one-dimensional and two-dimensional kinematics are covered.

- Big Idea Change is developed by means of the following activity: Calculating the unknown variables of motion for an object undergoing accelerated motion.

In Unit 2 topics such as Newton’s first and second laws, circular motion, and Newton’s third law are covered.

- Big Idea Force Interactions is developed by means of the following activity: Students determine the tension in the string of a conical pendulum using only a meterstick.

In Unit 3, topics such as the work-energy theorem, the relationship between force and potential energy, conservation of energy, and power are covered.

- Big Idea Force Interactions is developed by means of the following activity: Calculating the work done by a variable force in moving an object by integration.
- Big Idea Conservation is developed by means of the following activity: Solving problems with work and power.

In Unit 4, momentum topics (Big Ideas of Change, Force Interactions, and Conservation) such as impulse and momentum, conservation of momentum, elastic and inelastic collisions, and center of mass are covered.

- Big Idea Change is developed by means of the following activity: Students determine under which conditions momentum and kinetic energy are conserved or not during collisions.
- Big Idea Force Interactions is developed by means of the following activity: Students determine the relationship between the area under a force vs. time curve and the change in momentum of an object.
- Big Idea Conservation is developed by means of the following activity: Students use conservation of momentum and energy to solve problems.

In Unit 5, Rotation, topics such as torque and rotational statics, rotational kinematics, rotational dynamics and energy, and conservation of angular momentum are covered.

- Big Idea Change is developed by means of the following activity: Students calculate the total kinetic energy of a rolling body that has both translational and rotational kinetic energy.
- Big Idea Force Interactions is developed by means of the following activity: Students compare torques created by applying equal forces to different points on a long rod pivoted at one end.
- Big Idea Conservation is developed by means of the following activity: Students apply the conservation of angular momentum to make predictions in the laboratory and solve problems.

In Unit 6, Oscillation, topics such as simple harmonic motion, masses on springs, and pendulums are covered.

- Big Idea of Force Interactions is developed by means of the following activity: Students use Hooke's law to determine the spring constant of an unknown spring.

In Unit 7, Gravitation, topics such as gravitational field, force, and the orbits of planets and satellites are covered.

- Big Idea of Fields is developed by means of the following activity: Students describe the relationship between force and fields and prepare to make similar connections in later courses. They study the gravitational field created by an object and how it varies with distance.
- Big Idea of Conservation is developed by means of the following activity: Students derive Kepler's laws from the law of gravitation and the conservation of angular momentum.

Curricular Requirement 3

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

Required Evidence

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

Samples of Evidence

1. While studying projectile motion in kinematics, students will be asked to draw vectors representing the velocity and the acceleration of a projectile at different points in its trajectory, justifying the direction and the relative magnitude of the vectors. Vectors representing velocity and vectors representing acceleration will be identified in a distinct and consistent manner throughout the course. **(Skill 1.A)**
2. Students determine the acceleration of an object based on its free-body diagram. **(Skill 1.D)**
3. While studying forces on connected systems, students will draw free-body diagrams for the individual objects. They will also draw a free-body diagram for the system. **(Skill 1.C)**

Curricular Requirement 4

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

Required Evidence

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

Samples of Evidence

1. In this guided inquiry-based activity, students conduct an experiment to test the conservation of kinetic energy and linear momentum before, during, and after a collision between two carts on a low-friction cart/table apparatus. The data are gathered using motion sensors interfaced with a computer (or calculator, as an option). **(Skills 2.A, 2.B, 2.C, 2.D)**
2. Students will design an investigation to study centripetal force by deciding which variables to measure and what equipment to use. In their report they will justify their method and results as well as conduct an error analysis. **(Skills 2.A, 2.B, 2.C, 2.D, 2.E)**
3. One of the open labs required in the course will ask students to design an experiment, using equipment available in the lab, that illustrates conservation of mechanical energy. In the relevant report, students must clearly describe what was measured and how, and whether the obtained results agreed with predicted ones. **(Skills 2.A, 2.B, 2.C, 2.D)**

Curricular Requirement 5

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

Required Evidence

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

Samples of Evidence

1. Students create bar graphs of energy before and after an event, with a listing of the system in the middle (LOL charts) for a variety of scenarios. **(Skill 3.D)**
2. Analyzing Rectilinear Motion
Students will be instructed to sketch graphs of position versus time and velocity versus time for various cases of their own motion (e.g., “walk fast, then slow down at a uniform pace until you stop”). Then they will repeat the motion using a motion detector and compare relevant graphs. **(Skills 3.A, 3.B, 3.C)**
3. In the Hooke’s law lab, students will select and plot appropriate data to obtain spring constants from graphs. **(Skills 3.A, 3.B, 3.C)**

Curricular Requirement 6

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

Required Evidence

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

Samples of Evidence

1. In the lab, students will experimentally determine physical quantities using data analysis; for example, acceleration due to gravity using velocity versus time data for a freely falling object. **(Skills 4.A, 4.D)**
2. Using planetary data, students will use data analysis to demonstrate Kepler's third law. **(Skills 4.A, 4.D, 4.E)**
3. In this guided inquiry-based activity, students design and set up an experiment to test conservation of kinetic energy and linear momentum before, during, and after a collision between two carts on a low-friction cart/table apparatus. The data are gathered using motion sensors interfaced with a computer (or calculator, as an option).
Students will express their results graphically and verify them with calculations. **(Skills 4.A, 4.D)**

Curricular Requirement 7

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

Required Evidence

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

Samples of Evidence

1. Select an appropriate law, definition, mathematical relationship, or model to describe a physical situation.
For example, students will describe simple harmonic motion and predict the period using Hooke's law. **(Skill 5.A)**
2. Students will use calculus to derive theoretical relationships among physical quantities. For example, they will derive an expression for the rotational inertia of a thin rod about a perpendicular axis through the center of gravity. **(Skill 5.E)**
3. Students will be provided with a pull-back toy car and means to take video. They will record the position versus time data for the car as it speeds up and slows down. Then, they will fit a cubic polynomial to the position-time data and use calculus to predict the car's maximum speed and initial and final magnitude of acceleration.
(Skills 5.A, 5.B)

Curricular Requirement 8

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

Required Evidence

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

Samples of Evidence

1. During problem solving, students will use mathematical routines to solve unknown physical quantities.
For example, for a two-dimensional inelastic collision, students will write momentum conservation equations in two mutually perpendicular directions and solve them to find the final velocity of the colliding objects. **(Skill 6.B)**
2. In the laboratory, students will use mathematical routines to determine unknown physical quantities using experimentally measured quantities. **(Skills 6.A, 6.B)**
3. Students will be provided with a pull-back toy car and means to take video. They will record the position versus time data for the car as it speeds up and slows down. Then, they will fit a cubic polynomial to the position-time data and use calculus to predict the car's maximum speed and initial and final magnitude of acceleration.
(Skills 6.A, 6.B, 6.D)

Curricular Requirement 9

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

Required Evidence

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

Samples of Evidence

1. In the lab, students will verify laws by doing inquiry-based investigations.
For example, Newton's second law will be verified using Atwood's machine.
For another example, conservation of angular momentum will be verified by measuring the angular velocity as a function of rotational inertia for a rotating system.
(Skills 7.B, 7.D)
2. In their lab report, students will explain how experimental error affects results, outcomes, and conclusions. **(Skill 7.F)**
3. During a classroom activity, have students roll a hoop and a disk (of equal mass and radius) down identical ramps. Students then explain why the disk reaches the bottom in less time using energy bar charts and to-scale free-body diagrams. All explanations should follow the claim, evidence, and reasoning model. **(Skills 7.C, 7.E)**

Curricular Requirement 10

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

Required Evidence

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

Samples of Evidence

1. Students will be introduced to physics of everyday phenomena throughout the course. For example, in describing the motion of an automobile, kinematics and Newton's laws of motion will be employed. In addition, work, power, and friction can also be introduced. With this, the design of curving roads and safe speeds will be introduced.
2. Kepler's laws of planetary motion describe how planetary bodies in elliptical orbits (including each planet's orbit about the Sun) change speed in the orbit as the orbital radius changes. As Earth, for example, approaches its perihelion (point closest to the Sun), its orbital radius decreases and orbital speed increases, conserving angular momentum. In sports such as diving and skating, the performer can change angular velocity by "tucking," or quickly changing the person's effective radius (and changing rotational inertia). Students who have experience with skating or doing flips can report to others how important the quick change in rotational inertia is to the sport. Students will record and share some popular sports-related scenarios to support this concept.
3. Students encounter oscillating springs every day, from garage door springs that store elastic potential energy when the door is lowered (with the help of gravitational force) so that the spring can help do the work of lifting the door (saving work by the lifting motor) to spring-loaded toys and the shock absorbers in a car. Since springs will behave in space according to the same equations, students will work in small groups to determine how a torsional spring chair can be used to find the mass of astronauts in space. Their results will be presented and shared with other peer groups.

Curricular Requirement 11

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

Required Evidence

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

AND

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

Clarifying Terms

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

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

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

Samples of Evidence

1. Students will spend at least 25% of instructional time in the laboratory, where they will be exposed to hands-on, inquiry-based experiments. Labs, with titles, are listed below.

Unit	Lab Titles	Type	Description
2	Lab 1 - Models for Motion	Guided Inquiry	Students collect data and graphs for constant velocity, acceleration, and jerk. They construct and interpret multiple representations of the motions.
3	Lab 2 - Analysis of a Projectile Lab 3 - Kinematics of Rolling	Guided Inquiry	Students collect video data of a projectile and a rolling object. They construct and interpret multiple representations of the motions.
4	Lab 4 - Simple Newton's Second Law Lab 5 - Sliding Friction Lab 6 - Drag	4 - Guided Inquiry 5, 6 - Open Inquiry	In Lab 4, students predict and then examine graphs of force and other variables for a moving cart. In Lab 5 they choose variables to investigate that may affect sliding friction, and in Lab 6, they develop a model for drag using paper coffee filters.
5	Lab 7 - Modified Atwood's Machine Lab 8 - Centripetal Force Lab 9 - Flying Pigs	Open Inquiry	In Lab 7, students design a lab to investigate a modified Atwood's machine. In lab 8, they choose variables and design a lab to model circular motion using Vernier's centripetal force apparatus. Lab 9 is a practicum in which students find physical quantities of the flying pig with limited equipment.

Unit	Lab Titles	Type	Description
6	Lab 10 - Springs, Rubber Bands, and Energy Lab 11 - Energy Dissipation	Guided Inquiry	In Lab 10, students produce and analyze graphs of force versus stretch and potential energy versus stretch for a spring and a rubber band. In Lab 11, students examine the energy versus time relationships for a bouncing rubber ball.
7	Lab 12 - Impulse and Momentum Lab 13 - Increasing Mass System	Guided Inquiry	In Lab 12, students collect and analyze force-time and velocity-time data for dynamics cart collisions. In Lab 13, students model the acceleration of a fan cart as sand is added to a container on it.
8	Lab 14 - Torque and Statics Lab 15 - Rotational Inertia and Angular Acceleration Lab 16 - Rotational Kinetic Energy	14, 16 - Guided Inquiry 15 - Open Inquiry	In lab 14, students use New York demonstration balances to model rotational statics. In Lab 15, a rotary motion sensor and accessory kit show proportionalities of angular acceleration and rotational inertia. Lab 16 is a practicum in which students predict the results of a hoop and disk race.
9	Lab 17 - Modeling Mass-Spring Systems Lab 18 - Modeling Pendulums	Open Inquiry	In these two activities, students devise a lab to investigate the oscillatory motion of the systems.

2. Students spend a minimum of 25% instructional time engaged in a wide range of hands-on, inquiry-based laboratory investigations, spread throughout the course.

Kinematics

- a. Buggy Lab [**Guided Inquiry**] [SP1] [CR4]
 - i. Presented with a constant velocity toy car, students will generate a position versus time graph.
- b. Motion Detector Activity: Prescribed Motions
 - i. Students will predict the shape of x-t graphs given a set of motions. They will test these predictions using motions detectors.
- c. Dominoes Lab: Topple Speed [**Guided Inquiry**]
 - i. Shown a line of dominoes toppling, students will be asked to test what factors affect topple speed.
- d. Fast/Slow Buggy Collision Activity
 - i. Students will be given two toy cars—one fast, one slow. They will be given the task of determining the speeds of both cars and predicting where they will collide if the cars are allowed to roll toward each other starting four meters apart.
- e. Inclined Plane Lab: Acceleration vs. Angle [**Guided Inquiry**]
 - i. Shown a cart rolling down an incline, students are asked to investigate the effect of angle of incline on acceleration.
- f. Graph Matching Activity
 - i. Using Vernier motion detectors, students will perform a graph-matching activity.
- g. Rocket Launch Lab: Vertical
 - i. Using compressed air rockets, students will determine the height the rockets fly vertically using the time in the air.

h. 40-Yard Dash Lab **[Guided Inquiry]**

- i. Students are broken up into groups of 10 and asked to design an experiment in which one of their group members will stop speeding up and move at a constant speed during a 40-yard dash. This will be done on the football field.

Dynamics

a. Force Table Lab

- i. Given a force table, students are tasked with constructing a mathematical model for the location of the third mass and pulley when the other two pulleys and masses are located at zero and 90 degrees.

b. Spring Scale Lab (F_g)

- i. Given a spring scale and masses, the students graph weight versus mass and generate Earth's gravitational field strength from the slope.

c. Friction Lab: Kinetic/Analog Spring Scales **[Guided Inquiry]**

- i. Shown a wooden block being pulled at a constant speed along a table with an analog spring scale, students are asked what factors affect the force of friction (which is the same as the pulling force). Common IV's include normal force, surface types, surface area, and pulling speed. Coefficient of friction is determined from the normal force experiment.

d. Friction Lab: Static/Digital Spring Scales **[Guided Inquiry]**

- i. Using force probes to determine the force of static friction, students compare coefficients of static friction to those of kinetic friction.
- ii. Optional: Inclined Plane Friction Lab (determine μ from angle)

e. Modified Atwood Machine Lab **[Guided Inquiry]** [SP7] [CR10]

- i. Given the apparatus, students are tasked with using the GI five-step process. Newton's second law is generated through post-lab discussion.

2-D Kinematics

a. Projectile Physlet Lab **[Guided Inquiry]**

- i. Use the GI five-step process with the projectile physlet.

b. Ramp Lab/Contest

- i. Determine the speed of a marble rolling off a ramp horizontally. Using the speed and a new height, predict where to locate a tin can so that the marble rolls into the cup.

Energy

a. Rubber Band Shot Up (H vs. x) and Shot Horizontally (Range/Velocity vs. x) **[Guided Inquiry]**

- i. Students investigate the relationship between how far they pull back a rubber band and how high and how far it goes, relating U_s to U_g and K .

b. Ball Toss U/K Lab

- i. Vernier Lab

c. Spring Lab **[Guided Inquiry]** [SP3] [CR6]

- i. Simple lab where students hang different weights from a spring and graph deforming force versus deformation and determine that the slope is the spring constant. Three different springs are tested.

d. Kinetic Energy, Cart Spring Lab

- i. Further exploration of the relationship between U_s and K . Students are given a cart with an internal spring for which they must determine the spring constant using conservation of energy and a simple force versus deformation lab.

Momentum

- a. Egg Catch Lab [**Open Inquiry**] [**SP2**] [**CR5**]
 - i. Introductory contest where students are tasked with creating an egg catch no larger than one cubic foot that must catch a dropped egg without breaking the egg. Students drop eggs off successively higher steps into the catch. The student that drops their egg off the highest step wins.
- b. Impulse Vernier Lab
 - i. Vernier Lab
- c. Ballistic Pendulum Lab [**Open Inquiry**]
 - i. Using a ballistic pendulum apparatus, students determine the launch speed of a marble using the collision. They also check the launch speed by allowing the marble to shoot horizontally, using range and launch height.
- d. Hot Wheels Friction Lab [**SP4**] [**CR7**]
 - i. A toy car rolls down a track into a paper catch and skids to a stop. If you make several assumptions, the initial U_g equals the work done by friction.

Gravity and Circular Motion

- a. Force of Gravity Applet to Get G Lab [**Guided Inquiry**] [**SP6**] [**CR9**]
 - i. PhET applet
- b. Spinning Stopper Lab: Horizontal [**Guided Inquiry**]
 - i. String threaded through a tube with a rubber stopper on one end, spinning in a horizontal circle with a mass on the other end keeping a constant tension. Use the five steps of GI.
- c. Vertical Centripetal Force Lab (2001 B1)
 - i. Same apparatus as the previous lab, but the stopper spins in a vertical circle and instead of the mass, use a force probe. The resulting $F-t$ graph can be used to verify several things, including the mass of the rubber stopper and the period.
- d. Flying Pigs Lab [**Guided Inquiry**]
 - i. Students verify acceleration due to gravity using flying pigs.

Simple Harmonic Motion

- a. Pendulum Lab [**Guided Inquiry**]
 - i. Graphing data to possibly get $g \dots 4\pi^2 L$ vs T^2
- b. Spring Constant from Period of Oscillation Lab
 - i. Simple investigation of SHM with a mass oscillating on a spring.

Rotational Dynamics

- a. Stroboscope Lab
 - i. A piece of string is taped to the shaft of a motor that is hooked up to a power supply unit. A stroboscope is pointed toward the string, and the angular speed of the string is determined from FPM/RPM.
- b. Torque Lab [**Guided Inquiry**]
 - i. Students investigate an apparatus that consists of a meterstick balanced at the 50 cm point with different masses hanging at different distances. Students attempt to generate the torque equation.
- c. Ice Skater Lab [**SP5**] [**CR8**]
 - i. Students investigate the law of conservation of momentum by spinning on a spinning chair with their arms outstretched and then bringing their arms in close.

- d. Hoop/Puck/Ball Inclined Plane Lab with Rotational KE
 - i. The law of conservation of energy is investigated by observing a hoop and a puck rolling down an incline.
Have them fly off the end and land on padded mats at different distances from the track.
- e. Thickness of Racquet Ball Lab **[Guided Inquiry]**
 - i. The rotational inertia of a racquet ball is investigated by the speed of a ball rolling down an incline.

3. Twenty-five percent of this course is spent doing hands-on laboratory investigations, such as:

Laboratory Investigations:

- Constant Velocity/Constant Acceleration: Students design labs to show constant velocity and constant acceleration. (G.I.)
- Cops and Robbers: Students predict where the accelerating “cops” will catch up to a constant-velocity “robber.”
- Projectile Challenge: Students determine the landing spot for a projectile launched at an angle and lands below its launch point.
- Friction Lab: Students design experiments to determine the coefficients of friction for various surfaces. (G.I.)
- Flying Cow: Students design an experiment to determine the tension in the flying cows’ “leashes.” (G.I.)
- Atwood’s Machine: Students design an experiment to determine the relationship between acceleration and total mass as well as acceleration and mass difference. (G.I.)
- The Unknown Mass: Students design an experiment to predict the value for an unknown mass. (G.I.)
- Mechanical Energy: Students design an experiment to determine total mechanical energy of a tossed ball and an oscillating spring. (G.I.)
- Conservation of Energy: Students design a lab to show conservation of energy. (G.I.)
- Impulse/Momentum: Students verify the impulse-momentum theorem.
- 1-D Collisions: Students design experiments to determine in which types of 1-D collisions momentum and/or kinetic energy are conserved. (G.I.)
- 2-D Collisions: Students use hover disks to determine if momentum is conserved in 2-D. (G.I.)
- Rotational Inertia Lab: Given different shapes, students predict and verify the I values for each shape.
- Newton’s 2nd Law of Rotation: Students verify Newton’s second law of rotation.
- TP Lab: Students predict where to drop an unrolling roll of toilet paper so it hits the ground at the same time as a roll of toilet paper dropped from two meters.
- Conservation of Angular Momentum: Students verify conservation of angular momentum.
- Spring Lab: Given different springs, students must predict and verify the period of the spring.
- Gravitational Constant (PhET): Students calculate the gravitational constant of the PhET simulation.

Curricular Requirement 12

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

Required Evidence

- ☐ The syllabus must include the components of the written reports required of students for all laboratory investigations.
- AND
- ☐ The syllabus must include an explicit statement that students are required to maintain a lab notebook or portfolio (hard copy or electronic) that includes all their lab reports.

Samples of Evidence

1. For all laboratory investigations students will write lab reports using the guidelines provided (Purpose, Apparatus, Theory, Procedure, Experimental Data, Analysis, and Conclusion) and maintain a lab notebook or portfolio that includes all their lab reports.
2. At the completion of every laboratory investigation, students will write lab reports using the following content: Purpose, Apparatus, Theory, Procedure, Experimental Data, Data Analysis, Experimental Error, and Conclusion. They will maintain a lab notebook or portfolio with all their written lab reports.
3. Students will complete a lab report for each corresponding lab investigation. The lab report will contain the required components included in the lab notebook (Claim/Question, Hypothesis, Experimental Procedure, Experimental Data, Data Analysis, Conclusions, Error Analysis, etc.).