AP Physics 1

This page's url is: https://**bit.ly/4323vTQ**

Contact Information

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Purpose/Goals

Physics seeks to describe and predict natural events by seeking the relationships between motion, force, energy and time. Physics is at the root of all types of engineering; mechanical, electrical, nuclear, chemical, etcetera. This course will discuss the basics in fields of physics such as kinematics, dynamics, electricity, optics, nuclear, and etcetera. The curriculum will be that of the collegeboard's AP Physics 2 course. Topics will be covered on a college physics introductory level. The pace will be very fast.

Classroom rules and materials

1. Ask questions.
2. Treat others as you want to be treated.
3. If it is not yours, don't touch it.
4. Ask questions

Eraser

It is advisable for students to have a large separate eraser like Staedtler's Mars-Plastic eraser. "Plastic" or vinyl erasers are more effective than the historic pink erasers.

Calculator

It is important for a student to practice with the same SCIENTIFIC calculator at school and at home. This decreases frustration while increasing calculation speed. Students will learn the functions, how to change the settings, and the keys will remind them of functions they may have forgotten about. I cannot stress enough the importance of "owning" a scientific calculator in science instead of borrowing whatever is around. When a student does not have a calculator in class, they tend to copy numbers instead of practicing the math used on assessments and labs. (A scientific calculator has keys labeled "sin, cos, and tan" on it.) The calculator needs to be accessible at any time. While cell phones tend to have scientific calculators on them, they are not allowed in class. Cell phone scientific calculators are not designed for ease of use like most actual scientific calculators. Desmos, an online calculator used in math class, cannot be used because it is on the computer and the computer allows for Internet access during assessments. More details were sent home as a separate handout with your child. An email will also be sent out the first week.

Grading Policies

The class will follow the school's grading scale. All nine weeks' grades reported on the report card will be rounded to the nearest one's place; e.g. 89.532 becomes a 90 on the report card. However, the raw score will be used for semester averages. Semester averages will be rounded to the nearest one's place -like the nine weeks grades.

10% of the final grade will fit into a category called "Class Preparation."

All assignments for Physics 2 are found on this page, https://**bit.ly/ap1assignments**

"Class Prep" assignments will appear in the PowerSchool's gradebook book as collected, missing or excused. If a "class prep" assignment is missing I will leave a comment quoting the students as to why it is missing. (These comments can be enlightening.)

90% **of the final grade will be called "Final Grades."** It will be based on assessments such as tests and labs.

There are two parts to the final grade. Part 1 is a practice test or assignment. To improve a grade a student must follow a mastery learning process. This is detailed below.
After taking a test, a student may take another test on the same topic. I will record the higher of the two grades. But, the right to take the mastery test has to be earned. This is demonstrated two ways.
By completing an additional assignment from the unit. Depending on the unit's difficulty, students are usually given a weekend to work on the assignment. Students who do not understand how to do the problems need to see me or someone else for help. I am available before school and during most Patriot Periods.
This mastery assignment is checked for effort and completion and not absolute correctness. What "effort" looks like is discussed during every unit. Some notes, homework solutions, short videos highlighting the notes and/or problem solutions, and pretests are provided as online resources. Students are to complete the mastery assignment on time, (within 2 weeks of handing back graded tests.) The only way a due date extension is given, is if a parent or guardian writes a note explaining that the student was sick or was not able to work for other reasons. Late work, without a parent or guardian's note, forfeits the right to take a mastery test.

This 4 minute YouTube video is my description of how I do mastery learning.
`youtu.be/KsRRc_rQblI` …After the "b," that is a lowercase "L" followed by a capital "I."

<u>Communication</u>
If you have a question or comment please email or call me at school. I check my phone messages every business day. You can expect a return call during the next business day -if I'm not absent the day your message is left.) I will respond to your email within 2 business days of receiving it. Even if I don;t have time to give a detailed response, I will acknowledge your email. If you do not receive a response email, call me or resend the message. No response usually means that your message has been quarantined by the county's spam filter. If your student has a question about an assignment or grade, please encourage him or her to talk with me. I'll listen.

Program Info: AP Physics 1 is a one-year, one-credit science course. A majority of the students in the class are in 11^{th} grade and are taking to have completed honors Algebra II.

Textbook: College Physics by Stewart, Freedman, Ruskell, and Hesten 3rd edition, copyright 2023.

Additional Resources:

- Presentation notes created by the teacher.
- Workbook for AP Physics 1 from the College Board
- Additional questions by the teacher.

Course Structure: The students practice concepts, demonstrate understanding, and produce products through the following types of assignments:

- Reading assignments – generally assigned to prepare students for in-class learning.
- Homework assignments – All homework is assigned through Schoology. Nearly all homework will be assigned electronically. All homework will be checked nearly every day for completeness.
- Lab Write-Ups – After each laboratory activity, students create a write-up of the activity. All write-ups will be kept in a physics folder provided by the school. Each write-up must document the purpose of the experiment (or scientific question being answered) and date on which the experiment was performed, materials used, a procedure that another student can follow to replicate the experiment along with a labeled diagram, data taken presented in an organized way that makes sense based on the experiment's purpose, some sort of analysis of the data (graph or calculations) and conclusion that follows from the analysis. Many experiments ask students to extend their thinking by engaging in error analysis and propagation or making connections to other content previously learned. Experimental investigations make up at least 25% of in-class time.
- Tests – Each test will consist of a multiple choice section and free-response problems similar to and some actual to the ones on the AP exam.
- Performance Tasks – Each performance task consists of a task statement that requires the student to formulate and then follow a series of steps in order to accomplish an objective and produce a product, along with guidelines that point the student in a general direction to complete the task. Performance tasks are meant to connect the content being learned to real-life situations. The product of a performance task generally involves communicating how the task was completed and what the results were, along with evidence.

A note about test dates. This curriculum is new this year. While topics have been taught before, content within a topic and parts of the way it needs to be presented has changed. These dates are ESTIMATED targets. There will be even more variance due to student progress, weather, and un-announced changes in the school schedule, (e.g. PSAT testing.)

Activities and labs. We will not do all of them. We cannot do all of these because there is simply not enough time in the school year. But our activities and labs will be chosen from the list in each listing. Adjustments will be made to maintain pace in order to teach all the topics before the exam in May.

Calculators

It is important for a student to practice with the same SCIENTIFIC calculator at school and at home. This decreases frustration while increasing calculation speed. Students will learn the functions, how to change the settings, and the keys will remind them of functions they may have forgotten about. I cannot stress enough the importance of owning a scientific calculator in science instead of borrowing whatever is around. When a student does not have a calculator in class, they tend to copy numbers instead of practicing the math used on assessments and labs. (A scientific calculator has keys labeled "sin, cos, and tan" on it.) The calculator needs to be accessible at any time. **While cell phones tend to have scientific calculators on them, they are not allowed in class.** Cellphone scientific calculators are not designed for ease of use like most actual scientific calculators. **Desmos, an online calculator used in math class, cannot be used** because it is on the computer and the computer allows for Internet access during assessments.

What calculators to buy?
These calculators can be found at Walmart, Amazon, Target, Staples, Office Depot, Best Buy and many other sellers.

My recommendations:

Least expensive:
Texas Instruments TI-30XIIS Scientific Calculator
Around $10-$15.
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- Nice calculator. Perfect if you are not going to higher math classes like pre-calculus and calculus.
- Only shows two lines of information. (Some of our equations are close to that long.)
- 5 memories that correspond to the letters A, B, C, D, & E. Memories are very helpful.
- No built-in graphing capabilities. -not a concern for our class.
- No programming capabilities. -not a concern for our class.
- Solar powered and battery powered
- (This is a better calculator than I used in 1981 -At Western Albemarle HS.)

More helpful features:
Texas Instruments TI-36X Pro Four-line Scientific Calculator
Around $21.
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- Cannot be programmed. (Not important for us.)
- 4 lines are displayed. This means the student can see and compare multiple calculations on one screen.
- 6 memories
- The math expressions typed in look like they would in textbooks.
- Can do some basic calculus functions. (Not needed for us.)
- More functions than the TI-30IIS
- Built in software to solve multiple equations with multiple variables. (We use this.)
- Solar powered

- A great choice if you want more features and ease of use -but without the higher price of a “graphing” calculator.

Higher Price
Very adaptable and many helpful features:
TI-84, TI-84 Plus, or TI-84 Plus CE-10.
Around $90 (on sale) to $170 depending on features. The calculators with color screens, (models ending in “CE,”) are about $170. <u>We will have no need for the color functions.</u> Calculus class might-but I don’t know. The regular TI-84, & TI-84plus are around $100. (Shop around)
(New or used TI-83 or TI-83 Plus calculators will work well too. It is an older model, does everything that we want and is easy to use. Older means cheaper and there is a market for used TI-83’s.)
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- More lines of text on the screen.
- Text/alphabet on the screen
- Displays equations like you would see in a textbook or on our problems.
- Can be programmed.
- Can store numbers as letters of the alphabet. (That is convenient for physics.)
- A preferred calculator if going into calculus or thinking about a career in math, science or engineering after high school.
- Easiest calculator to use when we start getting into physics and its math.

Option four
Texas Instruments TI-30IIXS <u>school loaner</u> (free for the year)
Free -if not lost
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I have a few TI-30IIS model calculators, (that is the one at the top,) that I can loan out to any student for the year. Then I will collect it in May. If this is the option for you, reply to me with your child’s name and I’ll do the rest.
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This is a sampling of calculators with which I have experience. Casio, Sharp, HP, etc. make some terrific calculators. I’m not familiar with all of those brands, but I can usually figure them out. Make sure the calculator is a scientific calculator. (One with “cos, sin, and tan,” keys.) We use those special functions on the scientific calculator.

Course Units: The following pages outline each unit along with the science practices that are engaged in and experimental investigations performed.

Unit 0 Back to basics

- Unit systems
- Math prefixes
- Science shortcuts
- Basic conversions with a high use value. (like grams to kilograms, centimeter to meters)
- Unit conversions
- Unit conversions with Google
- Calculator usage

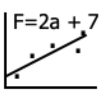
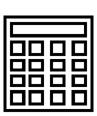
Unit 1 Part 1 of 3: Kinematics (Test date See part 2)

In this unit, students study motion with constant velocity or objects that exhibit segmented constant velocity (constant velocity motion that suddenly changes into a different constant velocity motion) in one dimension. Students learn the language of kinematics to describe motion (displacement/distance/position, average/instantaneous speed/velocity, time and time interval). Students represent these motions with position and/or velocity vs. time graphs, mathematical equations, and motion diagrams. Students also investigate how the motion observed depends on the reference frame chosen, and how to choose reference frames in order to most easily analyze a situation. Students use frame-of-reference transformations to easily analyze situations where two objects are in relative motion.

Students then study the types of forces (weight, normal, friction, tension, and the spring force) and learn to draw free-body diagrams for objects whose forces balance. Students study Newton's First Law and qualitatively learn how motion changes when an unbalanced force acts.

The skill emphasis for this unit is on writing an experimental procedure, graphing experimental data to show a trend, drawing best-fit lines to linear data, and drawing conclusions from linear trends in data.

Science Practices

 Representat ions	Students construct representations of constant-velocity and segmented-constant-velocity motions including position vs. time and velocity vs. time graphs, motion diagrams, and equations. Students construct free-body diagrams to represent forces acting on an object.
 Mathematic s	Students perform slope and area calculations on motion graphs in order to determine speed or distance quantities for an object's motion. Students use constant-velocity equations to predict where an object will be at a certain time or when an object will reach a certain place. Students also use Hooke's Law to predict the behavior of a spring, and the relationship between mass and weight to calculate the strength of forces in free-body diagrams. Students analyze data from experiments to quantify the constant motion of an object, the strength of gravitational field, and the force constant of a spring.
 Scientific Argumentati on	Students formulate procedures to investigate, quantify, and communicate the constant motion of an object, the relationship between mass and weight, and the relationship between force and stretch of a spring. Students also compose arguments using mathematical models to explain why it is that it takes longer for one car to catch another if the two cars have almost the same speed.

Performance Tasks

- Speed of Sound – Students formulate a procedure for measuring the speed of sound using materials readily available to them outside of school. Students take data and represent it on a graph. Students must use constant velocity principles (NOT standing wave physics) and their graph must be a distance vs. time graph. Students use linear regression to calculate a slope for their graph, and use the slope to report the speed of sound. [SP1] [SP2] [SP3]
- Trip to School – Students are to <u>quantitatively</u> represent the car (or bus) trip from home to school on a typical school day as a table, a distance vs. time graph, and a speed vs. time graph, assuming the trip consists of segments of constant velocity. Students are also to explain how they took the data used. This task involves the use of all three science practices. [SP1] [SP2] [SP3]

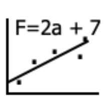
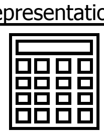
Unit 1 Part II: Kinematics Part 2 of 3 — Test date 11 days 10/3,10/7

Students investigate motion with constant acceleration and represent the motion as graphs (position, velocity, and/or acceleration vs. time), equations, and motion diagrams. If motion is not constant acceleration, it is modeled as segments (intervals where acceleration is constant, between which acceleration suddenly changes). These motions take place in one dimension.

Students also study Newton's Second Law. Students investigate situations where objects travel in straight-line paths but experience unbalanced forces. Elevators (vertical motion where weight and tension or weight and normal act) and objects moving along horizontal surfaces with friction are primarily studied. Students learn the difference between static and kinetic friction and about the relationship between friction and normal force.

Formulating, executing, and communicating an experimental procedure is given special emphasis in this unit, particularly the SQUARED method of writing an experimental procedure.
S—Setup
Q—Quantities (variables) to be measured
U—Units
A—Apparatus (tools)
R—Repetition (multiple trials)
E—Error reduction (more data points, or more trials of each point)
D—Diagram (labeled)

Science Practices

 Representations	Students construct position vs. time, velocity vs. time, and acceleration vs. time graphs to describe motion. Students also use motion diagrams to represent motion. Students use free-body diagrams to represent the forces acting on an object.
 Mathematics	Students use Newton's Second Law as well as the equations for constant acceleration to make determinations about the forces, motion, or position of an object in the past or in the future, depending on the demands of the situation. Students analyze data from an experiment to determine the acceleration of an object on an incline, the acceleration of a freely-falling object, the relationship between net force and acceleration, and the relationship between friction force and quantities that might affect the strength of friction.

 Scientific Argumentation	Students design an experiment to quantitatively determine the acceleration of an object on an incline, and to show that free-fall is constant acceleration and find the free-fall acceleration of an object. Students also design an experiment to show the relationship between the strength of the net force acting on an object and the object's resulting acceleration. Students construct an argument to explain the classic police-and-motorist problem (motorist moves with constant speed and police car starts from rest at the instant the motorist passes; the police car is moving at twice the speed of the motorist when the police car catches up again). Students also construct an argument explaining how a car's initial speed, the reaction time of the driver, and the braking acceleration all affect the stopping distance of a car.

Performance Tasks

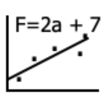
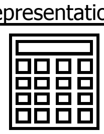
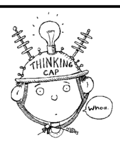
- Green Light, Red Light – Have a parent drive a car from one stop sign to the next so that the car has constant acceleration, then constant velocity, then constant deceleration. Take data necessary to determine the acceleration, constant speed, deceleration, as well as the time and distance of each of the three intervals. Use this data to construct a quantitatively-correct position vs. time, velocity vs. time, and acceleration vs. time graph of the motion. [SP1] [SP2] [SP3]

<u>Unit 1: Two Dimensions (Projectile Motion/Kinematics Part 3 of 3) Test Date: 10/15 & 10/16</u>

Students learn about vectors and components. Students then learn about projectile motion and use their knowledge of vectors and components to uncouple the horizontal and vertical motions of a projectile. Students then use vectors and components to analyze static force (equilibrium) situations, generally involving a weight force and two tension forces or a tension and normal force. Students then investigate situations where forces are not balanced and components must be employed (inclined planes and angled-tension problems).

The emphasis in this unit is on determining a type of relationship from lab data (whether data shows a direct proportion, a quadratic or root relationship, and inverse relationship, or an inverse-square or inverse-root relationship).

Science Practices

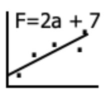
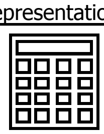
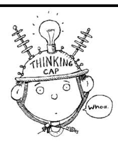
 Representations	Students graphically represent vector addition and subtraction using tail-to-tip and parallelogram methods. Students draw free-body diagrams with components to analyze situations where forces act in two dimensions. Students draw the six projectile motion graphs to represent various projectile motion scenarios.
 Mathematics	Students use free-body diagrams to construct balanced force equations and net force equations to analyze situations or make predictions. Students also use the equations for constant acceleration to model projectile motion and solve problems. Students analyze data from experiments that investigate the relationship between launch height and distance for a projectile, incline angle and "downhill force" on an incline, and the quantities that describe circular motion.
	Students design an experiment to determine the relationship between height of launch and horizontal distance of travel for a horizontally-launched object. Students also determine the relationship between the angle of incline and the amount of "downhill force" that acts on an object on the incline.

Scientific Argumentation	Students formulate arguments about whether increasing the angle of a tension force applied to a block will increase or decrease its acceleration, what quantities affect the maximum safe speed to take a turn and how they affect that speed, and how launch speed and angle affect the distance a projectile will travel.

Unit 2 (Part 1 of 2): Newton's Third Law (Forces and Translation Dynamics) Test Date:12/4 & 12/5

Students study interactions between two objects in terms of Newton's Third Law. Students also investigate situations and solve problems involving forces and motion for multiple objects, such as trains, objects, or Atwood machines. Students also gain their first exposure to the concept of center of mass, internal and external forces, and the relationship between center of mass and system momentum.

Science Practices

 Representations	Students write descriptions of Newton's Third Law interactions in the form of action force and reaction force and also in terms of cause (the force) and effect (the resulting change in motion of an object).
 Mathematics	Students translate free-body diagrams for entire systems or individual objects in systems into Newton's Second Law equations, and solve the equations (or systems of equations) to determine the acceleration of the system or some other quantity of interest.
 Scientific Argumentation	Students design an experiment to show that two objects exerting force on each other exert equal-strength forces in opposite directions at the same time. Students use the concepts related to objects and systems, action-reaction pairs, and internal and external forces to predict and explain what happens in a variety of two-object situations. An example is a block on a rough table connected to a rope that passes over a pulley, where in one case a certain weight is attached to the free end, and in the other case the rope is just pulled with the same amount of force (which produces greater acceleration?).

Performance Tasks:

- Motion Storybook – Students create a children's story where a single character in the story undergoes a different motion on each page. Students are given seven pages, and must show constant position, constant velocity in the positive and in the negative direction, speeding up in the positive and the negative direction, and slowing down in the positive and negative directions. For each page of the story, students clearly state exact values of distance, time, initial and final velocity, and acceleration, and create quantitative position vs. time and velocity vs. time graphs. Students also create quantitative free body diagrams, showing the strength of each force acting on the character on that page. Students are graded on their ability to select motion values that are consistent with kinematic relationships, and their ability to create quantitative representations and calculate force strengths. [SP1] [SP2]

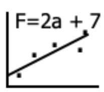
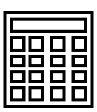
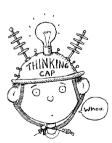
Unit 2 (part 2 of 2): Circular Motion and Gravitation — Test Date 12/19 & 12/24

Students then learn about circular motion and apply force concepts to turning cars, roller coaster loops, and conical pendulums. Students first learn about uniform circular motion, then about non-uniform curved motion (in terms of tangential acceleration and centripetal acceleration). Students are introduced to the angular kinematic quantities and their relationships with the linear kinematic quantities.

Students then learn about the Law of Universal Gravitation, the equation that relates the mass and radius of a planet to its gravitational field strength, and circular orbits.

This is the first unit where students are exposed to linearization of data. While students have used the slope of best-fit lines to linear data to draw conclusions before now, this is the first time that students manipulate data in order to force the data to form a linear graph.

Science Practices

 Representations	Students create free-body diagrams representing forces acting on objects performing circular motion. Students also draw vectors for velocity and acceleration, where appropriate, and show components of force and acceleration vectors in order to analyze non-uniform curved motions.
 Mathematics	Students use free-body diagrams to construct balanced force equations and net force equations to analyze situations or make predictions. Students also use the equations for constant acceleration to model projectile motion and solve problems. Students use the equation for centripetal acceleration to analyze circular motion situations. Students analyze data from experiments that investigate the relationship between the quantities that describe circular motion.
 Scientific Argumentation	Students design an experiment to determine the relationship between velocity, radius, and centripetal force for a circling object. Students formulate arguments about whether increasing the angle of a tension force applied to a block will increase or decrease its acceleration, what quantities affect the maximum safe speed to take a turn and how they affect that speed, and how launch speed and angle affect the distance a projectile will travel.

Performance Tasks:

- Mu Of My Shoe – Students are to calculate the coefficient of static friction between their shoe and a wood ramp in the following three scenarios:
    - o Students are given only a set of spring scales of different ranges.
    - o Students are given a pulley to attach to the track, a small bucket, an electronic balance, string, and water.
    - o Students are given only a protractor. [SP1] [SP2] [SP3]

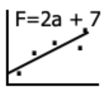
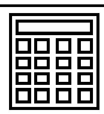
Unit 3: Conservation of Energy — Test Date: 2/4 & 2/5

Students study work, energy, and power in a variety of situations, particularly in two dimensions. Students are introduced to the types of energy, solve problems using conservation of energy, and reason qualitatively about physical phenomena using both energy principles and Newton's Laws. Students revisit inclined planes and projectile motion with the ability to apply conservation of energy.

Students also discuss how the mechanical energy of a system and its subsystems changes during some set of processes. Students are also introduced to power and its relationship to work and energy.

Students continue to use linearization of data techniques to draw conclusions in laboratory experiments, and a greater emphasis on symbolic derivations begins during this unit.

Science Practices

 Representations	Students construct bar-chart diagrams to show the amounts of various types of energy before, during, and after a process. Students also construct energy flow-charts, showing how energy goes from chemical (say, in a person), to mechanical (kinetic, gravitational and spring potential), to dissipated forms of energy. Students also construct force-displacement diagrams, where they draw one arrow representing a single force and another arrow representing the displacement of an object in order to judge whether that force performs positive, negative, or zero work.
 Mathematics	Students use energy bar charts to construct conservation of energy equations and solve those equations in order to make predictions or quantify the interactions and motions of objects in a system. Students analyze data from an experiment to determine whether mechanical energy is conserved. Students also analyze data from an experiment to determine the spring constant of the spring in a toy.
 Scientific Argumentation	Students design an experiment to determine whether mechanical energy is conserved for some simple phenomenon. Students also design an experiment to determine the spring constant of a spring-loaded toy and test accuracy of their measurement of spring constant by predicting how the toy will behave and then testing their prediction. Students use conservation of energy principles to formulate arguments while analyzing an object that becomes a projectile after progressing down an incline. These arguments may include discussing how the horizontal distance of the projectile's motion is affected by the object's height change, or how maximum height is affected by launch angle.

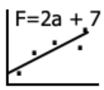
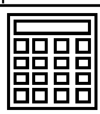
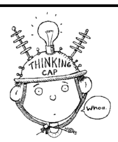
Performance Tasks

- Energy Of An Activity – Students choose some ordinary activity that involves at least three forms of energy we have studied, at least two energy transformations, at least three forces we have studied, and can be broken into at least four but no more than six intervals of time. For each instant of time between intervals, students create an energy bar chart for the system of interest. For each interval of time, students create a free-body diagram along with a vector for the object of interest's displacement, state whether each force performs positive/negative/zero work, and state what energy transformation (if any) takes place due to this amount of work. Students also choose two subsystems and discuss how the mechanical energy of each sub-system changes during each interval and how they know. Students present all of their findings individually to the class. [SP1] [SP3]

Unit 4: Conservation of Momentum   Test Date: 2/25 & 2/26

Students study impulse, momentum, and center-of-mass motion in a variety of situations, including in two dimensions. Students connect the idea of center of mass motion with net system momentum, and connect conservation of momentum with Newton’s Third Law and internal/external forces. Students also connect the Impulse Momentum Theorem with Newton’s Second Law. Students couple conservation of momentum principles with energy principles to judge whether a collision is elastic or inelastic. Students also represent collisions in a variety of ways, including motion graphs that they need to review, and momentum vs. time and force vs. time graphs.

Science Practices

 Representations	Students represent interactions involving impulse and Conservation of Momentum using position, velocity, momentum, and force vs. time graphs. Students are also introduced to “Momentum Square Diagrams” which can be used to represent the momentum of an object as the product of mass and velocity.
 Mathematics	Students write equations expressing the Impulse-Momentum Theorem and Conservation of Momentum and solve these equations in order to make predictions. Students analyze data from an experiment to determine whether momentum is conserved and whether kinetic energy is conserved during a collision.
 Scientific Argumentation	Students design an experiment to investigate the transfer of momentum and the transfer of energy that takes place during a not-perfectly-inelastic collision between two unequal-mass objects. Students use the Impulse-Momentum Theorem and Conservation of Momentum in order to formulate arguments about which types of collisions result in the greatest final velocity of one of the interacting objects, about the forces applied to a passenger in a car during a variety of collisions, and about the changes in motion of a system’s center of mass due to various forces acting on or within the system.

Performance Tasks:

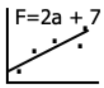
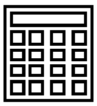
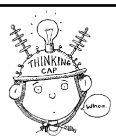
- The Conservation of Momentum Lab doubles as the performance task for this unit. For this lab, students produce a more sophisticated report than what normally appears in their lab notebooks. This “Formal Lab Report” models the sort of lab report they are likely to be required to produce in a college-level lab course. [SP1] [SP2] [SP3]

Unit 5: Rotational Kinematics and Dynamics — Test Date: 3/25 & 3/26

Students learn the rotational analogs to the translational quantities of motion, the relationships between each translational quantity (length, speed, acceleration) and its rotational analog (angle, angular speed, angular acceleration), and the constant acceleration equations for rotational motion. Students also review the principles of circular motion, particularly centripetal acceleration (and how it relates to angular speed) and tangential acceleration (and how it relates to change in angular speed).

Students then investigate torque and situations where both forces and torques are balanced. Students then learn about rotational inertia and finally deal with situations where torques are not balanced and rotational, translational, or both types of motion take place (particularly situations with pulleys that have mass).

Science Practices

 Representations	Students represent rotational motion and changes in this motion using graphs of rotational kinematic quantities as functions of time. Students use extended-body diagrams to not only show the type of force, direction of the force, and relative strength of the force acting on an object, but also the location on the object where the force is applied.
 Mathematics	Students use the kinematic equations for constant acceleration (rotation, translation, or both) along with equations for centripetal acceleration to make predictions about the motion of a rotating object or an object connected to a rotating object. Students also change extended-body diagrams into net torque and net force equations to make predictions about the translational and rotational motion of an object or system of objects. Students analyze data from an experiment to determine the relationship between torque and angular acceleration. Students analyze data from an experiment to determine how rotational inertia depends on the amount of mass an object has and where that mass is placed. Students analyze data from an experiment to determine the rotational inertia of an object and/or the frictional torque acting at the object's axis.
 Scientific Argumentation	Students design an experiment to determine the relationship between torque and angular acceleration. Students design an experiment to determine how the amount of mass and placement of mass affect the rotational inertia of an object. Students also design an experiment to determine the rotational inertia of a circular object such as a yo-yo or bike wheel using torque and rotational motion principles. Students also design an experiment to determine the frictional torque acting at the bearings of a known-rotational-inertia object. Students use torque principles to formulate arguments about why it is that a yo-yo's linear acceleration changes as it falls and unrolls and the string is wound around the axle is fewer and fewer layers. Students also use rotational inertia principles to explain the classic hoop-and-disk-down-the-incline demonstration.

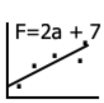
Performance Tasks:

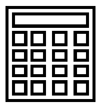
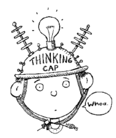
- The Rotational Dynamics Lab and Rotational Inertia Labs are combined into a single formal lab report that serves as the performance task for this unit. For this single lab report, students produce a more sophisticated report than what normally appears in their lab notebooks. This "Formal Lab Report" models the sort of lab report they are likely to be required to produce in a college-level lab course. [SP1] [SP2] [SP3]

Unit 6: Rotational Energy and Momentum — Test Date: 4/15 & 4/16

Students now consider and analyze phenomena and interactions involving rotational motion, but this time through the lens of rotational kinetic energy and angular momentum.

Science Practices

	Students use energy bar charts, now with a bar for rotational kinetic energy, to analyze rotational phenomena and support arguments. Students use new Square Diagrams to represent the angular momentum of rotating objects (as the product of

Representations	rotational inertia and angular speed) and the angular momentum of translating objects (as the product of linear momentum and perpendicular radius distance).
 Mathematics	Students change energy bar chart diagrams into conservation of energy equations in order to solve for an unknown, analyze lab data, or make a prediction. Students also change Angular Momentum Square Diagrams into conservation of angular momentum equations for the same purposes. Students analyze data from experiments intended to find the unknown rotational inertia of objects that are pivoted as physical pendulums, can roll down inclines, or that participate in rotational collisions.
 Scientific Argumentation	Students design an experiment to use energy principles to find the rotational inertia of a linear object pivoted at a point to form a physical pendulum. Students also design an experiment to find the rotational inertia of a rolling object using energy principles. Students also design an experiment to use angular momentum principles to find the rotational inertia of a linear object pivoted at its center of mass. Students use rotational energy or angular momentum principles to formulate arguments about rotational phenomena. In some cases, students revisit situations encountered in the previous unit (such as the hoop and disk demonstration) but make their arguments through the new lenses of rotational energy or momentum in addition to the previous lenses of kinematics and dynamics.

Performance Tasks:

- Rotational Inertia of an Object – Students select an object from their own home and perform an experiment to determine the rotational inertia of the object. Students are restrained to choose objects that can be rolled down an incline or that can be fixed to an axis and swing as a physical pendulum. [SP1] [SP2] [SP3]

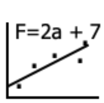
Unit 7: Simple Harmonic Motion

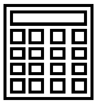
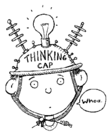
Optional for students taking the AP Exam Done over spring break or any other convenient time. No grades assignment.

Students study repeating motions (oscillations) and what properties must be present in order for an oscillation to be classified as Simple Harmonic Motion. Students then investigate the typical SHM's of high school physics: a spring-mass oscillator and a simple pendulum. Students also investigate other oscillations such as a bouncing ball, a bouncing cart, a physical pendulum, a torsion pendulum, a marble rolling back and forth at the bottom of a spherical bowl, and a mass wiggling on the end of a steel ruler clamped to a table.

This unit is framed as a review of motion graphs and principles, dynamics, and energy conservation. Conservation of momentum also appears when students have to consider an object colliding with an object attached to a spring (which may already be oscillating).

Science Practices

 Representations	Students construct graphs of motion quantities vs. time, force and momentum vs. time, and energy quantities vs. time for oscillations including SHM. Students also construct free-body diagrams and energy bar charts as necessary to defend arguments.

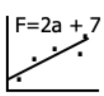
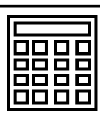
 Mathematics	Students use equations related to SHM to calculate unknown quantities such as maximum speed or acceleration of an SHM, total energy, period, or a property of the oscillator such as spring constant, mass, or acceleration of gravity. Students analyze data from experiments to determine if a particular repeating motion is SHM, to determine how length affects the period of a pendulum and how a pendulum can be used to calculate gravitational field, measure the spring constant of a spring with high precision, and show that gravitational mass is equal to inertial mass.
 Scientific Argumentation	Students design experiments to determine whether a repeating motion is SHM, investigate the factors that affect the period of a simple pendulum, investigate the factors that affect the period of a mass connected to a clamped steel ruler, and show that inertial mass and gravitational mass are the same quantity. Students use SHM principles and experimental data to formulate arguments about whether a particular repeating motion is SHM. Students also formulate arguments about how the quantities of SHM (motion, force, energy, and momentum quantities) change when properties of the oscillator are changed or when the oscillator interacts with some external object or system.

Unit 8: Fluid Dynamics Test Date: 5/12 & 5/13

Students study density, hydrostatic pressure and Pascal's Principle, and buoyancy concepts. (Fluids at rest.)

Students then study the Continuity Principle and fluid flow rate, as well as Bernoulli's Equation and Bernoulli's Principle. (Fluids in motion.)

Science Practices

 Representations	Students draw free-body diagrams for objects that are immersed or partially immersed in a fluid and change these equations into either balanced-force or Newton's Second Law equations as appropriate. Students also deal with graphs such as pressure vs. depth (from which they are to determine density of the fluid) or tension force vs. height of an object (where tension changes as the object becomes more or less submerged in the fluid). The relative values of the three terms in the Bernoulli Equation can be represented by bar charts. Students make Bernoulli bar charts in order to explain phenomena related to flowing fluids.
 Mathematics	Students change free-body diagrams into equations that relate the forces in order to solve for an unknown. Students also use symbolic equations derived from free-body diagrams in order to formulate qualitative arguments about the relationships between apparent weight and the density of the object immersed in the fluid (relative to the fluid's density). Students use Bernoulli's Equation and the Continuity Equation (and/or the definition of flow rate) in order to solve for some unknown quantity. Students analyze data from experiments in order to determine the relationships among density, volume, and mass, between hydrostatic pressure and depth, and between buoyancy force and volume displaced. Students also analyze data from experiments meant to determine the density of objects that do not follow regular geometric shapes.

	Students analyze data from an experiment investigating the Continuity Principle to show evidence of the validity of the Continuity Principle. Students also analyze data to determine the relationships among fluid height, force on a fluid, and the flow speed that results.
 Scientific Argumentation	Students design an experiment to investigate the relationship between density, volume, and mass. Students also design an experiment to investigate the relationship between hydrostatic pressure and depth. Students design an experiment to investigate the relationship between buoyancy force and volume submerged. Students also design experiments meant to measure the density of irregularly-shaped objects and evaluate whether these objects might be hollow. Students design an experiment in order to show evidence of the Continuity Principle. Students design experiments to investigate the relationships among fluid height above a hole and fluid speed through the hole and force on a fluid and the resulting flow speed. Students formulate arguments explaining how the difference in hydrostatic pressure on various points on an object results in the buoyancy force, explaining how a suction cup works, and explaining why it is that apparent weight is not different from actual weight when the solid object submerged is much denser than the fluid. Students also use the concept of average density to explain why a boat, made of denser-than-water metals, still floats in water. Students use the Continuity Principle/Equation along with the Bernoulli Principle/Equation, along with bar charts, to support arguments about specific flowing-fluid phenomena, such as how a straw works, how pressure varies with cross-sectional area in a pipe, and a Venturi Tube works, and how high winds can lift a roof off of a building.

Laboratory Investigations and Activities

Performance Tasks

- Build-A-Boat – Students are given a square of aluminum foil. The goal is to build the boat that requires the most mass to be sunk in a deep sink in a wash tub filled with water. Students then produce a scientific argument about why they chose to build the boat that they did, citing the relationship between buoyancy and volume. [SP2]